INSAR STUDY OF LANDSLIDES IN THE REGION OF LAKE SEVAN– ARMENIA

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ABSTRACT

The region of Lake Sevan in Armenia is of theoretical and practical interest due to its very high landslide phenomena caused by metrological and hydrological reasons. Based on the ESA Principal Investigator Number C1P-6051 and requested data from ASAR instrument of ESA ENVISAT satellite four single look complex images including two images from 2008 and two images from 2009 of the region of the Sevan Lake in Armenia are obtained and thoroughly investigated. The one of the images is pointed out as a master and the rest of them, three images as slaves. Hence, three interferometric pairs are produced. Then data of NASA SRTM mission is applied to the interferometric pairs in order to remove topography from the interferograms. Three interferograms generated illustrate decreasing of coherence caused by high temporary decorelation, which means decreasing the level of coincidence of SLC’s in each interferometric pair, according to the time of acquisition each of them.

1. GEOLOGICAL DESCRIPTION OF SEVAN LAKE REGION

Armenia is mountainous country, where 90% of its area lays above 1000 m altitude. Mountain slopes, ones forest and green, are nowadays bald, and remnants of the forests are vanishing, as they provide the some source of energy for winter heating of local inhabitants. Steep mountain slopes that has lost their natural protection against weathering together with torrential rains coming every year during springtime, and with regular earthquakes provide dangerous mixture of conditional prone to landslide [1,2].

Lake Sevan is situated in the northern part of the Armenian Volcanic Highland, 60 km to the north from the capital of Armenia, Yerevan. Lake Sevan is the greatest one of the Caucasus Region and one of the greatest freshwater high-mountain lakes in Eurasia. [3]

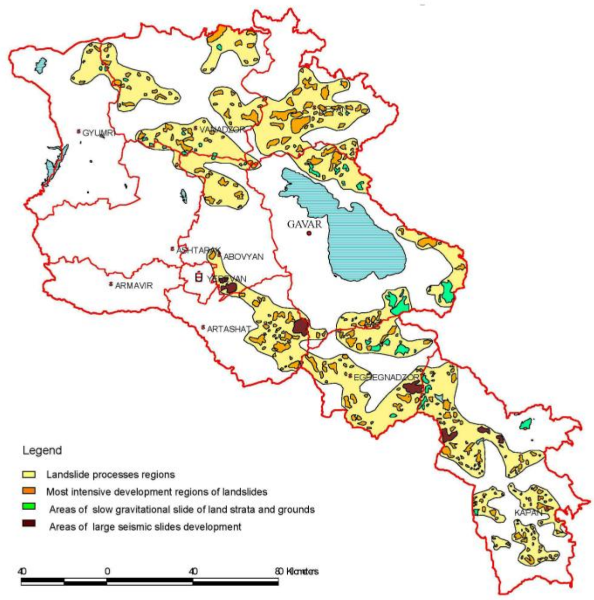

Figure 1. Map of landslides of Republic of Armenia

2. INTRODUCTION AND GOAL OF STUDY

As a partner of the European Space Agency (ESA) project C1P-6051, Burgas Free University has the opportunity to order, receive and process real satellite data. The only requirement is to point out ESA, as a source of data used for the study. In this research four satellite high-resolution images obtained from ESA ENVISAT satellite ASAR instrument are used. The list of used products is given in Table 1. Satellite images are acquired from the same ground area of National park Sevan, Armenia. Accordingly, two images from 2008 and two from 2009 have been ordered. SAR ASAR instrument uses radar technology to scan the ground and range-dopler algorithm is used for image reconstruction. The products obtained are complex images containing amplitude and phase information. Only the phase information is necessary to generate an interferometric pairs. From every two interferometric pairs a differential interferogram can be obtained by removing topography using DEM from NASA SRTM mission.

3. BASIC INTERFEROMETRIC CHARACTERISTICS

Synthetic Aperture Radar (SAR) works by recording the echo returns from many radar pulses and processing them to generate a single looks complex radar image.

The radiation transmitted from the radar has to reach the scatterers on the ground and then to come back to the radar in order to form the SAR image. The complex SAR image contains an information of the amplitude and phase of the radiation backscattered toward the radar by the objects (scatterers) contained in each SAR resolution cell. Scatterers at different distance from the radar introduce a different delay between transmission and reception of the radiation. Due to the almost pure sinusoidal nature of the transmitted signal, this delay is equivalent to a phase change between transmitted and received signals [4].

