1. INTRODUCTION

Against the background of availableness of good resolved SAR image pairs which come from the German radar satellite TerraSAR-X, we investigate in solving the problem of unwrapping the phase image obtained from a noisy interferometric SAR (InSAR) image. A Kalman filter based data fusion approach to unwrap and simultaneously filter the phases of interferometric SAR images is developed. The data fusion concept exploits phase information, extracted from the complex interferogram rather than from the phase image and fuses that information with phase slope information extracted from the power spectral density of the interferogram.

The German national SAR-satellite system TerraSAR-X [3] is based on a public-private-partnership agreement between the German Aerospace center DLR and EADS Astrium GmbH. This powerful system enables Earth observations in different SAR modes and polarizations. In the spotlight mode the resolution goes to 1m, which enables interferometry at a high quality level.

2. THE PRICIPLE OF THE ALGORITHM

Nearly all known phase unwrapping techniques try to unwrap the mapped phases by a sequence of differentiating, taking the principal value of the discrete derivative and integrating it again. A serious drawback of any differentiation of functions which are modulo mapped and noise contaminated is a bias resulting from the discrete derivative of noisy modulo-2Pi mapped phases. As a consequence of this bias, phase slopes are always underestimated. The resulting bias depends on the phase slope itself, as well as on the coherence. Our phase unwrapping algorithm is based on an Extended Kalman filter. The Kalman filter exploits a so called "Basic – Slope Model" enabling the filter to incorporate additional local slope information obtained from the sample frequency spectrum of the interferogram by a local slope estimator.

The local slope information is then optimally fused with the information directly obtained from real and imaginary part of the interferogram. For this reason it is not necessary to generate a phase error based on complicated statistics, phase unwrapping takes place simultaneously with removing the phase errors. Whereas some techniques try to reduce the phase noise by filtering before unwrapping the phase, the Kalman filtering approach simultaneously unwraps the phases and eliminates the phase noise, so that no pre-filtering is necessary.

Based on our experience in this area, we have done some refinements for improving the unwrapping results. Therefore the filter can yield excellent results of the unwrapped phase even in regions with steep and rough topography.
3. OPERATION IN AREAS OF LOW COHERENCE

The result of the unwrapped product will be dramatically reduced in quality if the coherence (e.g. caused by radar show, layover) is regionally low. Because of error propagation the filter can never return back to the correct phase. For getting rid of this problem we have implemented several methods. Because of our analysis of the regarded interferogram we have a lot of information (slopes, variance of the slope, noise prediction) we can use. Together with other information (like coherence) we are able to automatically mask out areas in which our algorithm will probably give wrong phase estimates. According to this only a small part of the interferogram is neglected by the processor while the most areas are processed correctly. If there is some a priori knowledge available we can take this information and complete our phase slope matrix, which otherwise will be filled with zeros. Driven by this model the Kalman filter can fill the gaps of the masked out areas. Another solution to avoid phase errors caused by areas of low coherence is to use a Kalman smoother: We can start the 2D filtering process from each edge of the interferogram in four different directions. The filter estimate of the individual filters is then combined with the prediction estimate of the other filters where the weighting of the individual estimates is inversely proportional to the corresponding error covariances.

4. RESULTS

The paper will give the used Kalman filter equations and the processing results of our approach using simulated as well as real data from TerraSAR-X. We compare these results with the results which are produced by the traditional phase unwrapping methods. We discuss the advantages of Kalman filtering for phase unwrapping applications deal with the drawbacks of this approach and show how to compensate them.

5. REFERENCES