Abstract—The paper investigates how to optimize the performances of unsupervised log-ratio based change detection algorithms for two-date 1-look amplitude SAR images. The usual approach of pre-processing the SAR images at different dates with state-of-the-art despeckling filters is critically discussed. Those adaptive filters are very efficient, also for the challenging case of 1-look images, for speckle reduction of single-date image data and then for providing reliable classification, detection, or parameter estimation results. However, they are not able to ease the discrimination of statistical from structural changes in 1-look SAR images for which reliable point-target detection is nearly impractical. A simple, yet very effective, multiscale method for change detection and automatic change mapping is proposed and tested on simulated 1-look SAR images. The adopted pre-processing is based on guided image filtering with different window sizes. It improves the detection of changed regions without introducing any geometrical constraint and significantly reduces the false alarm rate. Experimental tests on Spotlight COSMO-SkyMed SAR images will be presented in the final version of the paper.

I. INTRODUCTION AND PROBLEM FORMULATION

When considering multitemporal SAR images, in particular high spatial resolution 1-look data, an effective unsupervised discrimination between changed and unchanged pixels is a challenging task due to the presence of severe speckle noise [1]. Hence, a pre-processing step aimed at reducing speckle is usually adopted. Since SAR measures a reflectivity, that is the ratio of backscattered to incident power, and the speckle noise is originated by a multiplicative fading term, the use of a ratio at each pixel appears suitable for detecting changes [2]. Logarithmic-scaled ratio maps (log-ratio maps) are generated from pre-processed images and suitably thresholded for change detection [3], [4].

A number of well-known filters [5] have been used to adaptively filter the SAR images and optimally generate the log-ratio image feature. The Gamma-MAP filter [6], [7] is probably the most widely used filter. The finite size processing window of despeckling filters in spatial domain may produce outliers in homogeneous regions that are likely to be taken as spatial changes. This drawback can be mitigated by the advanced despeckling filters working in the multiresolution wavelet domain [8]. Alternatively, the speckle reduction can be performed during the generation of the ratio image, for example by combining gray level occurrences and spatial information in a neighborhood of the current pixel [9], or implicitly by computing a multiscale decomposition of the change image, selecting the reliable scales for each pixel and finally applying a fusion rule [10]. Any despeckling in the spatial domain is performed in the method proposed in [11], where the mean-shift enforced information-theoretic change detection (MSITCD) feature is computed starting from the scatterplot of the amplitude levels in the two images and then by applying the mean-shift (MS) algorithm to find the modes of the underlying bivariate distribution. This non-parametric algorithm is one of the most effective state-of-the-art single-scale change detection methods.

In this paper, we propose to apply guided image filtering [13] on local windows with different sizes to pre-process the original SAR images acquired at two dates. Derived from a local linear model, the guided filter computes the filtering output by considering the content of a guidance image, which, in this case, is the input image itself. The guided filter is an edge-preserving smoothing operator with improved behavior with respect to the bilateral filter, especially near edges. The rational is that speckle reduction filters aim at smoothing homogenous regions but also at preserving point-targets for classification and parameter estimation purposes. However, they are not able to ease the discrimination of statistical from structural changes in 1-look SAR images for which reliable point-target detection is nearly impractical.

It is worth noting that the proposed multiscale Guided-filter LogRatio (GLR) algorithm does not detect multitemporal changes starting from image segments as in [12], and it does not introduce any geometrical constraint on the detected changes.

II. PROPOSED ALGORITHM

As previously introduced, the proposed multiscale Guided-filter LogRatio (GLR) algorithm applies guided image filtering [13] to pre-process the two-date 1-look amplitude SAR images at $N$ different scales, i.e., by performing filtering on window sizes $\{w_1, w_2, \ldots, w_{N_s}\}$ in order to preserve fine geometrical details (small windows) and improve the rejection of false changes (large windows) at the same time.

This is also possible thanks to the effective edge-preserving smoothing of the guided filter. The combination of the log-ratio images at different scales is performed by averaging at log scale, which corresponds to computing the geometric mean at linear scale. The multiscale GLR algorithm can be formulated as follows.
True Positive Rate
720 through the 30% with modified backscattering, specifically a SAR images in Fig. 1, and are better shown by Fig.3(a), the simulated change patches are visible by comparing the two change detection and mapping algorithms.

