Vegetation effects on sub-pixel roughness measurements from NASA's Terra/ASTER stereo images.

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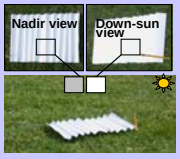
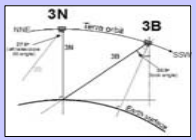
Background

- Unresolved shadows cast by sub-pixel roughness elements result in a measureable deviation from Lambertian reflection, which can be utilized as an effective proxy for mapping sub-pixel roughness variations from orbit.



*Rough surfaces appear lighter from the 'down-sun' view as shadows become progressively obscured by sunlit elements → The **ratio** between images acquired at such viewing geometries responds primarily to sub-pixel surface roughness*

ASTER 15 m/pixel stereo images offer a readily accessible and efficient resource for ratio images that can map unresolved, sub-pixel roughness variations on Earth's land surfaces.*

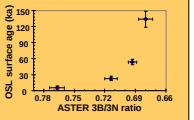


ASTER stereo images are routinely acquired along the SSW orbit of Terra using the aft-looking (3B) telescope

Advanced Spaceborne Thermal Emission Radiometer, ~65 km footprint; 3 VNIR channels between 0.56-0.81 μm (15 m/pixel); 6 SWIR channels between 1.65-2.45 μm (30 m/pixel); 5 TIR channels between 8.10-1.5 μm (90 m/pixel). Integrated **stereo capability made possible through an additional VNIR channel (~0.81 μm, 15 m/pixel) acquired through an aft-looking telescope designed for in-scene, independent generation of a 30 m/pixel DEM for each ASTER scene*

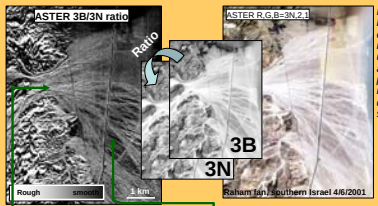
Bare surfaces

ASTER 3B/3N→ surface roughness ~ surface age

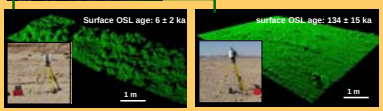


Age vs. ASTER 3B/3N calibration curve derived from data described below

ASTER 3B/3N images map sub-pixel surface roughness, which can be used as a quantitative proxy for surface ages of alluvial surfaces in arid environments



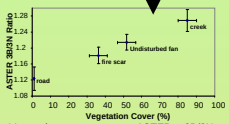
Ratio images between ASTER channels 3B and 3N respond to sub-pixel unresolved shadows and effectively map pixel-to-pixel surface roughness differences in the scene.



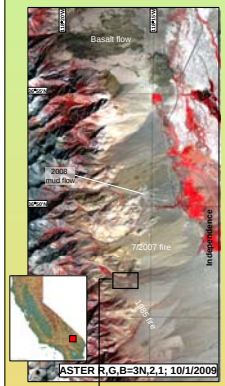
Ground-based LiDAR maps acquired at 5 mm resolution are used to characterize surface roughness of alluvial surfaces in the Raham fan

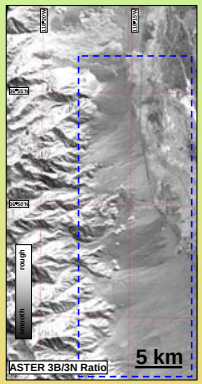
Partially vegetated surfaces

Recent fire scars on alluvial fans in semi-arid Owens Valley, CA present a natural laboratory to test the effects of vegetation % coverage on ASTER 3B/3N roughness images

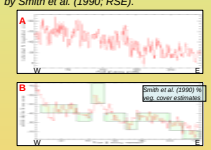


Vegetation cover vs. ASTER 3B/3N calibration curve derived from data described below. Vegetation cover on dirt road and in creek estimated at 1 and 80-90 %, respectively.

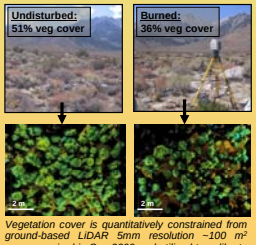




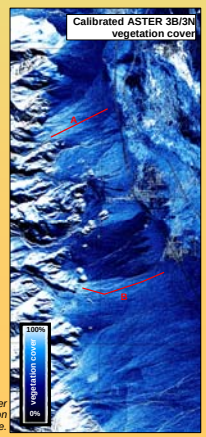
ASTER 3B/3N ratio images respond to sub-pixel unresolved shadows. As desert scrub (characterized in OV by Blackbrush [Coleogyne], Sage [Artemisia], Bitterbrush [Purshia] and Rabbitbrush [Chrysothamnus] in disturbed areas) exceed ~15% coverage they become the dominant shadow-casting elements on the granite-dominated fans and thus the 3B/3N ratio images respond primarily to differences in % vegetation cover.



