Long time scale INSAR by means of high coherence features

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Abstract

The monitoring of slow deformation processes by means of SAR Interferometry requests the observed area to mantain its correlation for more years. This usually happens only for those areas having particularly favourable characteristics, such as poor vegetation and dry and no windy climate. However, even in an area which decorrelates in a few weeks, a certain number of features has been observed, which appear to mantain high coherence values. The aim of this paper is therefore to investigate to which extent these structures, mainly man-made features, remain coherent on long time scales. For this purpose, a time series in a test area in the Northern Netherlands has been generated, with a maximum temporal extension of 3 1/2 years. Even on such a long time span, a considerable number of highly coherent features has been found. A sample of such features has then been selected and the coherence values have been traced in the whole time series. This technique has revealed to be useful in order to check the "goodness" in terms of coherence of an interferogram: in particular, in this way an interferogram could be identified having generally lower coherence, probably due to different seasonal conditions. Other tests have been performed in order to study the coherence as a function of time and of the baseline length.

1 Introduction

It is well-known that a strong limitation for time range applicability of repeat-pass differential SAR interferometry is temporal decorrelation. Therefore, we still cannot perform longterm studies of slow deformation processes like land subsidence and plate tectonics, in spite of the availability of SAR images over several years. However, we noticed that even on very long time spans, highly coherent features are still present, mainly man-made features. We thus want to investigate whether or not the coherence stability of these structures could be used for long time-scale monitoring of slow deformation processes. As a first step, we generated a time series of interferograms, which constitutes the database of the present work, spanning different time intervals between 1-day up to more than 3 years. The details and some remarks about the construction of such time series are shown in section 2. We then selected a sample of features showing high coherence on long time scale and we performed some tests on it. The first results are presented in section 3.

2 The 1992-1996 time series

The database is a time series of interferograms of the area around the city of Groningen, in the northern part of The Netherlands. The area is well known for its land subsidence, caused by the extraction of natural gas: the rate of land subsidence is up to 1 cm/yr. In order to be able to detect it by means of the INSAR technique, monitoring of the area for more years would be necessary. As a first step to assess whether this is possible, we want to study the features (mostly man-made structures) which preserve their coherence on such long periods.

master	slave	B_{par}	B_{perp}	days	no
16-3-96	17-3-96	-17	24	1	9
16-3-96	11-2-96	36	212	34	8
16-3-96	20-4-96	50	145	35	7
16-3-96	21-4-96	18	79	36	6
16-3-96	6-1-96	-109	-129	70	5
16-3-96	20-8-95	-62	-272	209	4
16-3-96	19-8-95	-26	-190	210	3
16-3-96	15-10-92	5	25	1248	2
16-3-96	10-9-92	43	52	1283	1

Figure 1: The Groningen dataset. The 5th column shows the time span in days , the 6th the serial number of the interferogram

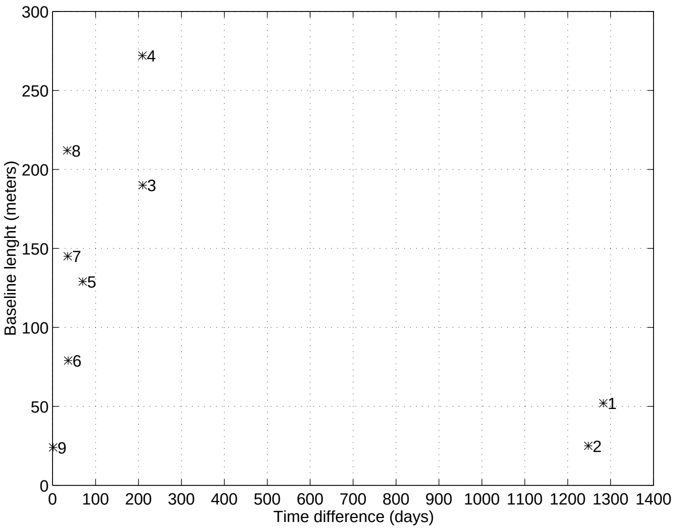

Figure 2: Perpendicular component of the baseline vs. temporal gap between the two images for each of the interferograms

The time series generated for this purpose has the following characteristics:

