The use of man-made features for long time scale INSAR

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Abstract — From a series of interferograms spanning 3 and 1/2 years, a sample of features has been extracted which appear to have constantly high coherence for the whole time interval. These features, mainly of anthropogenic nature, have then been studied in order to assess whether they can be used for long time monitoring of slow deformation processes in almost completely decorrelated areas. For this purpose, both the coherence and the phase stability of the features have been checked along the time series.

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, even on very long time spans, highly coherent features are still present, mainly man-made features. The aim of this work is to investigate whether or not these highly coherent structures could be used for long time-scale monitoring of slow deformation processes. As a first step, a time series of interferograms has been generated, which constitutes the database, spanning different time intervals between 1-day up to 3 1/2 years. The details and some remarks about the construction of such time series are shown. A sample of features showing high coherence on long time scale has then been selected, and their coherence has been studied along the whole series. For a subset of these features the phase stability has also been checked by means of the differential technique.

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

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. Fig.1 shows the interferograms generated, and their baseline components, column 5 contains the interferogram serial numbers, which are used as reference in the plots.

ANALYSIS OF THE COHERENCE

The coherence is estimated on a 2 × 10 window, the coherence and phase images are 2 × 10 multilooked. Fig.2 represents the coherence images on the shortest (tandem pair, no.9) and on the longest (about 3 1/2 years, no.1) time interval considered. Only those pixels having coherence higher than 0.8 in the coherence image no.1 were considered. Of this set of pixels, a subset has been considered, located in the area of the city of Assen (low left in the coherence images of fig.2), which contains a statistically significant number of such pixels. Fig.3 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. From fig.3 it is evident that interferogram no.8 presents a generally lower coherence: therefore, it has been excluded from the series in the second part of the work, the study on the interferometric phase. For more details about the construction of the time series and the results of the study on the coherence, see [2].

