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New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite

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D3.5

Deformation time series obtained by exploiting C-band data from Terrafirma project

Project Start Date	1 November 2012
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Due Date Of Deliverable	
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Organization/Author (s)	INGV/Salvatore STRAMONDO

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

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1 INTRODUCTION

A comprehensive analysis of the earthquake cycle is a key issue for the definition of the hazard in seismic areas. The analysis of active tectonic topics is oriented towards the investigation of three seismic phases: pre-, co- and post-earthquake. Although the effects of the co-seismic phase are now widely known and modelled accordingly by conventional Differential SAR Interferometry, there are major issues with regards to the remaining phases. Thus, the utility of this service for the end users is mostly related to the PSI technique, which is the tool that is best able to answer the remaining issues, and which allows the information gap on the interseismic phase, i.e. pre- and post- seismic phases to be filled. In particular, the post-seismic phase can be monitored to measure the amount and the surface extension of possible deformation rebound or residual strain release. This is a relevant issue for end users to estimate seismic hazard effectively. On the other hand the preseismic, or a-seismic, deformation remains an open issue, in particular for its modeling complexities.

Deliverable 3.5 is one of the preliminary ones of WP3 - Task 3. “Integration and harmonization of InSAR, GPS and seismic data”. D 3.5 contains the velocity maps and time series provided by applying the Persistent Scatterer Interferometry (PSI) data processing technique to a huge dataset covering the time period 1992-2010. The region of interest is extended from the Metropolitan area of Istanbul far to the East beyond the epicenter of 1999 Duzce earthquake.

2 SAR DATA

The PSInSAR technique has been applied to two different areas in the Marmara region. The first one is related to the Metropolitan area of Istanbul and the PSInSAR coverage has been obtained using 6 SAR frames. In particular, the entire dataset is composed of two Envisat frames along Ascending orbit, two Envisat frames along the Descending one, and two ERS frames along Descending path. The overall number of SAR data is 180.
Temporal coverage of ERS data spans from 1992 to 2000 while each Envisat analysis has covered 2003-2010. The spatial extension ranges 800-4000 km^2 while the PS density is between 30 up to 220 PS/km^2.

Table 1 shows parameters for each satellite data.

No	Process	Analysis Data Range	Sattelites		Number of scenes used	Extension of the Area of Interest (km^2)	Number of PS identified	PS density (PS/km2)	Average annual motion rate of the entire processed area	Standard deviation of average annual motion rate
1	ISTANBUL_WEST_ENVS2_V_D_T107_ESA	2003 - 2010	ENVS2-V		27	2390.56	346740	145.08	-1.02	1.92
2	ISTANBUL_EAST_ENVS2_V_A_T429_ESA	2002 - 2009	ENVS2-V		32	3658.41	795873	217.57	-0.72	1.47
3	ISTANBUL_EAST_ENVS2_V_D_T336_ESA	2003 - 2010	ENVS2-V		28	2010.47	349138	173.7	-0.43	1.15
4	ISTANBUL_EAST_ERS_D_T336_2781_ESA	1992 - 2000	ERS1	ERS2	40	2889.68	512897	177.43	-0.6	1.65
5	ISTANBUL_WEST_ERS_D_T107_2781_ESA	1992 - 2000	ERS1	ERS2	32	763.54	22829	29.92	0.86	1.83
6	ISTANBUL_WESTI_ENVS2_V_A_T200_ESA	2003 - 2010	ENVS2-V		23	1233	36231	29.38	0.93	1.31

Table 1: Parameters of the satellite data for Istanbul test area

On the other hand, the second area of interest concerns the North Anatolian Fault System (NAFS). It has been observed by means 14 portions of frames acquired by ERS1-2 and Envisat satellites. Also in this case, Envisat data are available either from ascending or from descending paths while ERS only from descending orbit. The overall number of SAR data is 137.

As far as the temporal coverage is concerned the ERS dataset spans 1992-1999 up to consider the last image just before the August 17th, 1999, Izmit earthquake. On the contrary each Envisat analysis exploits data roughly covering 2002-2009. The spatial extension ranges 400-4000 km^2 while the PS density is between 3 up to 182 PS/km^2. This latter value ranges a very large interval and in some cases seems to be below the minimum threshold to have a reliable meaning over the whole frame.

No	Name of elaboration	Analysis Data range	Satellite	N° scenes used	Extension of the area of interest (~km2)	N° of measurement points identified	Measurement point density (PS/Km2)
1	IZMIT_ENVS2_V_D_T64_TERRAFIRMA	07/2003-12/2009	ENVI Desc	23	2830	209399	73,99257951
2	SILE_ENVS2_V_D_T64_TERRAFIRMA				1640	74359	45,34085366
3	DUZCE_ENVS2_V_D_T293_TERRAFIRMA	12/2002-08/2009		20	480	4120	8,583333333
4	ADAPAZANI_ENVS2_V_D_T293_TERRAFIRMA				640	7275	11,3671875
5	KARASU_ENVS2_V_D_T293_TERRAFIRMA				2600	27398	10,53769231
6	IZMIT_ENVS2_V_A_T157_TERRAFIRMA	04/2003-12/2008	ENVI Asc	25	3580	177332	49,53407821
7	KANDIRA_ENVS2_V_A_T157_TERRAFIRMA				4180	138381	33,10550239
8	KOCAALI_ENVS2_V_A_T386_TERRAFIRMA	12/2002-09/2009		19	702	15849	22,57692308
9	DUZCE_ENVS2_V_A_T386_TERRAFIRMA				950	29375	30,92105263
10	KARASU_ERS_D_T293_TERRAFIRMA	11/1992-04/1999	ERS Desc	21	3305	37686	11,40272315
11	DUZCE_ERS_D_T293_TERRAFIRMA				374	1154	3,085561497
12	ADAPAZARI_ERS_D_T293_TERRAFIRMA				814	27253	33,48034398
13	SILE_ERS_D_T64_2781_TERRAFIRMA	06/1992-04/1999		29	1960	358024	182,6653061
14	IZMIT_ERS_D_T64_2781_TERRAFIRMA				1020	129950	127,4019608

Table 2: Parameters of satellite data available for NAFS test area

3 DATA PROCESSING

The multitemporal interferometric technique used for SAR processing is the Persistent Scatterer Interferometry. PSI is the collective term used within the InSAR community to distinguish between single interferogram DInSAR and the second generation of InSAR technologies, of which there are but a few. The first of these to appear, in 1999, was the PS Technique™, the base algorithm of which is PSInSAR™ (from the Politecnico di Milano (Polimi) and licensed exclusively to TRE).

