

An Influence of Meteorological Conditions on the Accuracy of PS Interferometry Measurements

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Abstract— We discuss analysis of the PS scatterers located in Moscow city using long-term series of PALSAR images. 29 PALSAR observations made from ALOS satellite repeated orbits in 2006–2010 were used in our analysis. One of important features of the data stack was the fact the observations were made in different meteorological conditions — in warm and cold seasons, in dry days and in the case of precipitations. To demonstrate the manifestation of meteorological conditions we selected a set of PSs on the Delta hotel building located in the eastern part of Moscow city. Analysis of the PSs displacements shows that long-term stability of the Delta hotel location is about 0.9 cm. The value is most likely determined by SAR instrument thermal noise and clutter, not the stability of the hotel location. The accuracy of the separate scatterers location having 30–35 dB sigma-zero is 0.5–1 cm. The accuracy decreases till 2–2.5 cm in rainy and winter days.

1. INTRODUCTION

Persistent scatterers interferometry is a modification of radar interferometry technique for a case of strong temporal decorrelation [1]. The basic idea is a selection of so-called Persistent Scatterers (PS) keeping the stability of backscattering properties — both an amplitude and initial phase of scattered signal. In urban territories such scatterers are formed typically by buildings structures reminding corner reflectors. The PSs are frequent in urban territories and rare in natural environments. Typical initial criterion of the PS selection is the stability of the image pixel amplitude.

2. STUDY AREA AND EXPERIMENTAL DATA

In our report we discuss analysis of the PS scatterers located in Moscow city using long-term series of PALSAR images. 29 PALSAR observations made from ALOS satellite repeated orbits in different observation modes (FBS34.3 and FBD34.3) in 2006–2010 were used in our analysis (see Table 1). FBD mode was used mainly in warm period of the year, and FBS in cold winter days. One of the important features of the data stack was the fact the observations were made in different meteorological conditions — in warm and cold seasons, in dry days and in the case of precipitations.

3. DATA PROCESSING DETAILS

The observation made on September 21, 2007 was selected as basic one, and 28 coregistered interferograms were generated. The perpendicular baseline values for the interferograms are shown in a form of plot in Fig. 1. PSs for our study were selected from the analysis of interferograms via standard statistical analysis of the PSs amplitude stability in a form of amplitude dispersion index [1]. The amplitude dispersion index threshold in the selection procedure was set 0.3.

The specific feature of the series of PALSAR observations used was the monotonous alteration of interferometric baseline from –3800 m till 4000 m. The reason was the steady alteration of ALOS satellite orbital parameters with abrupt jump in 2008 because of orbital maneuver.

Interefrometric phase difference $\Delta\varphi = \varphi_1 - \varphi_2$ is a function of $\Delta\varphi_t(\Delta h)$ topography height variations Δh , small-scale surface displacements (surface dynamics) $\Delta\varphi_s$ between SAR observations, atmospheris fluctuations of signal path length $\Delta\varphi_a$, system noise $\Delta\varphi_n$ and unknown initial phase $\Delta\varphi_0$:

$$\Delta\varphi = \Delta\varphi_t + \Delta\varphi_s + \Delta\varphi_a + \Delta\varphi_n + \Delta\varphi_0. \quad (1)$$

To demonstrate the manifestation of meteorological conditions we selected 7 PSs located on the Delta hotel building in Izmailovo district of the city of Moscow. SRTM DEM was used to calculate topographic phase and remove it from (1). We did not calculate phase screen effects for each of the

Table 1. PALSAR observation dates and meteorological conditions.

No.	Observ. dates	Temperature, precipitations	No. Π/Π	Observ. dates	Temperature, precipitations
1	18.06.2006	+20	16	08.11.2008	-1
2	03.08.2006	+18, rain	17	24.12.2008	-5, snow
3	18.09.2006	+10, 8	18	08.02.2009	+0, smog
4	03.11.2006	-4, drizzle	19	26.06.2009	+15, rain
5	03.02.2007	-12	20	11.08.2009	+18
6	21.06.2007	+16	21	26.09.2009	+9, rain
7	06.08.2007	+20	22	27.12.2009	+2, wet snow
8	21.09.2007	+9	23	11.02.2010	-11
9	06.11.2007	-4, wet snow	24	29.03.2010	+4
10	22.12.2007	+1, rain	25	29.06.2010	+20
11	06.02.2008	-1, wet snow	26	14.08.2010	+25
12	23.03.2008	+2	27	29.09.2010	+6
13	08.05.2008	+5	28	30.12.2010	-7
14	23.06.2008	+17	29	14.02.2011	-19
15	23.09.2008	+8			