Interferometric Synthetic Aperture Radar (InSAR) data can be acquired using two antennas on one satellite or by two slightly offset passes of a satellite with a single antenna. Typical geometry of the repeat-pass satellite InSAR is represented in Figure 2.

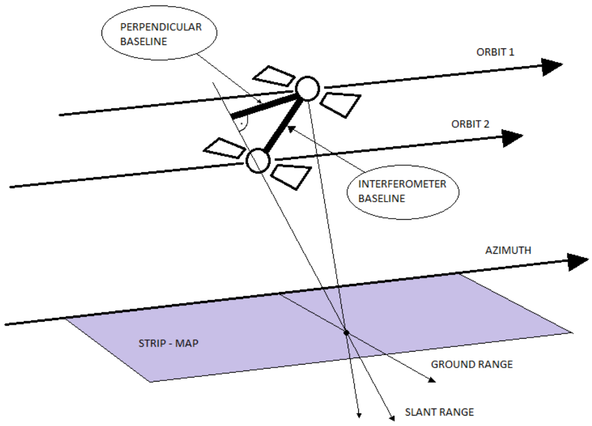

Figure 2. InSAR geometry

The SAR complex interferogram is generated by a complex conjugate multiplication of two SAR images acquired by two passes. The amplitude of the complex interferogram is the coherence map, whereas its phase is the interferogram, the phase difference between the two images [4].

4. DATA AND INSTRUMENT DESCRIPTION

In this research InSAR technique to produce interferograms is used. The ENVISAT satellite data products (listed in Table 1) from ASAR instrument delivered by ESA is processed.

Short name	File name
33985	ASA_IMS_1PNIPA20080830_071539_00000016 2071_00364_33985_5065.N1
34486	ASA_IMS_1PNIPA20081004_071540_00000016 2072_00364_34486_5066.N1
38494	ASA_IMS_1PNIPA20090711_071540_00000016 2080_00364_38494_1122.N1
40498	ASA_IMS_1PNIPA20091128_071532_00000016 2084_00364_40498_1121.N1

Table 1. File list and short names

Table 2 illustrates amplitudes and phases of the four scaled and cropped single lock complex images in ratio 1:5, as follows: 33985A, 33985P, 34986A, 34986P, 38494A, 38494P, 40498A, 40498P.

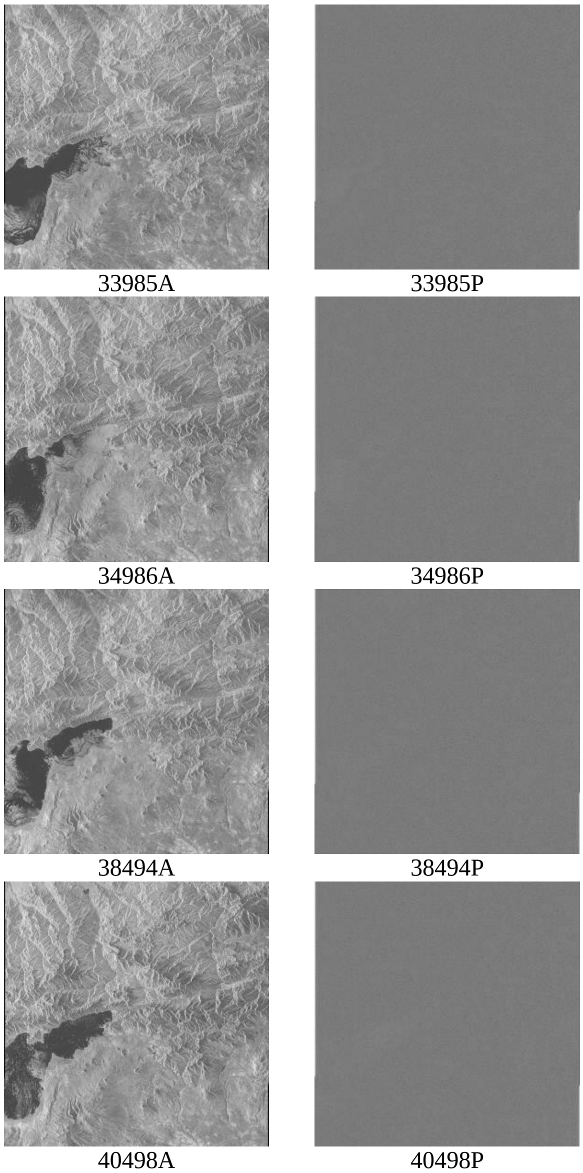

Table 2. Scaled and Cropped SLC Images

For the purpose of the interferometric processing it is necessary to choose one of the images as master, and the rest three of them as slaves. In this work the image