All PSI technologies are advanced forms of DInSAR. In other words, the interferogram is at the core of PSI. The fundamental difference is that PSI technologies develop multiple interferograms from a stack of radar images. As a minimum, 15 radar scenes are usually required for PSI methods, even though there are circumstances when an analysis can be conducted with fewer images (typically in urban areas). However, it should be noted that the more there are radar scenes available, the more accurate will be the results of PSI methods.

The main driver for the development of PSI was the need to overcome the errors introduced into signal phase values by atmospheric artifacts. By examining multiple images, usually a minimum of 15 scenes, many interferograms (in this case 14 interferograms) are generated by selecting one of the scenes as a master to which the other 14 scenes become slaves.

The process by which removal of atmospheric effects is achieved involves searching the imagery and interferograms for pixels that display stable amplitude and coherent phase throughout every image of the data set. They are referred to as Permanent, or Persistent, Scatterers. Thus a sparse grid of point-like targets characterized by high signal to noise ratios (SNR) is identified across an area of interest on which the atmospheric correction procedure can be performed. Once these errors are removed, a history of motion can be created for each target.

Having removed the atmospheric artifacts, the interferometric data that remain are displacement values (resolved along the satellite LOS) plus noise, dependent on the quality (SNR) of the reflector.

All measurements are made in the satellite's LOS radar beam and are relative to a point that is pre-selected as being stable and not moving (P0). The selection of the reference point is best made conjunctively with the client, the latter having better local knowledge on which sub-areas are stable within an area of interest (AOI).

Once the data have been analyzed, it is possible to develop the history of movement across the AOI. This is achieved by sequentially calculating the relative displacement between an individual radar target and the reference point, throughout the entire period of the analysis. Thus, the deformation is relative in time and space (from http://treuropa.com/technique/insar-evolution/).

In the following pages is an example of the processing report for PSI provided to Marsite project from TERRAFIRMA ESA project, through a Service Level Agreement signed by the responsible of both projects.

PROCESSING REPORT: IZMIT ERS DESCENDING

Process Date	22 November 2010
Software used	PS processing chain
Version	3.2.10
Analysis type	**H1c**
Number of scenes used	29
Date range of analysis	6/10/1992 - 4/24/1999
Satellite data used	ENVS2-V
Master Scene Date	11/11/1995
Georeference (X,Y) accuracy	±4 m, ±10 m
Critical Baseline [m]	1286.86047601
Pulse Repetition Frequency [Hz]	1679.902343800000
Reference data used for georeference	Microsoft Virtual Earth
Projection system used	GCS-WGS84
Reference point location	LAT: 40,817 LON: 29,5116
Area of results	1018,42 Km^2

Dataset used for the analysis

#	Data	Satellite	Dc *	Bn ^	Bt [giorni]
1	**6/10/1992**	ERS1	0,125	0,14	-1249
2	**7/15/1992**	ERS1	0,115278	-0,26	-1214
3	**8/19/1992**	ERS1	0,102778	-0,22	-1179
4	**9/23/1992**	ERS1	0,106944	-0,16	-1144
5	**4/21/1993**	ERS1	0,111111	0,34	-934
6	**6/30/1993**	ERS1	0,114583	-0,38	-864
7	**9/8/1993**	ERS1	0,103472	0,33	-794
8	**4/14/1995**	ERS1	0,104861	-0,21	-211
9	**5/19/1995**	ERS1	0,109722	-0,3	-176
10	**6/23/1995**	ERS1	0,129167	-0,51	-141
11	**7/28/1995**	ERS1	0,102083	0,09	-106
12	**7/29/1995**	ERS2	-0.020	0,07	-105
13	**9/1/1995**	ERS1	0,122917	-0,26	-71
14	**9/2/1995**	ERS2	0.005	-0,31	-70
15	**10/6/1995**	ERS1	0,1	0,17	-36
16	**10/7/1995**	ERS2	-0.018	0,56	-35
17	**11/10/1995**	ERS1	0,115278	0,19	-1
(M) 18	**11/11/1995**	ERS2	0.000	0	0
19	**5/3/1996**	ERS1	0,109722	0,48	174
20	**5/4/1996**	ERS2	0.017	0,42	175
21	**6/8/1996**	ERS2	0.000	-0,65	210
22	**7/13/1996**	ERS2	-0.000	0,15	245
23	**8/17/1996**	ERS2	0,125	-0,28	280
24	**9/21/1996**	ERS2	0,115278	-0,1	315
25	**4/19/1997**	ERS2	0,102778	0,29	525
26	**5/24/1997**	ERS2	0,106944	-0,17	560
27	**8/2/1997**	ERS2	0,111111	-0,16	630
28	**3/20/1999**	ERS2	0,114583	-0,03	1225
29	**4/24/1999**	ERS2	0,103472	-0,2	1260

^ Fraction of critical baseline * Fraction of PRF (M) Master Image

Number of PS identified	129950
PS density (PS/km^2)	~128
Point motion statistics (mm/year classes)	points in each mm/year class
-18.81 to -5.0	4341
-5.0 to -3.5	1692
-3.5 to -1.5	11358
-1.5 to 1.5	108346
1.5 to 3.5	4029
3.5 to 5.0	162
>5	22
Average annual motion rate of the entire processed area	-0.61
Standard deviation of average annual motion rate	2.47
Observations	None
Uncompensated atmospherics	No
Visible tilt or phase trends in motion map	No
Are there any regions not covered by InSAR results?	No

4 TIME SERIES AND VELOCITY MAPS

As stated above, in order to have a reliable coverage of the Istanbul test area two SAR frames have been needed for each satellite pass. In this way we obtained 4 velocity maps for ascending and descending orbit for Envisat datasets and 2 velocity maps for descending orbit ERS datasets.
Figure 1 to 6 show the velocity maps.