- The same image is used as master for all the interferometric pairs, in order to guarantee that all the slave images are interpolated on the same grid, namely the master. In this way, a given pixel represents the same area in all the interferograms.
- Azimuth filtering has been applied: our tests confirmed what was already highlighted in the literature ([1],[2]), i.e. that azimuth filtering highly improves the coherence. This is particularly important for the long time scale interferograms, where the coregistration is more difficult because of the generally low coherence. Figure 1 shows the interferograms generated, and their baseline components, column 5 contains the interferogram serial numbers, which are used as reference in the plots. In figure 2 the distribution of the time spans and of the perpendicular component of the baselines is visualized.
- The final products, i.e. the coherence and phase images, are mediated over 2 pixels $\times$ 10 lines.

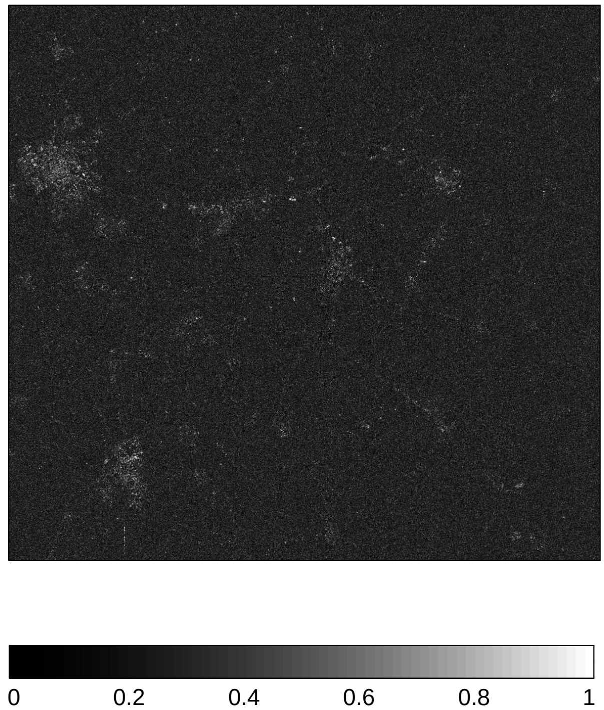

Figure 3: Coherence image of interferogram no.1 (16-3-96/10-9-92)

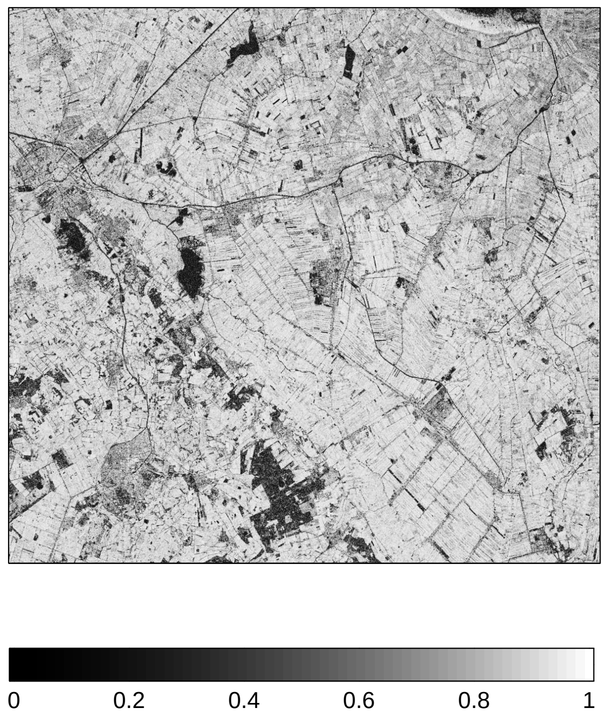

Figure 4: Coherence image of interferogram no.9 (16-3-96/17-3-96)