Vegetation cover transects for undisturbed regions agree with % vegetation cover estimated for the same regions using SMA by Smith et al. (1990; RSE).



Vegetation cover is quantitatively constrained from ground-based LiDAR 5mm resolution ~100 m² maps acquired in Sep 2009 and utilized to calibrate 3B/3N ASTER ratios



Calibrated 3B/3N vegetation cover map using ASTER data and calibration curve shown above.

ASTER 3B/3N maps 0-80% differences in vegetation cover on the OV granite fans.

NDVI appears to be an ineffective proxy in these desert scrublands for <~80% vegetation cover

ASTER 3B/3N ratio images provide an effective tool for quantitative mapping of vegetation % cover on partially vegetated granite-dominated fans in Owens Valley, CA.

Acknowledgements

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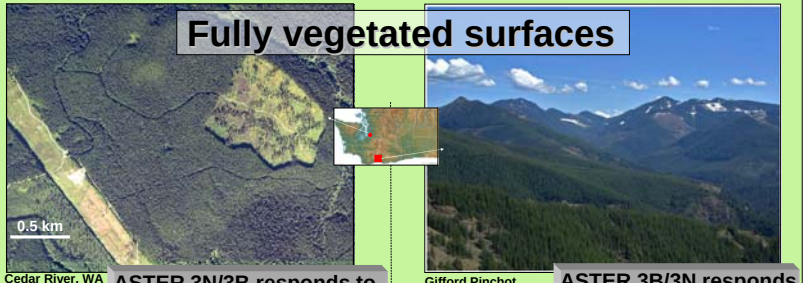
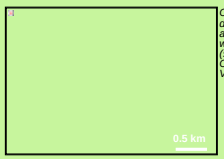
Fully vegetated surfaces



ASTER 3N/3B responds to canopy roughness

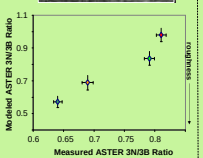
ASTER 3B/3N responds to structural stage

High-resolution airborne LiDAR data in the Cedar River watershed in western Washington provide a unique opportunity to test the ASTER 3B/3N ratio in a forested setting



Canopy height model (1 m/pixel) derived from airborne LiDAR data for a ~10 km² area in the Cedar River watershed in western Washington (same area as orthophoto above). Courtesy of Washington State and Van Kane.

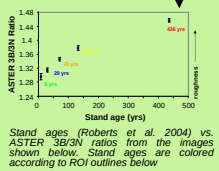
Shaded relief image produced from the LiDAR data shown above. In color - ROI's for which modeled and measured ASTER 3N/3B ratios are compared in the graph to the right



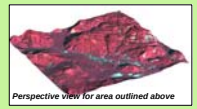
Numerical simulations for ASTER 3N/3B ratios using a 1 m/pixel canopy height model vs. measured 3N/3B ratios

In the Cedar River shadowing calculated from a 1 m/pixel DEM represents a 1st order control on ASTER 3N/3B ratios, which in practice integrate sub-pixel (15 m) roughness elements down to the optical path length. Large surface elements dominate shadowing because their shadows occlude smaller shadow-casting elements.

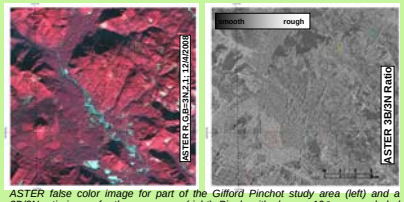
Monitored logging activity in the Gifford Pinchot Natl' Forest provides an opportunity to test the sensitivity of ASTER 3B/3N ratios to forest structural stage and stand age



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



Calibrated ASTER 3B/3N ratios provide a proxy for forest structural stage and stand age



ASTER false color image for part of the Gifford Pinchot study area (left) and a 3B/3N ratio image for the same area (right). Pixels with slopes >10° were excluded from the stand-age vs. ASTER 3B/3N calibration curve shown above.

Conclusions

1. **For bare surfaces ASTER 3B/3N ratios ~ sub-pixel surface roughness ~ age**
2. **For partially vegetated scrublands (> ~15% cover) vegetation dominates surface roughness and ASTER 3B/3N ratios ~vegetation % cover**
3. **For fully vegetated surfaces canopy roughness explains most of 3B/3N the signal**
4. **In forests, ASTER 3B/3N ratios respond to structural stage / stand age**