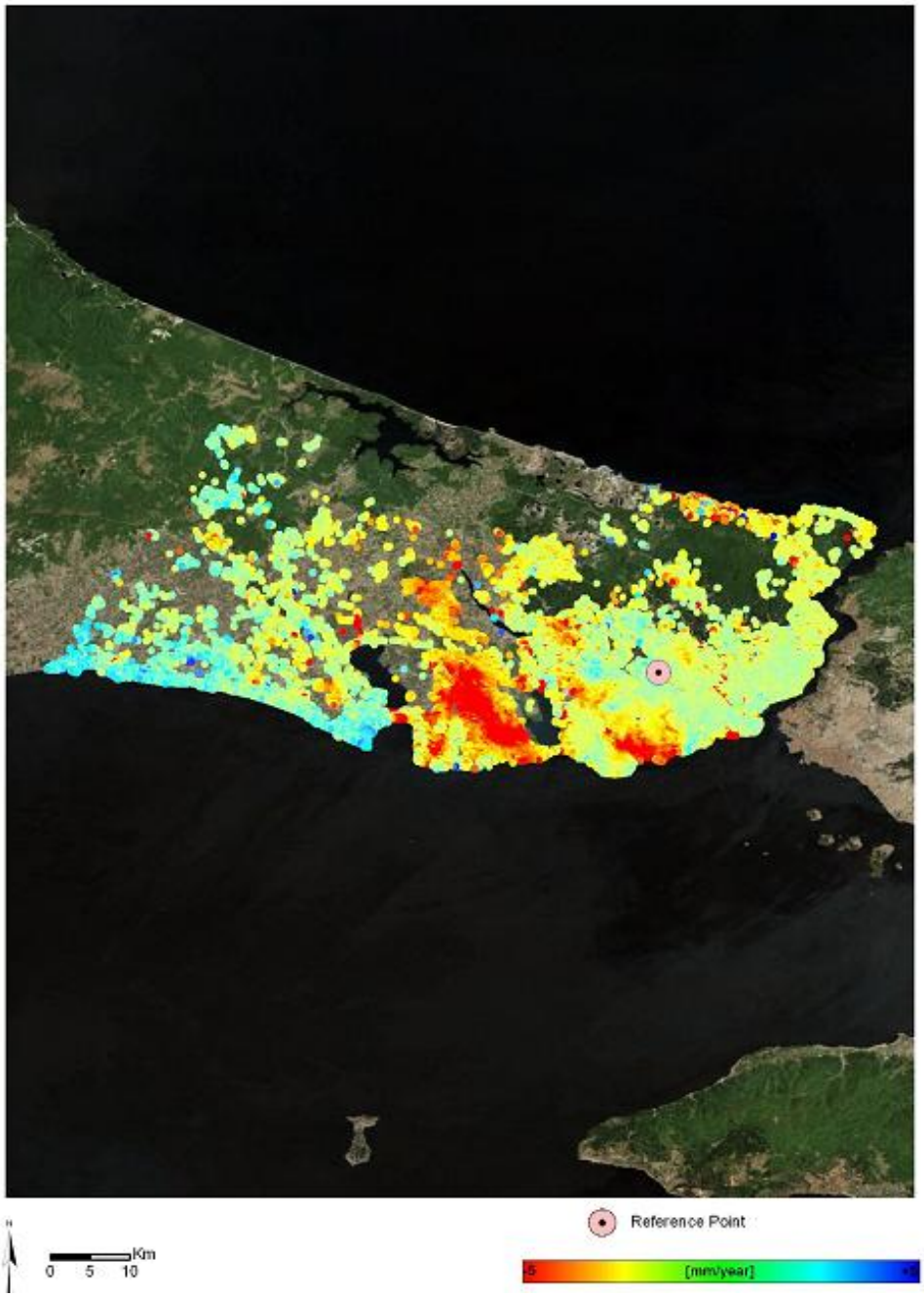

Figure 1: The Velocity field map of ISTANBUL_WEST_ENVS2_V_D_T107_ESA satellite data

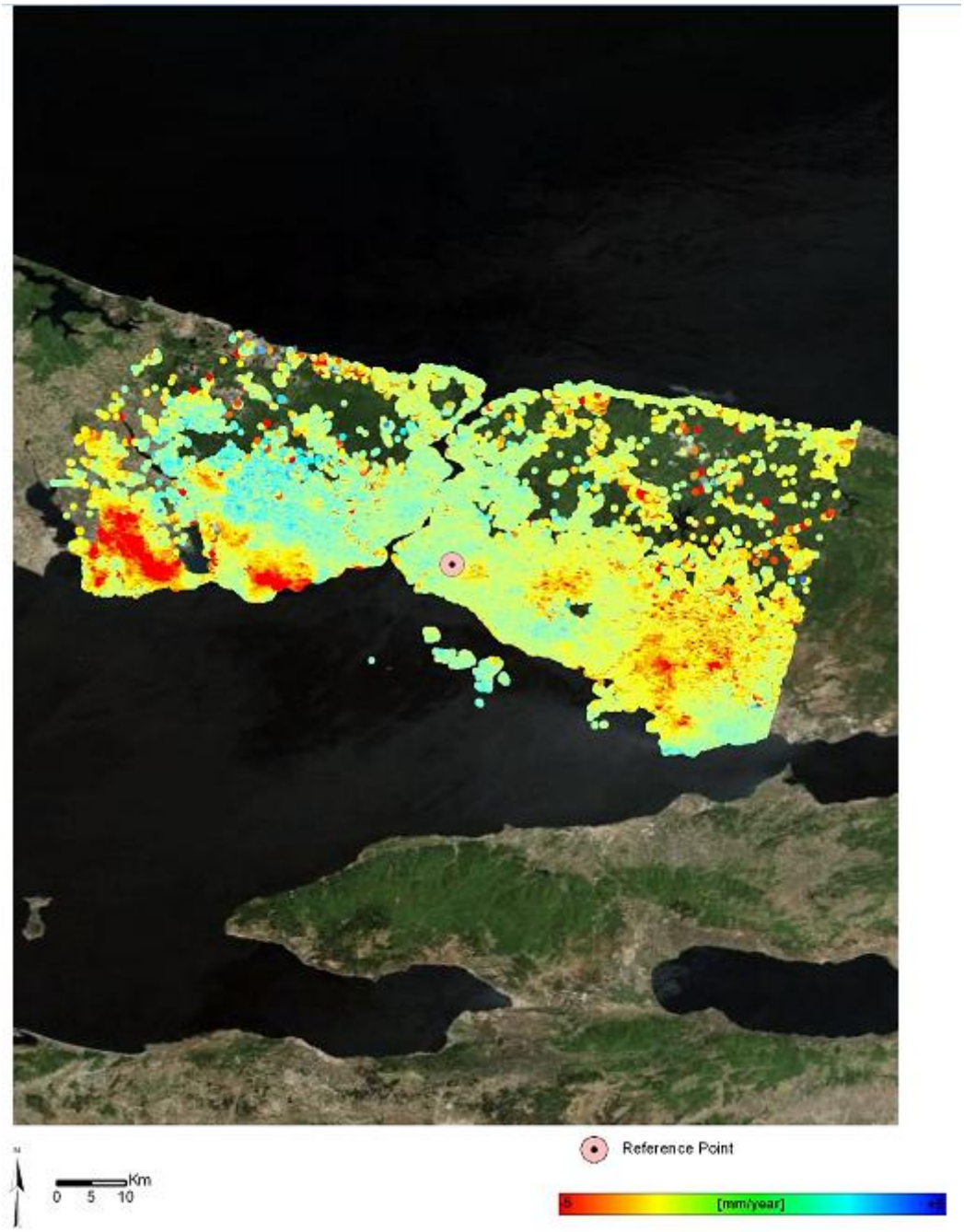

Figure 2: The Velocity field map of ISTANBUL_EAST_ENVS2_V_A_T429_ESA satellite data