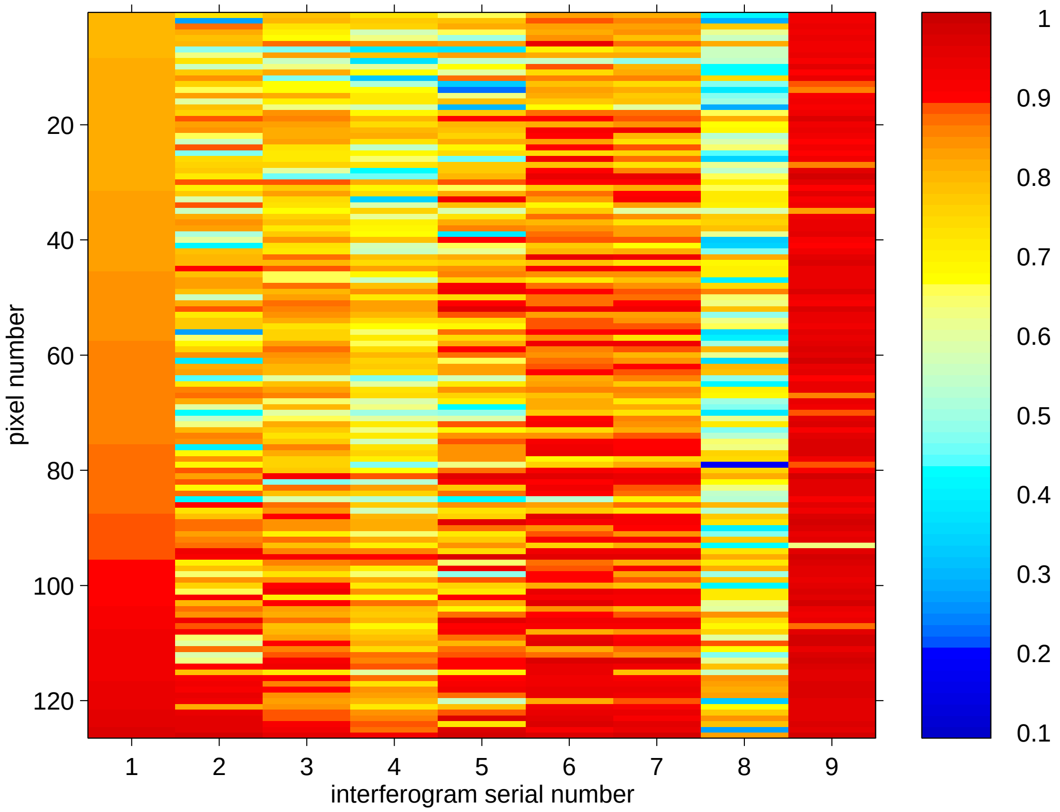

Figure 5: Coherence values for each point of the dataset and for each interferogram