33985 is considered as a master, and each of other's images plays a role of a slave (34986, 38494, 40498). Accordingly three interferometric pairs are formed as follows: 33985-34986, 33985-38494, 33985-40498. In Table 3 estimates of the baseline between each pair of images is shown. The first column represents the perpendicular baseline (in meters), the second column represents temporal baseline (in days) and the last column are the short names of the complex images used.

0	0	33985
35	-185,3	34486
315	-96,9	38494
455	38,1	40498

Table 3. Baseline estimation

Figure 3 graphically illustrates the dimensions of the baselines: the perpendicular baseline (in meters) is along Ox axis, while the temporal baseline (in days) is along Oy axis.

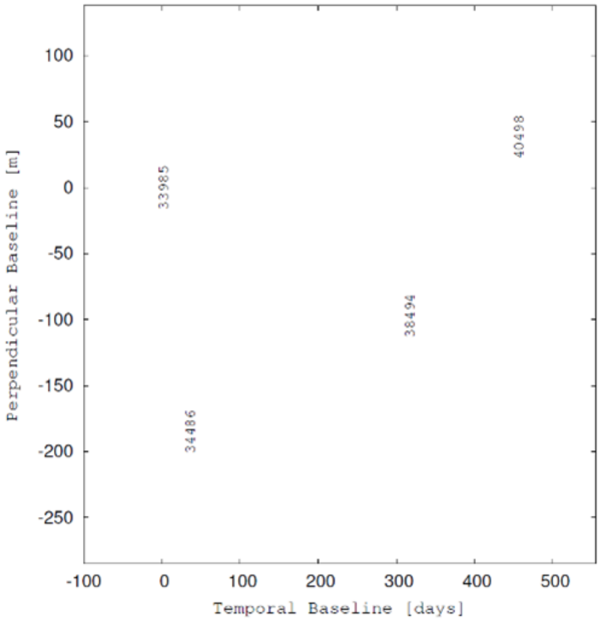

Figure 3. Perpendicular vs Temporal Baselines

5. APPLYING DIGITAL ELEVATION MODEL (DEM) FROM NASA SRTM MISSION

For differential interferometric processing, data from SRTM3 mission of NASA are used. It provides a digital terrain model (Digital Elevation Model) with a resolution of 30 meters in height. The following files from SRTM are used: N39E043.hgt, N39E044.hgt, N39E045.hgt, N40E043.hgt, N40E044.hgt, N40E045.hgt, N41E043.hgt, N41E044.hgt, N41E045.hgt. Two DEM files are constructed, as follows: E020N40.dem and E020N90.dem. Figure 4 illustrates a unified image generated from those input files. It represents the whole digital model of the relief of interest.

Figure 4. Unified DEM

6. RESULTS OF THE DATA IMAGING AND INTERFEROMETRIC STUDY

Table 4 shows results of processing for each interferometric pairs: first column 33985-34986 pair, middle column 33985-38494 pair and last column (right) 33985-40498 pair. The images in the table 4 illustrate the results of interferometric processing steps as follows:

- Complex interferogram;
- Flatened interferogram;
- Topography removed interferogram (DEM assisted);
- Coherence Map;
- Errors and rotated vectors.