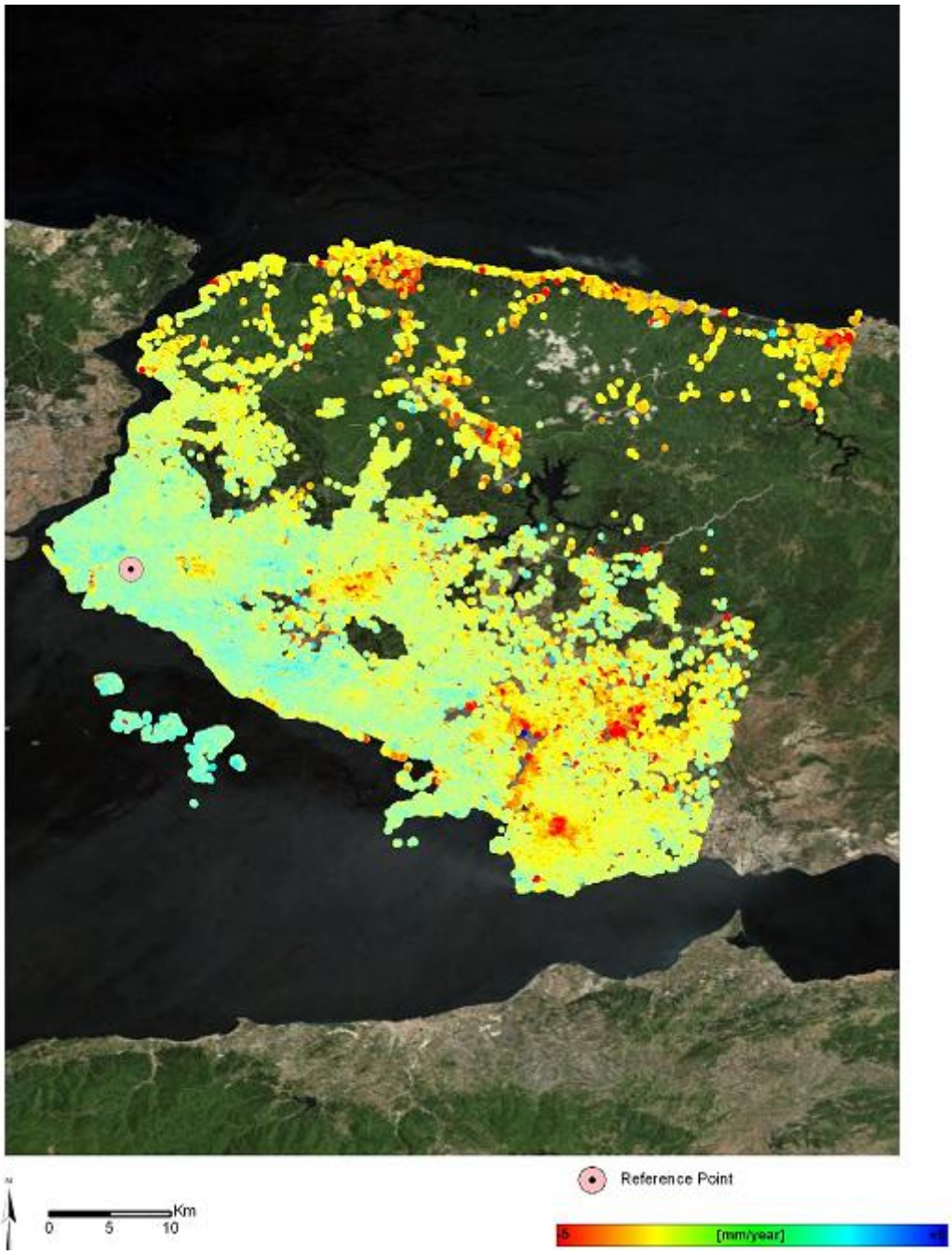

Figure 3: The Velocity field map of ISTANBUL_EAST_ENVS2_V_D_T336_ESA satellite data

