

URBAN GEO BIG DATA Meeting Rome, 22 January 2018

CNR-IREA Napoli

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PRIN PROJECT: URBAN GEOmatics for Bulk Information Generation, Data Assessment and Technology Awareness



MINISTERO DELL'ISTRUZIONE DELL'UNIVERSITA' E DELLA RICERCA



IREA-CNR (Napoli) Three-Year Activities

- Generation of InSAR products from historical (ERS-ENVISAT) SAR data
- InSAR data and metadata

✤ Generation of InSAR products with new Sentinel-1 SAR data. SBAS analyses require large sets of data. Sentinel-1 archives are being populated.

- Development of new methods for the calibration of SAR images (research activity)
- * Evaluation of SAR backscattering changes in urban areas with Sentinel-1 data (research activity)







Differential interferometric phase

For each interferogram, the phase relevant to a generic point with coordinates x and r, azimuth and range rispectively, can be written as following:

Differential interferometric phase.

Phase component relevant to the deformation occurred in the time period between the two acquisitions.

 $\delta\phi_m(x,r) \approx D\left(t_{IE_m}, x, r\right) - D\left(t_{IS_m}, x, r\right)$

Phase component relevant to the residual topography (DEM Atmospheric errors and position of the phase center respect to the ground). Noise

 $+ \Delta s_{topo}(x,r) + (ATM_m(x,r)) + \Delta n_m(x,r)$





SBAS worflow





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ERS-ENVISAT SAR Data Distribution: the Napoli case study



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Key ideas of the SBAS algorithm

To produce time-series deformation from a SAR data sequence by:

> using DInSAR interferograms characterized by a "*small baseline*" (smaller than the critical one) in order to mitigate noise (decorrelation) phenomena;

> properly "*linking*" interferometric SAR data subset separated by large baselines. This is done by searching for an LS solution with a velocity minimum norm constraint, easily achieved by applying the SVD method.





Mathematical framework of the SBAS algorithm

Following the unwrapping operation we evaluate (for each pixel) the displacement velocity vector \underline{v}

$$\underline{\mathbf{v}}^{T} = \left[v_{1} = \frac{\phi(t_{1}) - \phi(t_{0})}{t_{1} - t_{0}} , \dots , v_{M-1} = \frac{\phi(t_{M-1}) - \phi(t_{M-2})}{t_{M-1} - t_{M-2}} \right]$$

by solving the linear system

$$\mathbf{B}\underline{\mathbf{v}} = \underline{\delta\phi}$$

To solve the linear system, the SVD method is applied.¹

¹ Berardino P. et alii: "A new Algorithm for Surface Deformation Monitoring based on Small Baseline Differential SAR Interferograms", IEEE *Trans. Geosci. Remote Sensing*, Vol. 40, No. 11, pp. 2375-2383, November 2002.



SBAS: a two scale approach





Low resolution SBAS Approach

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SBAS: a two scale approach





Extended SBAS approach: from low to full resolution analysis

Multi-look (low resolution) Interferogram

Single-look

(full resolution)

Interferogram









ERS-ENVISAT SAR Data Distribution: the Napoli case study



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ERS-ENVISAT SAR Data Distribution: the Napoli case study

PRIN PROJECT: URBAN GEOmatics for Bulk Information Generation, Data Assessment and Technology Awareness

ERSENV

Advanced DInSAR technique: the Small BAseline Subset (SBAS)

71 ERS-1/2 and 39 ENVISAT images acquired on ascending orbits (1993-2007)

197 ERS and 115 ENVISAT interferograms

Deformation measurements: the Vomero quarter

> 1.0

LOS Velocity

< -1.0

[cm/year]

Deformation Time Series Data Format

Data Type: LOS Displacement Time Series	
Processing ID:	
User ID: CNR-IREA	
Software_version: CNR-IREA P-SBAS 24	
Applied_algorithm_description: Parallel SBAS Interferometry Chain	
Main_reference: 10.1109/TGRS.2002.803792, 10.1109/JSTARS.2014.2322671	
Date_of_production: 20170906T19:55:03Z	
Date_of_publication: 20170906T19:55:03Z	Data Type: LOS Displacement Time Series
Service_used_for_generation: CNR-IREA	
Geographic_CS_Type_Code: 4326	Processing_ID:
Spatial_Resolution: 10	User TD: CNR-TREA
Sensor: ERS/ENV	Coff and the CAID TREA D CDAC 24
Mode: SIRIP	SOTTWARE_VERSION: UNK-IREA P-SBAS 24
Belative Orbit Number:	Applied algorithm description: Parallel SBAS Interferometry Chain
Wavelenght: 0.056564617	Main reference: 10 1100/TCDS 2002 002702 10 1100/JSTADS 2014 2222671
Number of dates: 164	Main_Telefence: 10.1109/TGR5.2002.003/92, 10.1109/JSTAR5.2014.25220/1
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Deformation Time Series Data Format

