A REVISED RADIOMETRIC NORMALISATION STANDARD FOR SAR IMAGERY

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1. INTRODUCTION

The increased availability of highly accurate information describing the acquisition geometry of spaceborne SAR imagery since the launch of ENVISAT enables tie-point free orthorectification of imagery from (for example) the ASAR, PALSAR, and TerraSAR-X sensors [7]. Contemporary nearly ubiquitous highly accurate knowledge of the imaging geometry suggests that it would be appropriate to revisit implicit assumptions made at the dawn of SAR imaging. Specifically, the most appropriate standard radiometric normalisation of the imagery provided by the sensors may no longer implicitly assume that only the broad ellipsoidal Earth geometry of the acquisition is well known. Instead, consideration of the actual lay of the terrain within the imaged area is fast becoming a realistic default option.

2. METHODOLOGY

Evaluating the predictability of corner reflector positions using state vectors and timing annotations, we first demonstrate our highly accurate knowledge of the imaging geometry for ASAR, PALSAR, and TSX, including consideration of the effects of tropospheric refraction [2], ionospheric path delays [6], and processor-specific azimuth "slow time" annotation conventions [8] where appropriate.

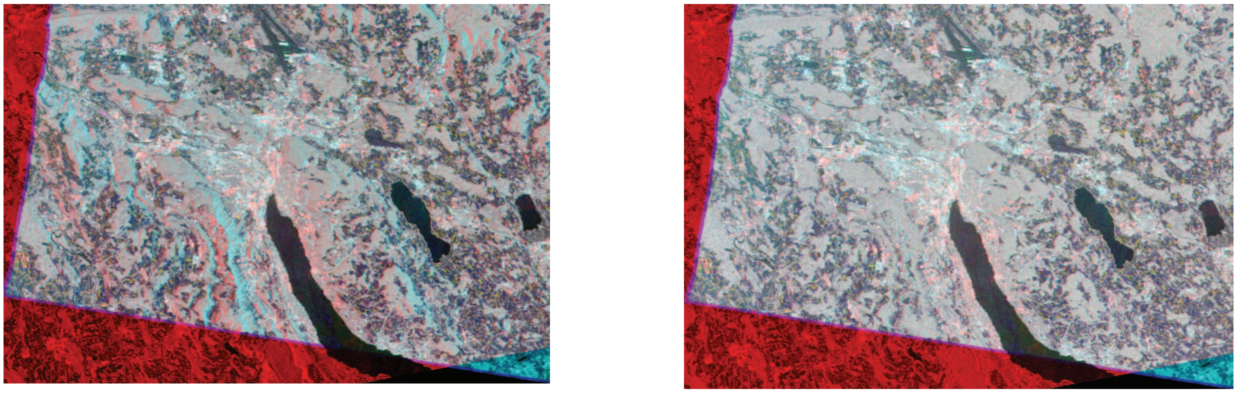
The three well-known radar backscatter standard conventions β^0, σ^0, and γ^0 differ in their choice of their definition of a standard reference area to be applied in the radar equation. The β^0 convention provides the natural radar observable [4], normalising simply by the slant range resolution; however the other two conventions typically normalise by a standard area calculated using a relatively simple ellipsoidal Earth model. In the case of sigma nought, the reference area A_E is defined to be in the "plane" defined by the local ellipsoidal Earth normal vector; in the case of gamma, the area A_E^R describes the area projected into the plane defined by a normal vector in the slant range direction. We append to conventional ellipsoid-model-based sigma nought and gamma retrieval [1][5] the subscript "E":

$$\sigma_E^0 = K_\sigma \cdot \frac{\beta^0}{A_E} \qquad \gamma_E^0 = K_\gamma \cdot \frac{\beta^0}{A_E^R}$$

Note that although "terrain-geocoding" of SAR imagery has become increasingly commonplace since the launch of ERS-1, the word "terrain" there refers to compensation for the effects of height variations on the *geometry* of the resulting image, especially on elevation-induced shifts inherent in converting from slant range to a *geocoded terrain corrected* (GTC) image in a map projection geometry. Note that the radiometric values within such a GTC image are usually σ_E^0 or γ_E^0: i.e. although the *geometry* is terrain corrected, the *radiometry* remains ellipsoid-model-based. We propose to complement the conventional ellipsoid-based backscatter coefficient definitions with more rigorous terrain-based versions, whereby the actual local illuminated area is modelled. The algorithms used to derive the locally appropriate terrain-based normalisation factors A_T (perp. to Earth normal) and A_T^R (projected on to the plane perp. to the slant range direction) are detailed – both factors can be evaluated at each range and azimuth grid location. We append to terrain-based σ^0 and γ^0 retrieval the subscript "T":

$$\sigma_T^0 = K_\sigma \cdot \frac{\beta^0}{A_T} \qquad \gamma_T^0 = K_\gamma \cdot \frac{\beta^0}{A_T^R}$$

When images comprised of σ_T^0 or γ_T^0 values are terrain-geocoded, we refer to the resulting products as *radiometrically terrain corrected* (RTC) to differentiate them from GTC products that use a more conventional ellipsoid-based radar backscatter retrieval scheme. GTC images typically provide images of σ_E^0 or γ_E^0 in a map geometry. In Fig. 1, compare the relative confusion of terrain-induced and thematic differences in the *ascending/descending* PALSAR FBS GTC image overlay of the Zürich area to its RTC counterpart, where terrain-influences are considerably "flattened" [6].



(a) GTC: γ_E^0 (b) RTC: γ_T^0

Figure 1 Geometric vs. Radiometric Terrain Correction – PALSAR FBS Ascending/Descending Image Overlay

Local incidence angle (LIA) masks [3] expressed in map geometry are often used to drive radiometric normalisation of SAR imagery. We instead use a more refined radiometric image simulation algorithm [9] to estimate the local illuminated area value at each radar geometry grid location, dispensing with the fixation on incidence angles [11] inherited from ellipsoid-based backscatter retrieval. In the terrain of Switzerland, there is often *no single local incidence angle* that can be used to estimate the local area at a given radar geometry grid position. Instead, taking care to ensure that digital elevation model facets out of view due to radar shadow are discounted, all remaining facets are integrated across the image to directly estimate the exposed area at each radar geometry grid location. An *integrated* approach is described, whereby variations in the local illuminated area as well as range spreading loss, and trends induced by elevation antenna gain pattern (AGP) draped on the scene's specific topographic variations [9] are all considered in the radar image simulation result that is later used for normalisation. We quantify and discuss differences in the normalisation factors produced by our recommended methodology with results from traditional LIA-based approaches.

3. CONCLUSIONS

We show that both data fusion from multiple sensors as well as thematic land cover change detection from time series single-sensor multi-track acquisitions [10] are made less ambiguous when terrain-induced radiometric effects are first normalised to "flatten" scene-dependent differences. Insisting on radiometric terrain correction raises the standard beyond conventional geometric terrain correction, providing significant added value when image comparison from non-uniform geometries is required. We discuss the implications for future spaceborne SAR sensors such as those that will comprise the Sentinel-1 ESA mission.

4. REFERENCES

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