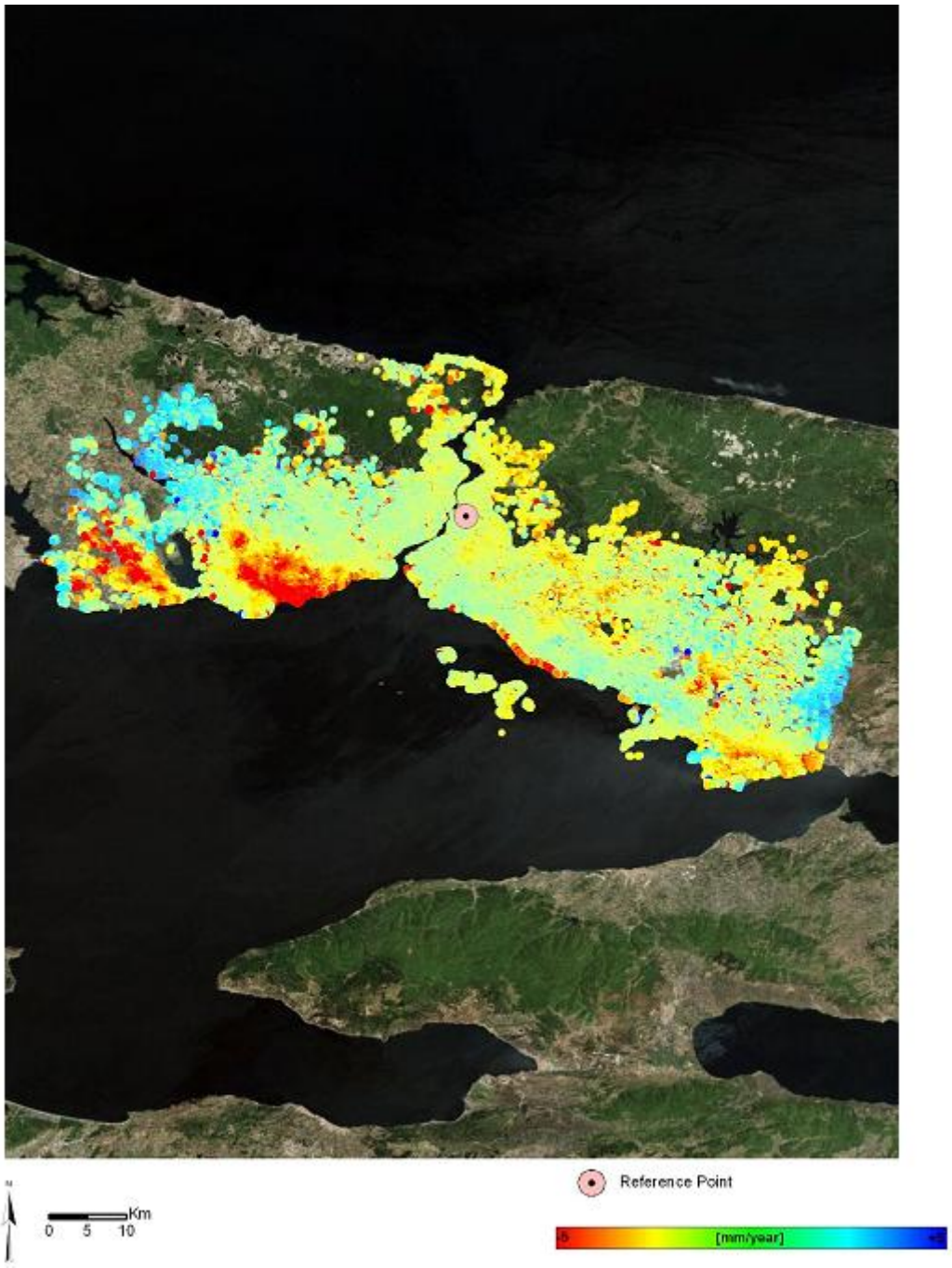

Figure 4: The Velocity field map of ISTANBUL_EAST_ERS_D_T336_2781_ESA satellite data

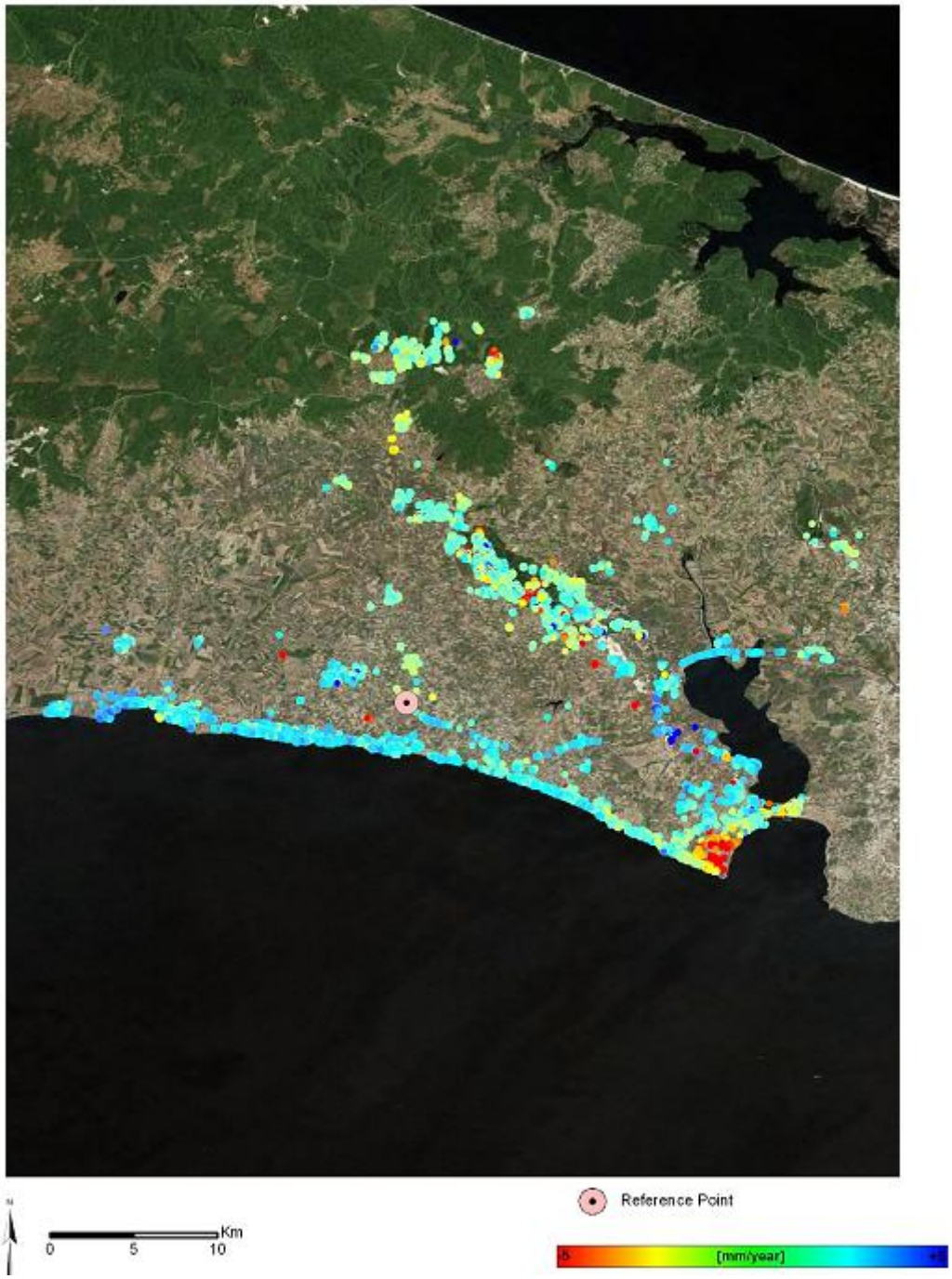

Figure 5: The Velocity field map of ISTANBUL_WEST_ERS_D_T107_2781_ESA satellite data