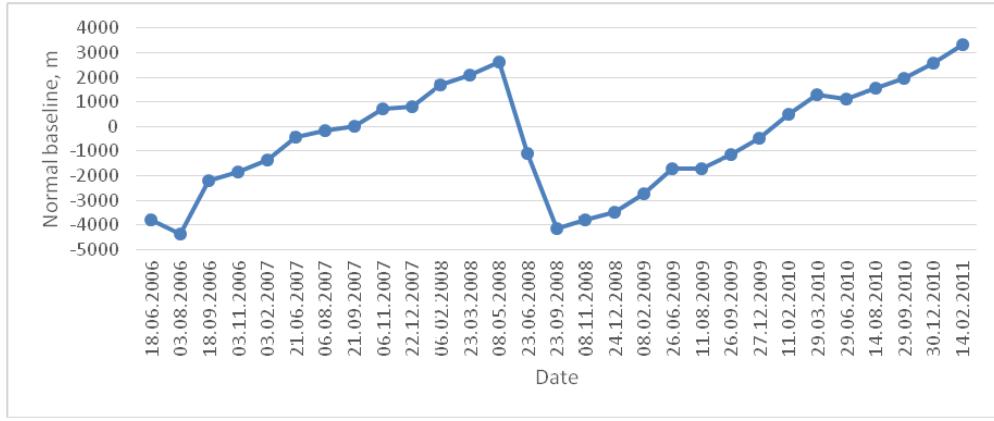


Figure 1. Perpendicular baseline values for 28 interferograms from a stack.

interferograms because of relatively close location of the targets selected. The pseudo displacements of 7 PSs after topographic phase correction are presented in Fig. 2.

Strong correlation of interferometry baseline variations in Fig. 1 with PSs displacements in Fig. 2 may be explained by errors in scattered signal phase center location in the altitude. Before the final calculation of the PS displacements we refined the altitude of these scatterers location on the building in root-mean-square procedure and compensated erroneous displacements caused by DEM errors. It was discovered that error in the location of PSs in altitude is $\Delta h_e = -4.9$ M (PSs scattering altitude is below the altitude taken from SRTM DEM).

In Fig. 3 the average displacement l of the 7 PSs after the correction of topography induced errors is presented. There is now any linear trend which might be caused by steady subsidence of the Delta building during 2006–2011. The fluctuations present on the plot are caused mainly by clutter signal within the resolution cells. The estimation error of displacements of the building as a set of 7 PSs is about 0.9 cm. There is no dependence on the observation mode and season of the year.

In Fig. 4 root mean square deviations of the PSs locations for the data from Fig. 2 are presented. Among the mostly moderate (0.5–1 cm) deviations there are large ~ 2.5 cm outliers. The observation on 03.08.2006 was made in heavy rain conditions, and the observations on 06.02.2008, 02.08.2009 and 30.12.2010 were made in winter time, what may be an explanation of the increase

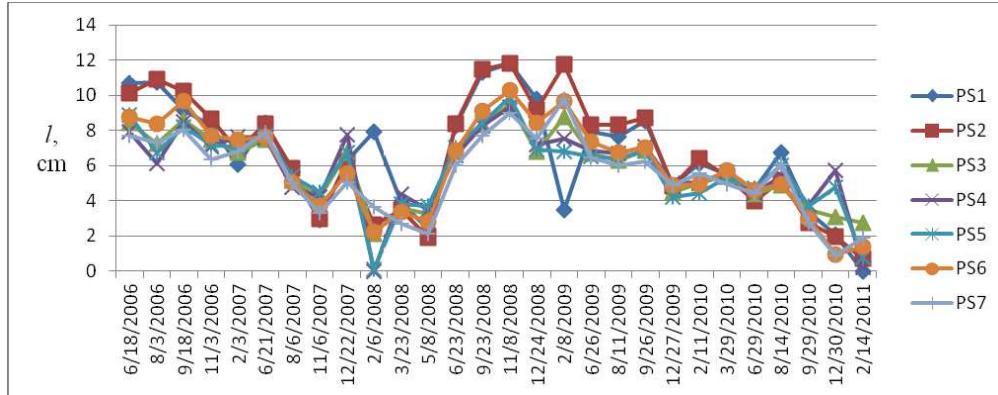


Figure 2. History of 7 PSs pseudo displacements in 2006–2011.