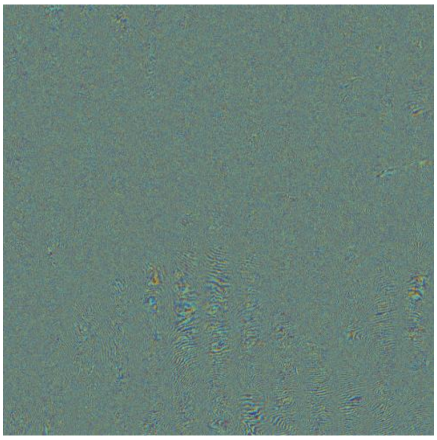

Figure 6,a. Master: 33985-Slave: 34486
- Complex interferogram

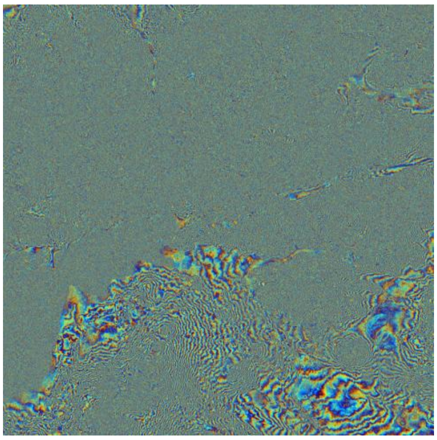

Figure 6,b. Master: 33985-Slave: 34486
- Flatened interferograms

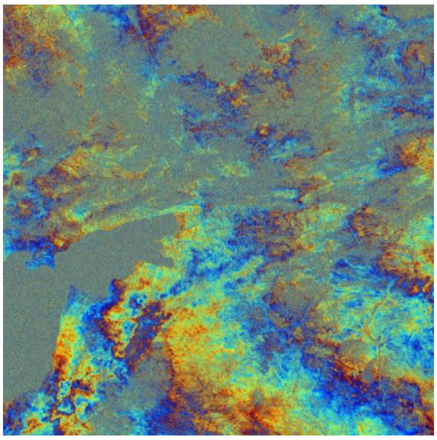

Figure 6,c. Master: 33985-Slave: 34486
- Topography removed interferograms

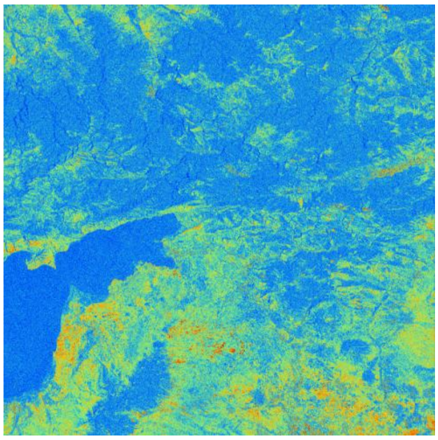

Figure 6,d. Master: 33985-Slave: 34486
- Coherence Map

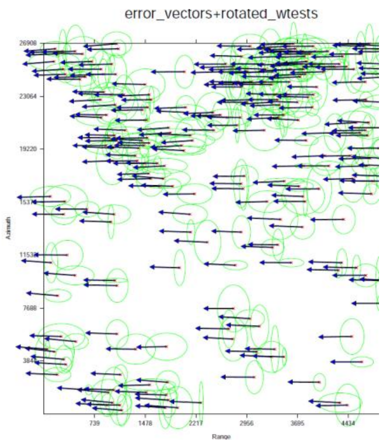

Figure 6,e. Master: 33985-Slave: 34486
- Errors and rotated vectors

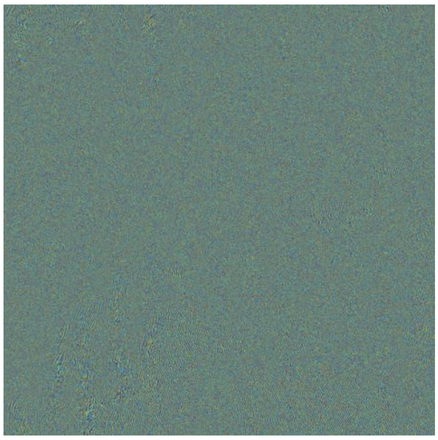

Figure 7,a. Master: 33985 - Slave: 38494
Complex interferograms

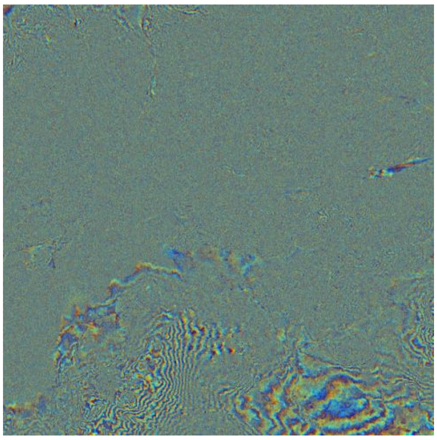

Figure 7,b. Master: 33985 - Slave: 38494
Flatened interferograms

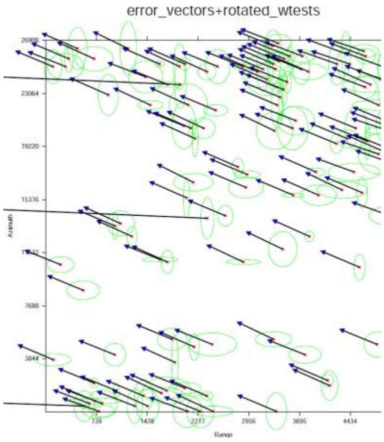

Figure 7,e. Master: 33985 - Slave: 38494
Errors and rotated vectors

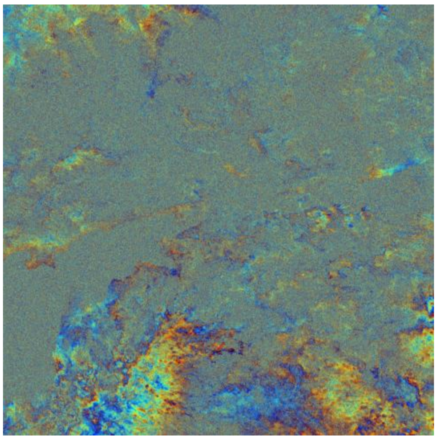

Figure 7,c. Master: 33985 - Slave: 38494
Topography removed interferograms

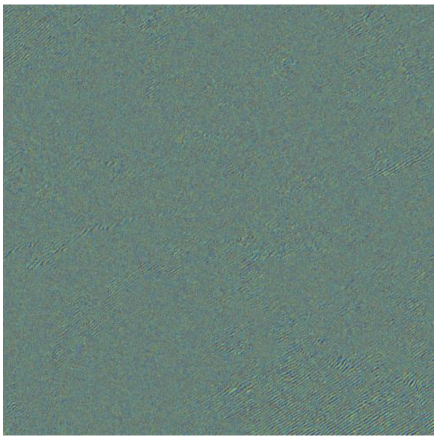

Figure 8,a. Master: 33985 - Slave: 38494
Complex interferograms

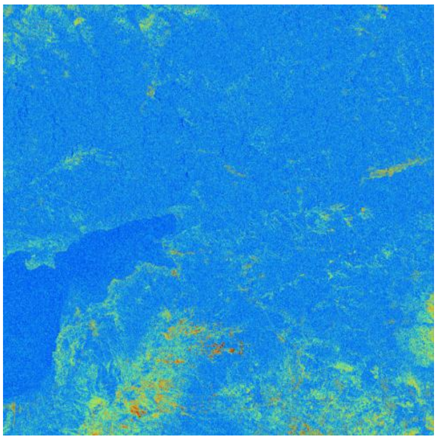

Figure 7,d. Master: 33985 - Slave: 38494
Coherence Map

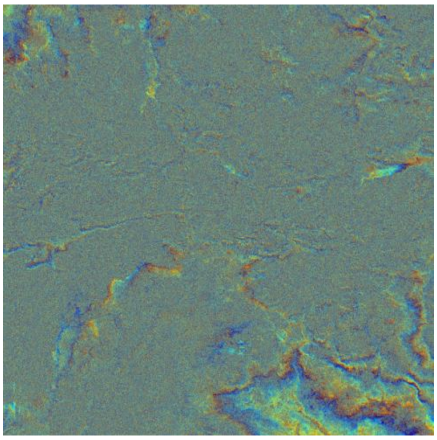

Figure 8,b. Master: 33985 - Slave: 38494
Flatened interferograms

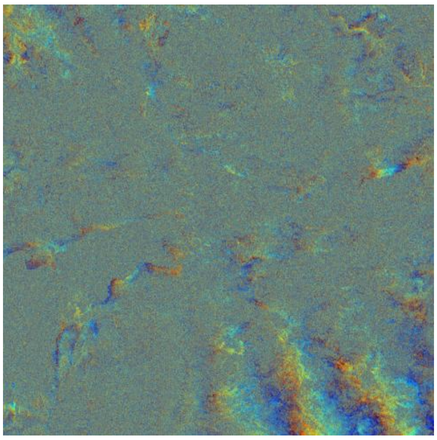