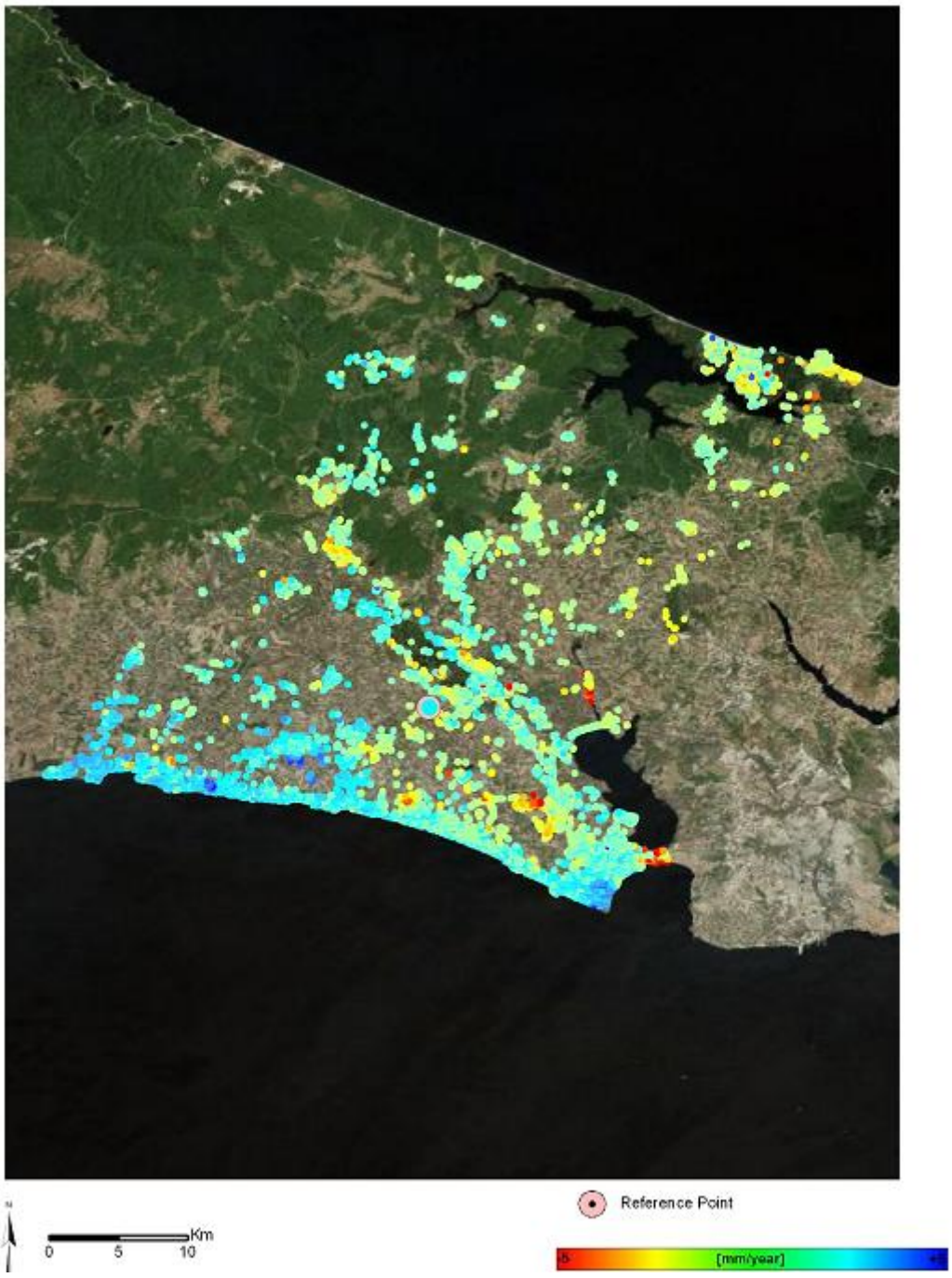

Figure 6: The Velocity field map of ISTANBUL_WESTI_ENVS2_V_A_T200_ESA satellite data

In the case of the NAFS it has been concatened 5 frames for each datasets covering each a different portion of the investigated area. The resulting velocity maps can be then shown in three different figures. The first one (Figure 7) concerns the ERS_Desc PSI.

On the other hand Figure 8 and 9 show the Envisat velocity maps estimated along ascending and descending orbit respectively.

The temporal coverage for each datasets is shown in table 2.