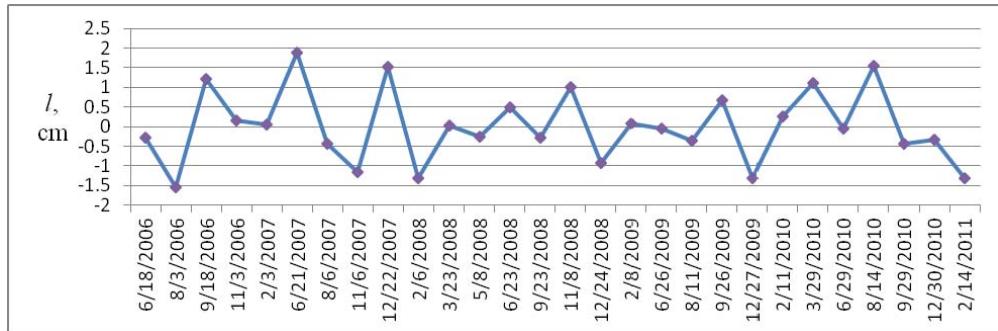


Figure 3. Average displacements of 7 scatterers after the correction of topography induced errors.

of the measurement errors of PSs location on the body of the hotel building.

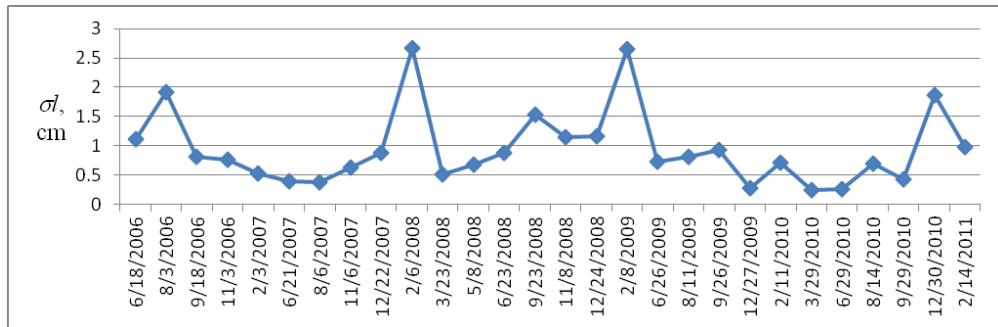


Figure 4. The errors of the location errors for 7 PSs on the body of Delta hotel.

Analysis of the PSs displacements shows that long-term stability of the Delta hotel is about 0.9 cm. The value is most likely determined by SAR instrument thermal noise, not the stability of the hotel location. The accuracy of the separate scatterers location having 30–35 dB sigma-zero is 0.5–1 cm. The accuracy decreases till 2.5 cm in rainy and winter days. The effect should be taken into account at the stage of the data selection.

4. CONCLUSION

PS interferometry technique is an effective tool for the detection of the scattering surface displacements in the case of strong temporal decorrelation. The technique is especially effective tool in urban territories with numerous stable scattering structures reminding corner reflectors. The hotel Delta building in the city of Moscow was used to show an influence of meteorological conditions on the accuracy of the buildings displacements measurements with a use of PS technique.

An important requirement in the differential interferometry technique used for the displacements measurements is accurate knowledge of scatterers elevations. In our case significant errors in the displacements of PSs were discovered because of errors in the values of PSs location in altitude.

The improvement of the PS heights is an important step in the procedure of the elevated PSs displacements estimations.

The long-term stability of the PSs with normalized radar cross-section 30–35 dB found on the Delta hotel body is about 0.9 cm. Very likely it is determined by SAR system thermal noise and clutter within the image pixels. The accuracy decreases till 2.5 cm in rainy days and in winter time.

REFERENCES

1. Ferretti, A., C. Prati, and F. Rocca, “Permanent scatterers in SAR interferometry,” *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 39, 8–20, 2001.