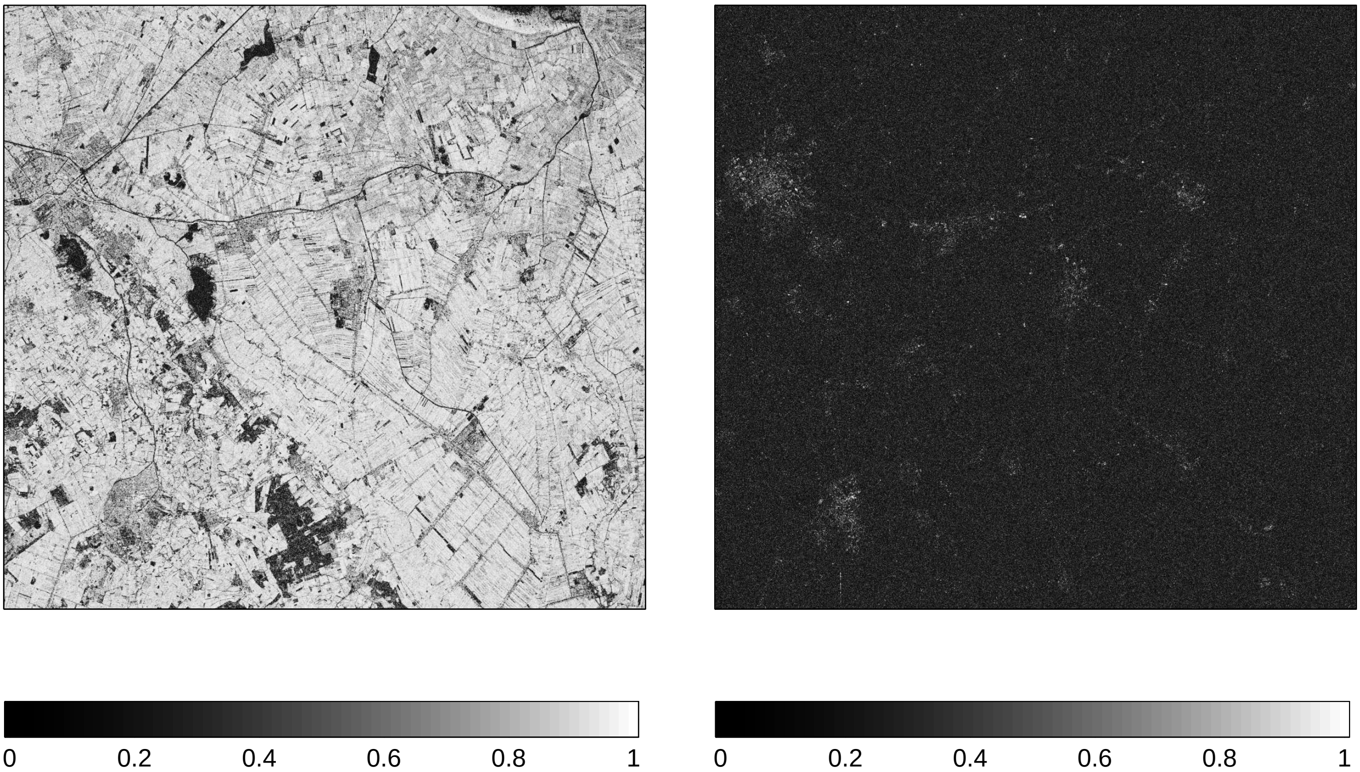

Figure 2: Coherence images respectively in the interferograms no. 9 (16-3-96/17-3-96) and no.1 (16-3-96/10-9-92)

ANALYSIS OF THE PHASE

The second step of the analysis consisted in checking whether those features showing constantly high coherence along the time series do mantain also phase stability in time. For this test, the area of Assen was particularly suitable, not only for the high concentration of features,

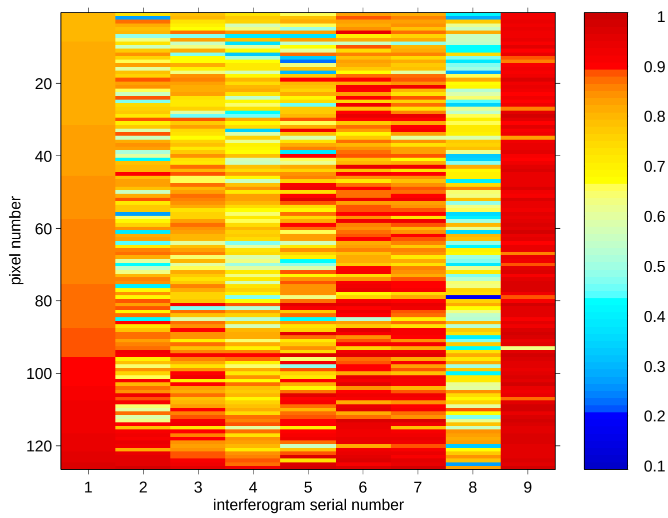

Figure 3: Coherence values for each point of the dataset and for each interferogram

but also because it is the only city in the area which is not subject to land subsidence. The test consisted in applying the differential INSAR technique [1] along the time series. The interferograms no.1,2,5,6,7,9, have been considered for this purpose. From the set of pixels used for the study on the coherence (126 pixels), only those mantaining coherence above 0.8 in all the 6 interferograms were selected. They turned out to be 42. In each interferogram, the "spatial" phase difference of each pixels with respect to a reference pixel (which is the same in all interferograms) has been computed. For each of these differences, the value in interferogram no.7 has been taken as reference value and rescaled and subtracted from the corresponding phase difference value in all the other 5 interferograms. The "temporal" phase difference computed in this way, is shown in fig.4. Every line is the "spatial" phase difference between one pixel and the reference pixel plotted along the time serie. From fig.4 it seems that most of the pixels considered do mantain phase stability on long time scale. From the same figure, it is also evident that the differential phases in interferogram no.2 has been undergone some disturbing effects (maybe bad meteorological conditions) which has affected the phase of many points. This is also evident from fig.5, where the standard deviations of all data within an interferogram has been plotted. Since interferogram no.6 differs from the reference interferogram no.7 of only one day, it seems reasonable to assume that for the most pixels the area represented is not changed