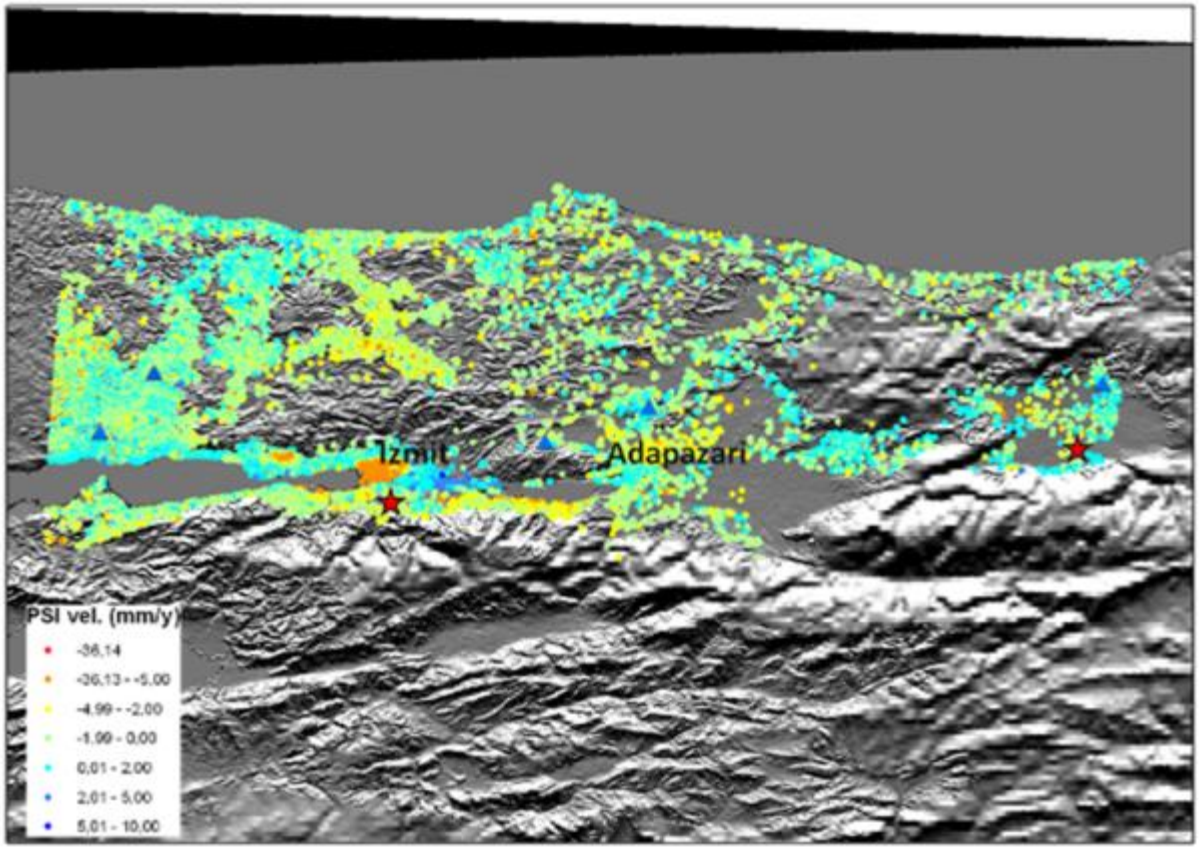

Figure 7: ERS velocity map. The red stars are the epicentres of 1999 earthquakes

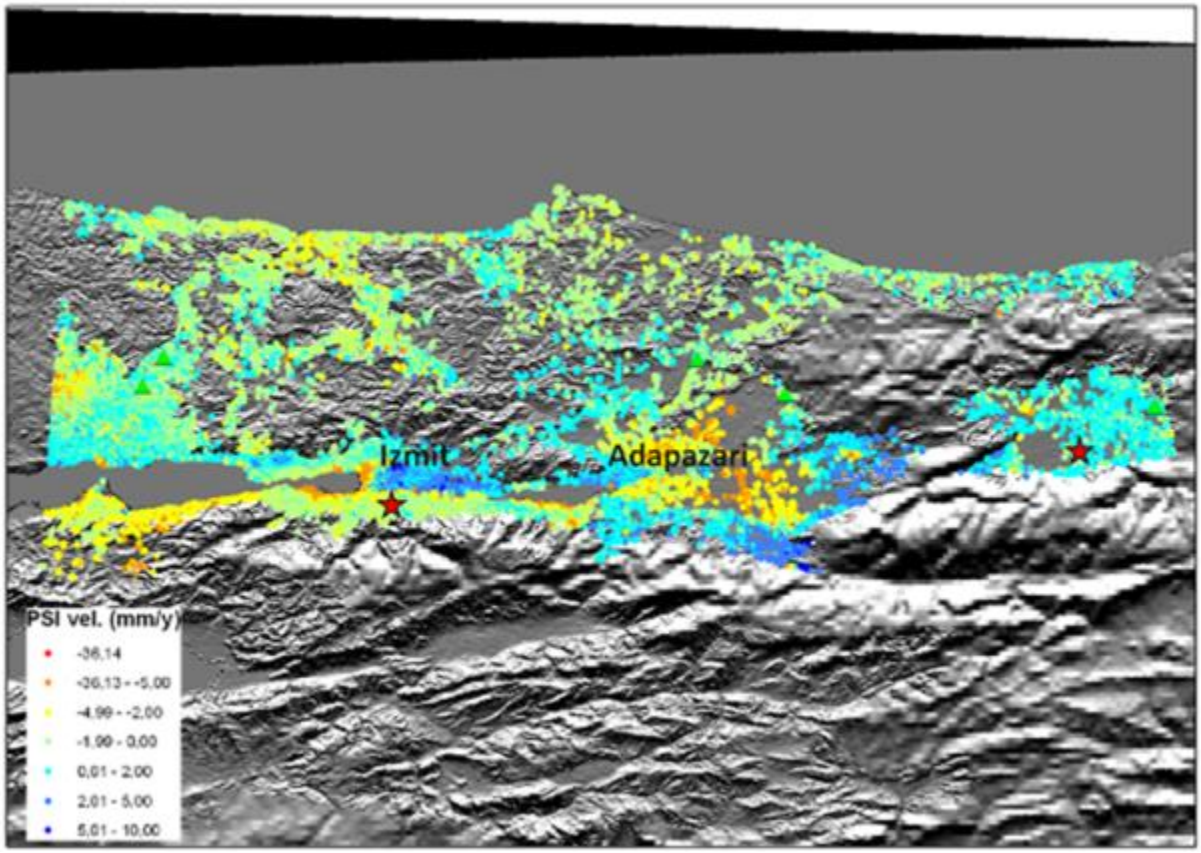

Figure 8: Envisat ascending velocity map. The red stars are the epicentres of 1999 earthquakes.

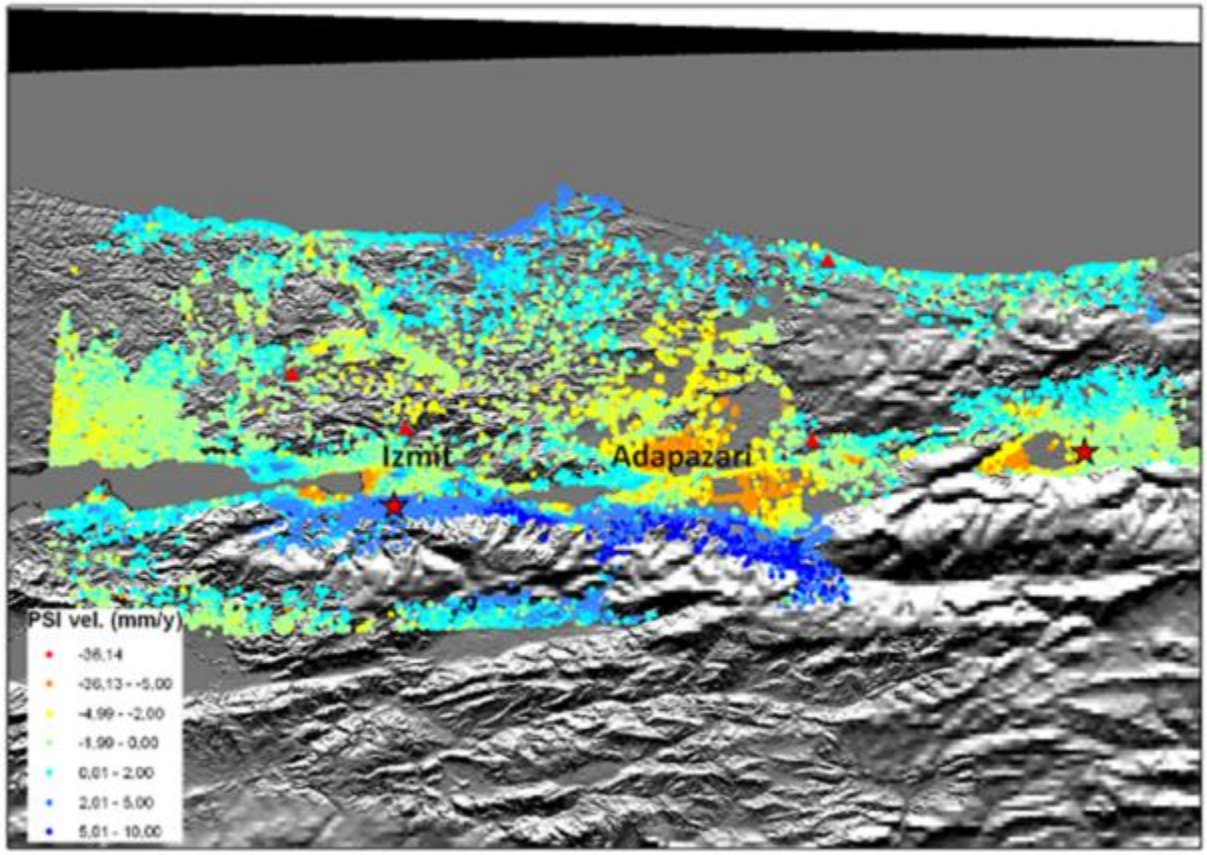

Figure 9: Envisat descending velocity map. The red stars are the epicentres of 1999 earthquakes