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	20100603T09:19:017. 20100812T09:19:037. 20100916T09:19:027	
ID, Lat, Lon, To	Topo, vet, coer, cosw, cose, cosu, is	
0, 40.79619, 14.55528, 23.0	3.63, -0.0150, 0.4977162,-0.0708348, 0.3309509, 0.9409856, 0.0000, -0.0447, 0.5588, 0.8460, 0.5617, 0.0314, -0.0337, 0.0580, 0.4956, -0.3504, 0.0918, -0.3526,	0.0883, -0.2442,
0.1199, -0.9397, -0.0916, -0.5173	1/5, 0.1186, -0.5135, -0.7090, -1.4423, -1.0200, -0.74/2, -0.8378, -0.7120, -0.9707, -0.6839, -0.6927, -0.7284, -1.3812, -0.3774, -0.7050, -1.3457, -0.6018 7164, -0.3557, -0.9132, -0.0111, -0.615, -0.2640, -0.4426, -0.219, -0.6554, -0.2156, -0.1075, -0.9652, -0.1240, -0.5240, -0.6574, -0.4657, -0.658	-0.3687, -0.3964,
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	0142, -0//3/8, -1/0238, -1/0359, -1/0021, -0/3540, -0/3580, -1/0534, -0/3529 3.G0.0811 0.5550467 _0.0708348 0.3306111 0.040856 0.04000 _0.6490 0.6713 0.4650 0.3871 _0.3206 _0.2056 _0.3410 0.3408 _0.0633 _0.1700 _0.6772	-0 2120 -0 3700
-0.6062, -1.3241, -1.0061, -1.20	(-1, -1) = (-1, -1)	9, -0.5611, -0.9347.
-0.8108, -1.3637, -0.6868, -0.68	6813, -0.6416, -0.7490, -0.4043, -0.4973, -0.3890, -0.3513, -0.0088, -1.1278, -0.4046, -0.3960, -0.4018, -0.0544, -0.9219, -1.0493, -1.1079, -0.7512, -1.059	6, -1.3980, -0.9368,
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-1.29041.71941.20281.34	5.64, -2.929, -0.6730, -1.1994, -1.7375, -1.2930, -1.8644, -0.3964, -0.7911, -1.5760, -1.2899, -1.2970, -1.2159, -1.4817, -0.9655, -1.8565, -1.5177, -1.3864, -0.7911, -1.5760, -1.2899, -1.2570, -1.2159, -1.4817, -0.9655, -1.8565, -1.5177, -1.3864, -1.3864, -1.3864, -1.3864, -1.3864, -1.5970, -1.2159, -1.4817, -0.9655, -1.8565, -1.5177, -1.3864, -1.5177, -1.5864, -1.5977, -1.5977, -1.2159, -1.2159, -1.5867, -1.5867, -1.5177, -1.5864, -1.5867, -1.58	2, -2.3523, -2.1114.
-1.5432, -1.8544, -1.9770, -1.88	8833, -2.2069, -1.9684, -2.6540, -1.9523, -2.2804, -1.9461, -2.4001, -1.9420	
2, 40.79610, 14.55526, 23.	3,39, -0.1246, 0.5990841, -0.0708348, 0.3309514, 0.9409854, 0.0000, 0.7673, 1.3539, 1.5718, 1.4283, 0.8956, 0.9227, 0.4100, 1.2002, -0.0099, 0.8860, 0.5134,	0.8030, 0.7781,
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Deformation Time Series Data Format