Figure 8,c. Master: 33985 - Slave: 38494
Topography removed interferograms

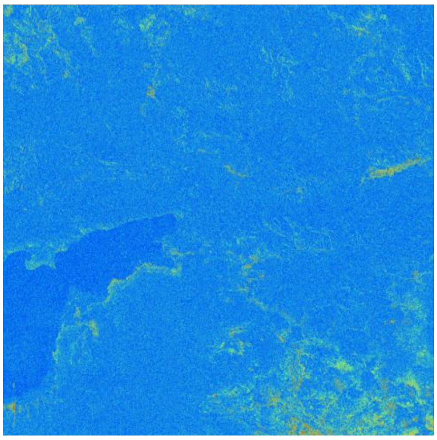

Figure 8,d. Master: 33985 - Slave: 38494
Coherence Map

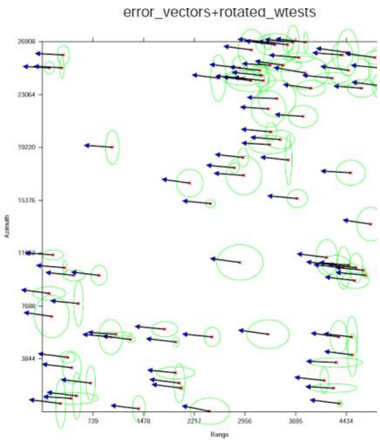

Figure 8,e. Master: 33985 - Slave: 38494
Errors and rotated vectors

In figures 6, *a* – *e* computational results for Master: 33985 - Slave: 34486 are presented. In figures 7, *a* – *e* computational results for Master: 33985 - Slave: 38494 are presented. In figures 8, *a* – *e* computational results for Master: 33985 - Slave: 38494 are presented.

7. CONCLUSION

Comparison analysis of computational results shows slight shifts of the ground around the lake of Sevan and higher parts of the landscape research area. Due to coherence lost (figures 6,*d* and 7,*d*, and 8,*d*) caused by temporal decorrelation in single look complex images it is difficult to produce a proper evaluation of deformation of the surface of interest. It is worthy to note that the decorrelation can be seen both in the coherence map and in topography removed interferogram. Most clearly visible are interferometric fringes in the interferometric pair 33985-34986 and the least they are expressed in 33985-40498. The difference between baselines has not to be underestimated. Perpendicular baseline (in meters) and temporal baseline (in days) has to be chosen precisely, because