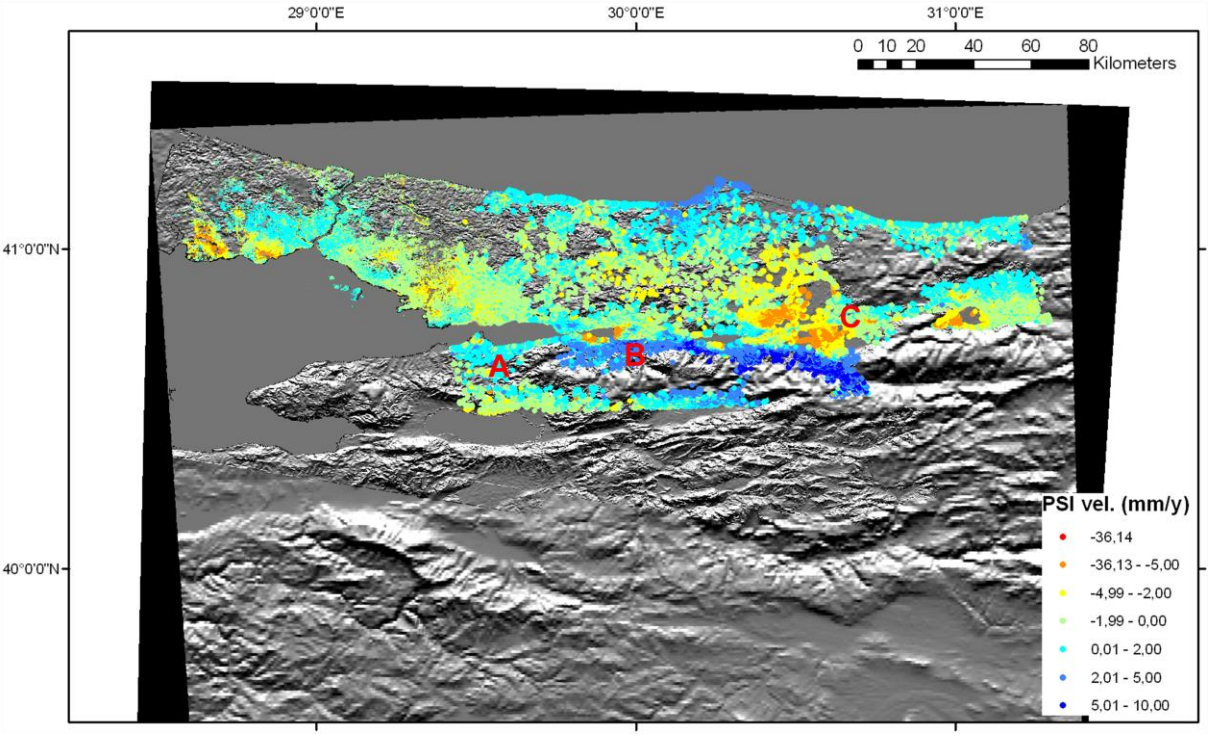

Figure 10 show the time series for the Envisat descending dataset extracted by some PS in 3 different zones.

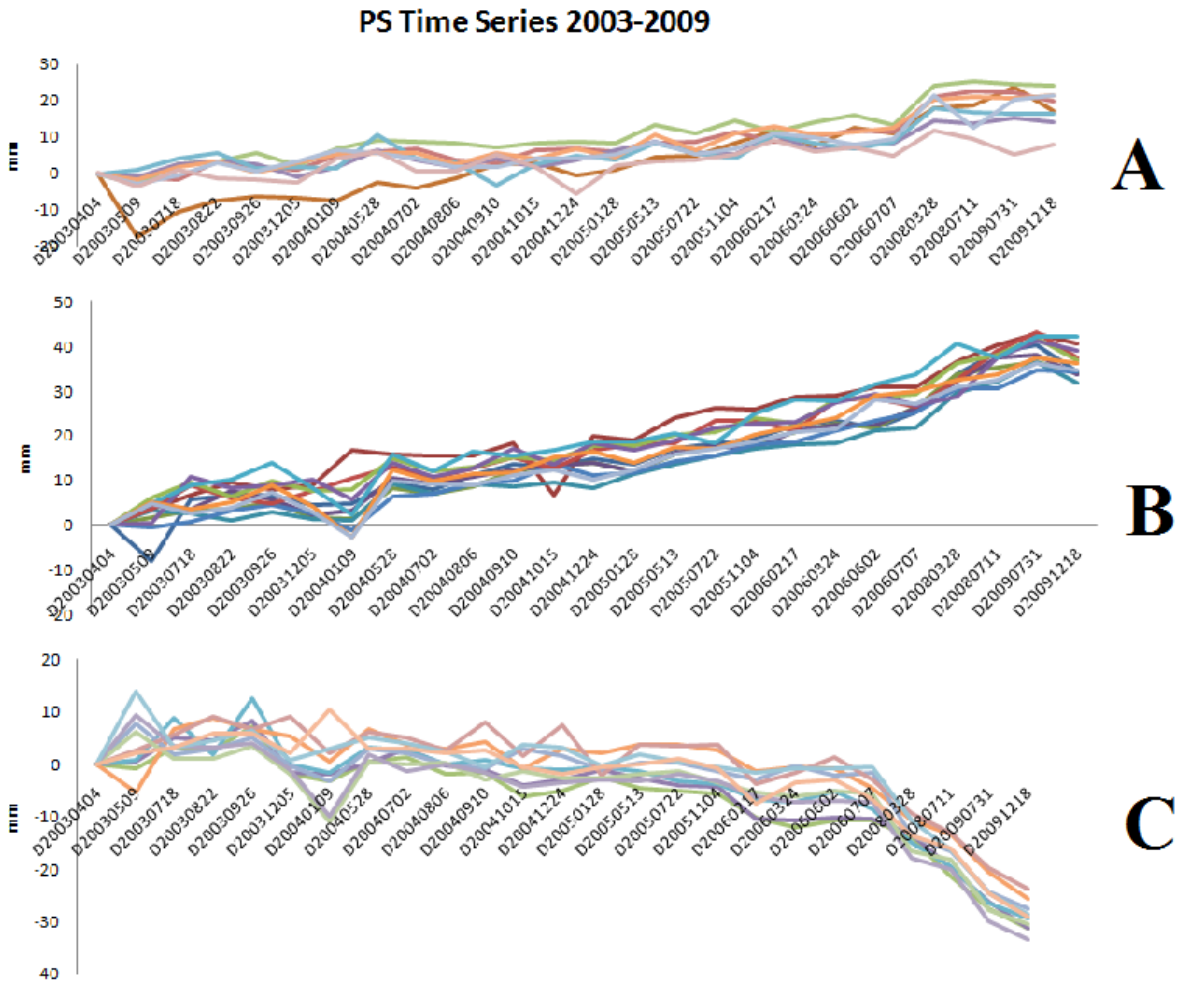

Figure 11: Time series of some points along the NAF