Sizes are considered in order to test the performances of the regions with smooth or irregular contours and having different constant increase of pasting image values in the R2, R3 and R4 regions, and a date in the R1 region, deterministic cover changes through the amplitude levels in the second date with respect to the first pair. It represents a geographical area of about 0.5 km², thus simulating a CSK Enhanced Spotlight image spacing, therefore simulating a CSK Enhanced Spotlight image.

The dataset has 1m spatial resolution and pixel spacing, thus simulating a CSK Enhanced Spotlight image pair. It represents a geographical area of about 0.5 km², through the 720 × 720 image pair reported in Fig.1. The simulated change patches are visible by comparing the two SAR images in Fig. 1, and are better shown by Fig.3(a), the reference change image. The patches correspond to regions with modified backscattering, specifically a 30% reduction of the amplitude levels in the second date with respect to the first date in the R1 region, deterministic cover changes through pasting image values in the R2, R3 and R4 regions, and a constant increase of 80 amplitude levels on the R5 region. Regions with smooth or irregular contours and having different sizes are considered in order to test the performances of the change detection and mapping algorithms.

Three algorithms are compared: the classical log-ratio (LR) computed after 7 × 7 Gamma-MAP despeckling, the MSITCD algorithm [11], and the proposed GLR method with W = {3, 5, 7, . . . , 25}. For all features, the final change maps are computed by automatic thresholding (see steps 4-6 of the GLR pseudo-code).

Steps 4-6 describe how the detected change map is automatically computed. Decreased and increased backscattering pixels are independently processed. Each of the two thresholds used to discriminate changed and unchanged pixels is obtained through two-level Max-Lloyd quantization. A different approach can be adopted in case of an extremely skewed distribution of FGLR. This situation is usually encountered when all structural changes have produced increased (or decreased) backscattering values only in the second image. In this case, optimally thresholding the absolute value of FGLR provides a more reliable result.

III. EXPERIMENTAL RESULTS AND CONCLUSIONS

A synthetic image pair with known patches with different shapes, sizes and change levels has been generated from an optical remote sensing image, a panchromatic Ikonos image of Toulouse, France, with 12-bit dynamic range. Nakagami-distributed speckle patterns have been synthesized with an equivalent number of looks L = 1 and a spatial correlation ρ₀ = 0.3. The dataset has 1m spatial resolution and pixel spacing, thus simulating a CSK Enhanced Spotlight image pair. It represents a geographical area of about 0.5 km², through the 720 × 720 image pair reported in Fig.1. The simulated change patches are visible by comparing the two SAR images in Fig. 1, and are better shown by Fig.3(a), the reference change image. The patches correspond to regions with modified backscattering, specifically a 30% reduction of the amplitude levels in the second date with respect to the first date in the R1 region, deterministic cover changes through pasting image values in the R2, R3 and R4 regions, and a constant increase of 80 amplitude levels on the R5 region. Regions with smooth or irregular contours and having different sizes are considered in order to test the performances of the change detection and mapping algorithms.

Figure 2 reports the receiver operating characteristics (ROC) in semi-logarithmic scale for the three tested algorithms. The improvement of the proposed strategy with respect to the standard single scale LR change feature is considerable. GLR also outperforms the MSITCD method. The asterisks indicate the optimal operating points corresponding to the Cohen’s Kappa highest values which almost perfectly correspond to the operating points (the final change maps) automatically computed by optimal quantization.

Figure 1. Simulated 720 × 720 1-look image pair. The shapes of the change regions are better shown in Fig.3(a) which represents the reference change image.

Figure 2. ROC plots of the GLR, MSITCD and LogRatio change features for the 1-look simulated image pair of Fig.1(a)-(b). The asterisks highlight the optimal operating points corresponding to the Cohen’s Kappa highest values.
The final change maps in Fig.3 confirm the results of Fig.2 and prove the capability of the proposed GLR method to preserve edges and contours (see for example Region 5 in Fig.3(d)). The false alarm rejection of GLR can be appreciated as well. The Cohen’s Kappa values of the three final maps are $\kappa_{LR} = 0.794$, $\kappa_{MSITCD} = 0.860$, and $\kappa_{GLR} = 0.902$.

Experimental tests on Spotlight COSMO-SkyMed SAR images will be presented in the final version of the paper.

REFERENCES