both of them are equally important for DInSAR processing. Even small error in baselines estimation can produce decorrelation. Therefore selected images in the interferometric pair have to be acquired in time difference no greater than 3 months if displacement is fast, or higher if the displacement is slow. It is valid for at least three single complex images needed for two interferometric pairs to generate differential interferogram.

8. ACKNOWLEDGMENT

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REFERENCES

[1] 2002, Armenian landslide project, R.F.Bucek, P.Nesvara, M.Srb, ISBN 90 5809 393 X

[2] http://books.google.bg/books?id=psFSK_nUqqMC&lpg=PA124&ots=bbTnVPSFXx&dq=landslides%20in%20Sevan%20Lake&pg=PA126#v=onepage&q=landslides%20in%20Sevan%20Lake&f=false

[3] 2006, Lake Sevan – Experience and Lessons Learned Brief, A.Babayan, S.Hakobyan, K.Jenderedjian, S.Muradyan, M.Voskanov

[4] 2007, Introduction to INSAR, F.Rocca, http://earth.esa.int/landtraining07/D1LA2-Rocca.pdf

[5] 2010, ESA Living Planet 2010, Bergen, Norway, LANDSLIDE PHENOMENA IN SEVAN NATIONAL PARK – ARMENIA, A.Lazarov, D.Minchev, G. Aleksanyan, M.Ilieva.

[6] 2011 3rd International Conference on Environmental Science and Information Application Technology, Synthesis of Interferogram Based on DEM of Dilijan in Caucasus region - Armenia, A.Lazarov, D.Minchev.