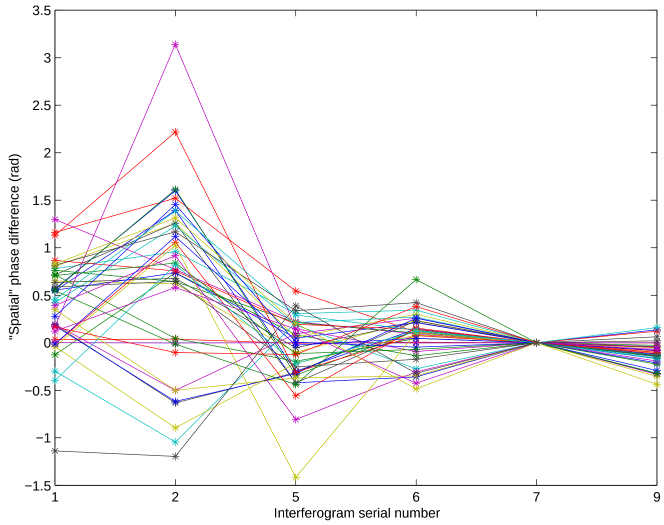

Figure 4: Differential phase values along the time series for constantly highly coherent pixels (Interf. no.7 has zero values because is taken as reference interferogram)

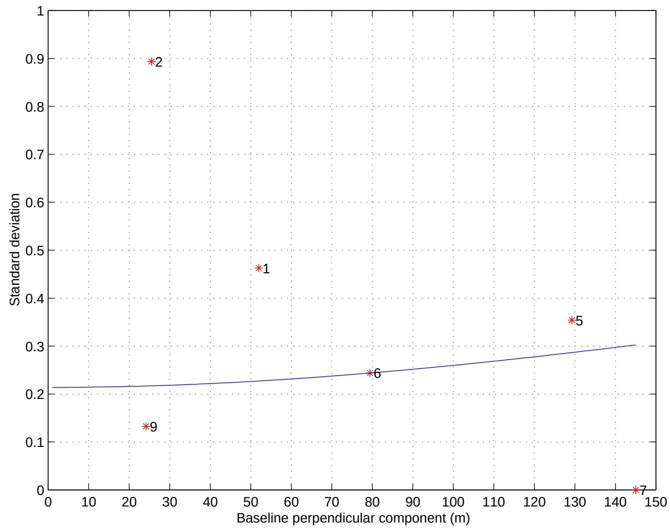

Figure 5: Standard deviations of the differential phases for each interferogram. The line is the "theoretical" standard deviation as derived from the value in interferogram no.6, the * are the computed values from the data.

intrinsically, i.e. that a pixel represents an identical area in no.6 and no. 7. With this assumption, the standard deviation of the pixels in interferogram no.6 should represent occasional external disturbances of the backscattering from the pixels, due for example to different meteorological conditions, or to the presence of different scattering sources. The standard deviation in no.6 can thus be taken as representative of the "noise" of the computed differential phase measurements. From this standard deviation, with a simple error propagation it is possible to derive the standard deviation as a function of the perpendicular baseline, also represented in fig.5. Note that the "theoretical" values derived from the value in no.6, are generally lower than the standard deviations as determined from the data.

CONCLUSIONS

A time series of 9 interferograms has been generated covering time spans up to 3 and 1/2 years. Even on such a long time span, highly coherent features could be identified. The analysis of these features in the whole series permitted the identification and the exclusion of an interferogram showing significantly lower coherence than the others. A subset of constantly highly coherent pixels located in an urban area not subject to land subsidence has then been examined in order to assess the degree of phase stability of these features with respect to other factors than effective ground deformations. Most of these features turned out to be very stable even on the longest time span considered. However, reducing the time series only to those interferograms having baselines shorter than the baseline of the reference one, has limited the time series to 6 elements. Moreover, in one of the interferograms the differential phase values turned out to be generally affected by some disturbing effect. It is evident that, in order to have more clear results, the time series should contain a large number of interferograms. This would make easier the identification of "bad" interferograms and at the same time the exclusion of such interferograms wouldn't impoverish significantly the time series. Finally, it has to be stressed that these are the first attempts to assess whether phase information coming from very small structures, whose reflection is limited to one or few more pixels, can be used for extending the time range applicability of the INSAR technique. In this sense, the results presented are an encouragement to perform more refined tests to study the interferometric characteristics of such features.

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