Data_Type: LOS_Displacement_Time_Series	5														
Processing_ID:															
Software_version: CNR-IREA P-SBAS 24														_	
Applied_algorithm_description: Paralle	####	0.53	10055											1	
Main_reference: 10.1109/TGRS.2002.80379	TD	Lat	Lon	Topo	Ve1	Coer	COSN	COSE	cosli	TS					
Date_of_production: 20170906T19:55:03Z	10,	40 70610	14 55529	22 63	-0 0150	4077162 -1	0709349	0 3300500	0 0100956	0 0000	0 0117	0 5500	0 9460		
Date_ot_publication: 201/0906/19:55:034	0 5617	40.79019,	14.33320	0 0500	0.0150,	0.49//102,-1	0.0010	0.3309309,	0.9409030,	0.0000,	-0.0447,	0.0307	0.0400,		
Geographic CS Type Code: 4326	0.3017,	0.0314,	-0.0337,	0.0580,	0.4950,	-0.3504,	0.0918,	-0.3520,	0.0883,	-0.2442,	0.1199,	-0.9397,	-0.0910,		
Spatial Resolution: 10	-0.51/5,	0.1186,	-0.5135,	-0.7090,	-1.4423,	-1.0200,	-0.7472	, -0.8378,	-0.7120,	-0.9/0/,	-0.6839,	-0.6927,	-0.7284,		
Sensor: ERS/ENV	-1.3812,	-0.3774,	-0.7050,	-1.3457,	-0.0618,	-0.3687,	-0.3964,	, -0.2656,	-0.3921,	-0.1357,	-0.7164,	-0.3537,	-0.8132,		
Mode: STRIP	-0.0111,	-0.6115,	-0.2649,	-0.4436,	-0.2018,	-0.6554,	-0.2136,	, 0.1075,	-0.0862,	-0.1700,	-0.2309,	0.5714,	-0.4668,		
Antenna_Side: Right	-0.6589,	-0.6371,	-0.8101,	0.0341,	-0.2904,	-0.4609,	-0.6353,	, -0.5529,	0.4250,	-0.3450,	-0.3409,	0.0416,	-0.3454,		
Relative_Orbit_Number:	-0.7578,	-0.2740,	0.0507,	0.0210,	1.0166,	0.5949,	0.0731,	, -0.4265,	1.2682,	0.9623,	-0.2040,	-0.1390,	-0.8602,		
Number of dates: 164	-1.1585,	0.0320,	-0.2427,	-0.2448,	-0.6898,	-1.2993,	-0.8081	, -0.2727,	-1.5483,	-1.6003,	-1.6408,	-1.1059,	-0.7593,		
Time Years: 1992.4397. 1992.6310. 1992	-1.0069.	-0.1959.	0.0679.	-0.0516.	0.0694.	-0.8841.	-0.8382	-0.5145.	-1,4829.	-0.9601.	-0.7658.	0.0430.	-0.2961.	4. 1995.5751. 1995.66	66. 1995.669
1995.7648, 1995.8591, 1995.9534, 1995.9	-0.6888.	-0.8383.	-0.7406.	-0.4620.	-0.3646.	-0.2338.	-0.1466	-0.5486.	-0.8241.	-0.6292.	-0.9149.	-0.7899.	0.2065.	1997.3947, 1997.5861	, 1997.6787,
1997.7758, 1997.8701, 1997.9671, 1998.1	-0.3052	-0.9247	-0.8277	-0.4250	-0.1803	0.4468	0.0352	-0.1421	1.0865	0.6091	0.0481	0,0020	-0.3539	2000.0751, 2000.1705	, 2000.1733,
2000.2676, 2000.3646, 2000.4589, 2000.5	-0 1126	-0 0401	-0 5522	-0 3287	0 0100	-0 3076	-0 3731	_0 0354	-0 1042	-0 3878	0 6312	-0 2608	-0 0822	2003.6228, 2003.6228	, 2003.7170,
2003.8141, 2003.8141, 2003.9084, 2004.	0 4152	0.6512	0.5007	1 0707	0.01105,	0.1001	0. 7012	0.7301	0 6142,	0.3070,	1 0220	1 0556	1 0022,	2005.7280, 2005.7281,	, 2005.8250,
2005.8251, 2005.9205, 2005.9205, 2006.0	-0.4152,	-0.0513,	-0.5007,	-1.0/0/,	-0.9410,	-0.4231,	-0.7913	, -0.7391,	-0.0142,	-0.7576,	-1.0236,	-1.0550,	-1.0021,	2007.8371, 2007.9342,	, 2008.1228,
2010 3305 2010 4259 2010 6173 2010 1	-0.8540,	-0.8580,	-1.0034,	-0.8529	0 00.11			0. 0000544		0 0000	0 0100	0 0700		2010.0394, 2010.1337,	, 2010.2502,