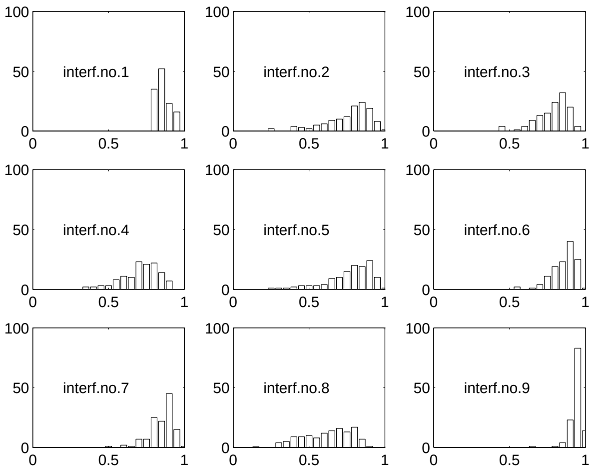

Figure 6: Histograms of the coherence values for each interferogram

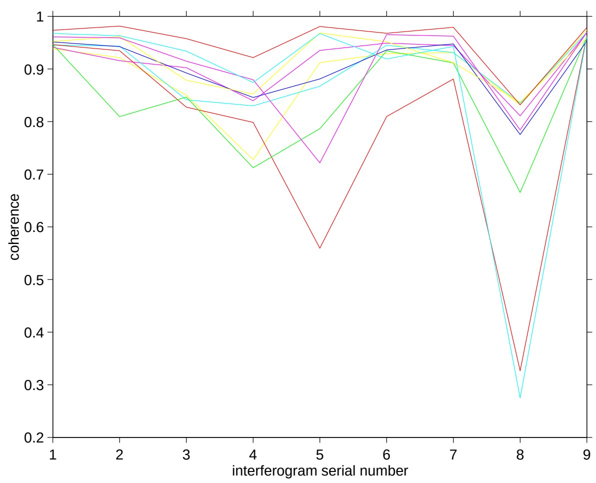

Figure 7: Coherence values in the series for the ten highest-coherence points

3 Analysis of the coherence

The coherence is estimated on a 2×10 window. Figure 4 and figure 3 are the coherence images respectively on the shortest (tandem pair, no.9) and on the longest (about 3 $1/2$ years, no.1) time interval considered. We selected in the coherence image no.1 those pixels having coherence higher than 0.8. We concentrated then for our tests on the area of the city of Assen (low left in figure 3), which contains a statistically significant number of such pixels. The area has an extension of 200 pixels $\times$ 300 lines. The coherence of those pixels has been traced in the whole time series. Figure 5 represents the coherence of these points as results in all the interferograms: each column represents an interferogram of the series, each horizontal line contains the values of the coherence for a given point.

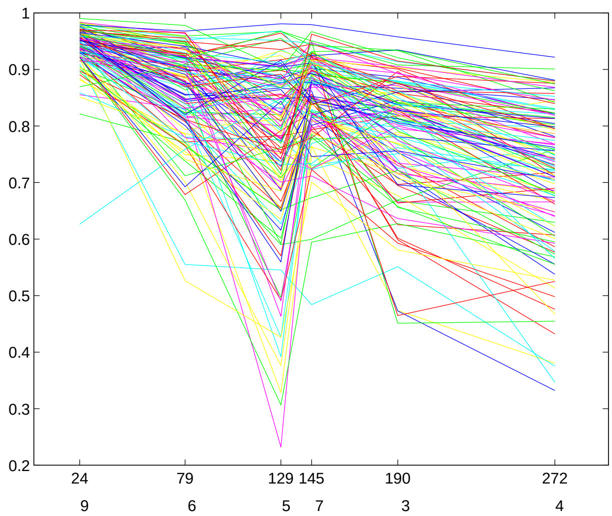

Figure 8: Coherence vs. baseline length (perpendicular component) in the series. Under the baseline values, the corresponding interferogram numbers are given.

Note that high coherence in the longest time span interferogram (no.1) doesn't seem to imply high coherence in other interferograms on shorter time intervals. As we could expect, in fact, the time gap doesn't seem to have any influence on the coherence values. This is also confirmed by the fact that any attempt to find a linear trend in the coherence as a function of time didn't give any significant result. It is also evident from figure 5 that interferogram no.8 presents a generally lower coherence. We don't know the reason for this; it can be possibly due to different weather conditions (the master image is taken in March, the second in February, during a period of snow precipitation) and to the long baseline. Figure 6 shows the coherence histograms of the time series. Figure 7 is the plot of the coherence values along the series for the ten highest-coherence points.
We also considered the possibility of a dependence of the coherence on the baseline length. For this purpose, the coherence has been plotted against the baseline length (perpendicular component) in figure 8, where under each baseline value, along the x-axis, also the corresponding interferogram serial number has been indicated. The interferogram having coherence generally lower than the others (no.8) has not been considered here. We also did not consider the two long-period interferograms (no.1 and no.2): we restricted ourselves to the temporally nearest interferograms. From the figure there seems to be some trend, but we have to perform more detailed tests in order to be able to assess it. We note also that for interferogram no.5 the coherence is worse than for the other interferograms with higher baseline. Since the slave in this pair is taken in January, this could be due to different weather conditions with respect to the time the master has been taken.

4 Conclusions

A time series of interferograms has been generated covering time spans up to 3 $1/2$ years. Even on such a long time span, highly coherent features could be identified. The analysis of the series in its whole permitted the identification of an interferogram showing significantly lower coherence than the others. No significant signatures of dependence of the coherence values from the time have been found. Some dependence of the coherence from the baselines could be present, but more tests are necessary in order to assess it.

5 Acknowledgements

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References

[1] Geudtner D. *Die interferometrische verarbeitung von SAR-daten des ERS-1*. PhD thesis, Universität Stuttgart, 1994.

[2] Schwäbisch M. and Geudtner D. Improvement of Phase and Coherence Map Quality Using Azimuth Prefiltering: Examples from ERS-1 and X-SAR. In *International Geoscience and Remote Sensing Symposium, Florence, Italy, 10–14 July 1995*, pages 205–207, 1995.