List of Dates: 19920608T09:49:13Z. 1992	1,	40.79613,	14.55526	, 23.69,	-0.0841,	0.5550467,-0	0.0/08348,	0.3309511,	0.9409856,	0.0000,	-0.6489,	0.6/13,	0.4659,	0802T09:49:17Z, 19930	906T09:49:18
19931011T09:49:14Z, 19931115T09:49:08Z,	0.3871,	-0.3206,	-0.2056,	-0.3410,	0.3008,	-0.9633,	-0.1709,	-0.6272,	-0.2120,	-0.3700,	-0.6062,	-1.3241,	-1.0061,	19951109T09:49:21Z,	
19951213T09:49:21Z, 19951214T09:49:23Z,	-1.2058,	0.0382,	-0.4689,	-1.1392,	-1.6203,	-1.2624,	-0.9336,	, -1.1100,	-0.9320,	-1.6653,	-1.2112,	-1.2797,	-1.2244,	19960919T09:49:19Z,	
19961024T09:49:19Z, 19961128T09:49:14Z,	-1.2644,	-0.5793,	-0.5549,	-1.1882,	-0.8539,	-0.5611,	-0.9347	, -0.8108,	-1.3637,	-0.6868,	-0.6813,	-0.6416,	-0.7490,	19971218T09:49:12Z,	
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20000024109:49:242, 20000928109:49:242, 20021107700.10.147 20021212700.47.367	-1.8293.	-0.8277.	-1.2254.	-0.9360.	0.2584.	0.0701.	0.3300	-0.3589.	-0.4467.	0.4078.	-0.9137.	-1.2769.	-2.1279.	20021003109:47:412,	
20021107109:19:142, 20021212109:47:302, 20040311T09:19:19:217, 20040415T09:19:187	-1 0331	-1 0727	-1 1611	-1 4169	-1 8877	-2 2804	-1 9156	-1 7966	-1 8981	-2 3272	-2 3595	-2 1116	-1 8899	20050505T09:47:537	
20050609T09:47:55Z, 20050714T09:19:26Z	_2 5220	_0 9900	_0 0552	_1 2004	_1 10077,	1 5966	-2 1249	_1 0204	_1 9167	-2 2727	_1 9677	_1 0001	_1 4506	20060316T09:19:11Z,	
20060525T09:19:17Z, 20060525T09:47:51Z	-2. 5229,	1 0762	1 0425	1 6272	1 7004	-1.3600,	1 2120	, -1.9394,	-1.0107,	1 5531,	-1.00/7,	1 0453	-1.4390,	20070510T09:19:16Z,	
20070719T09:19:18Z, 20070823T09:47:37Z,	-1.5900,	-1.9702,	-1.0423,	-1.03/3,	-1.7994,	-1.4034,	-1.3130	, -1.9079,	-1.5500,	-1.5551,	-2.0012,	-1.0455,	-0.9475,	20080911T09:19:08Z,	
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20091210109:19:012, 20100114109:19:042,	-0.6/30,	-1.1094,	-1./3/5,	-1.2930,	-1.0544,	-1.3064,	-0.7911,	, -1.55/6,	-1.2899,	-1.5970,	-1.2159,	-1.481/,	-0.9565,		
Reference Point: 14 605127 41 204173	-1.8565,	-1.5177,	-1.3892,	-2.3523,	-2.1114,	-1.5432,	-1.8544,	, -1.9770,	-1.8833,	-2.2069,	-1.9684,	-2.6540,	-1.9523,		
Applied Corrections: n/a	-2.2804,	-1.9461,	-2.4001,	-1.9420											
Applied Filter: none	2,	40.79610,	14.55526	, 23.39,	-0.1246,	0.5990841,-0	0.0708348,	0.3309514,	0.9409854,	0.0000,	0.7673,	1.3539,	1.5718,		
Map of incidence angle for geotiff: n/a	1.4283,	0.8956,	0.9227,	0.4100,	1.2002,	-0.0099,	0.8860,	0.5134,	0.8030,	0.7781,	0.4034,	-0.0901,	-0.2394,		
Lookup table from radar to ground: n/a	-0.4342.	0.4551.	0.3762.	-0.1230.	-0.5861.	-0.2110.	0.0237	-0.0258.	-0.1176.	-0.0072.	-0.5681.	-0.4695.	0.0238.		
Inputs_ID: inputIDs.txt	0.2228.	-0.6481.	0.2543.	0.1261.	-0.0197.	0.2637.	-0.1321.	0.4251.	0.0647.	0.0923.	0.3694.	0.2032.	0.3776.		
L1ST_ot_interrerograms_osear n/a	0.3921	0.7701	0.5940	0.3039	0.2618	0.3538	0 1894	0.4781	1.0522	1.0297	0.9890	0.2202	0.2093		
TD. Lat. Lon. Tor	0 2427	-0 2103	0 0633	0 2440	-0 1825	-0 0385	0 4358	0 3300	0 4128	0 2776	-0 7135	0 1250	-0 2733		
0. 40.79619. 14.55528. 23.6	0.7205	0.2195,	0 4222	1 6197	0.5010	-010303,	1 0700	0 1459	1 2077	1 1209	0, 2126	0.1235,	0 0121	0.3526. 0.0883.	-0.2442.
0.1199, -0.9397, -0.0916, -0.5175	-0.7305,	0.2247,	0.4232,	1.1250	1. 3400,	0.4050,	1.1001	, -0.1430,	1.20//,	1.1590,	-0.2130,	1 7272	-0.0434,	-0.0618, -0.3687,	-0.3964,
-0.2656, -0.3921, -0.1357, -0.716	-0.3375,	-0.3543,	-0.5903,	-1.1259,	-1.2409,	-1.4953,	-1.1901,	, -1.4550,	-0.9181,	-1.1048,	-2.0907,	-1./2/2,	-1.0397,	-0.6371, -0.8101,	0.0341,
-0.2904, -0.4609, -0.6353, -0.552	-0.9131,	-1.3514,	-0.7922,	-0.5565,	-0.6128,	-0.38/8,	-0.8495	, -1.3844,	-1.0523,	-1.8036,	-1.3288,	-0.4339,	-1.2589,	-0.1390, -0.8602,	-1.1585,
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-0.4231 -0.7913 -0.7391 -0.614	-0 7378	-1 0238	-1 0556 -1	0021 -0 8540	-0 8580	-1 0634	-0 8529			· · · · · · · · · · · · · · · · · · ·		·····, ·····		-0.5007, -1.0707,	-0.9410,
1. 40.79613. 14.55526. 23.6	-0.0841	0.55504670.0	708348. 0.3309	511. 0.9409856.	0.0000.	-0.6489.	0.6713. 0.	4659. 0.3871	0.3206.	-0.2056	0.3410. 0.30	080.9633.	-0.1709.	-0.62720.2120.	-0.3700.
-0.6062, -1.3241, -1.0061, -1.205	8, 0.0382,	-0.4689,	-1.1392, -1.	6203, -1.2624	, -0.9336	, -1.1100,	-0.9320, -	1.6653, -1.21	12, -1.2797	-1.2244,	-1.2644, -0.	5793, -0.554	9, -1.1882.	-0.8539, -0.5611,	-0.9347,
-0.8108, -1.3637, -0.6868, -0.681	3, -0.6416,	-0.7490,	-0.4043, -0.	4973, -0.3890	, -0.3513	, -0.0088,	-1.1278, -	0.4046, -0.39	60, -0.4018	-0.0544,	-0.9219, -1.	0493, -1.107	9, -0.7512,	-1.0596, -1.3980,	-0.9368,
-1.0472, -1.0496, -0.8935, -0.502	25, -0.3689,	-0.8782,	-0.6977, -1.	1389, -1.2191	, -1.8293	, -0.8277,	-1.2254, -	0.9360, 0.25	84, 0.0701,	0.3300,	-0.3589, -0.	4467, 0.407	8, -0.9137,	-1.2769, -2.1279,	-1.9331,
-1.0727, -1.1611, -1.4169, -1.887	7, -2.2804,	-1.9156,	-1.7966, -1.	8981, -2.3272	2, -2.3595	, -2.1116,	-1.8899, -	2.5229, -0.88		-1.3094,	-1.1083, -1.	5866, -2.124	8, -1.9394,	-1.8167, -2.2737,	-1.8677,
-1.0891, -1.4596 , -1.5966 , -1.976	2, -1.8425,	-1.6373,	-1.7994, -1.	4634, -1.3138	s, -1.9679	, -1.5566,	-1.5531, -	-2.0612, -1.84	-0.9473,	-2.5125,	-2.1403, -1.	90/3, -0.983	5, -1.2471,	-0.7116, -1.0134,	-0.8116,
-1.2904, -1.7194 , -1.2028 , $-1.346-1.5432$, -1.8544 , -1.0770 , -1.092	-2.0929,	-1.0684	-2.6540 -1	9523 _2 200/		, -1.3004,	-1.9420	-1.28	, -1.5970	-1.2159,	-1.481/, -0.	a202, -1.820	5, -1.51//,	-1.3092, -2.3523,	-2.1114,
2. 40.79610. 14.55526. 23.3	90.1246	0.59908410.0	708348. 0.3300	514. 0.9409854	0.0000	0.7673.	1.3539. 1.	5718. 1.4283	0,8956	0.9227.	0.4100. 1.20	020.0099	0.8860.	0.5134. 0.8030	0.7781.
0.4034, -0.0901, -0.2394, -0.4342	0.4551.	0.3762, -	-0.1230, -0.5	5861, -0.2110	0.0237.	-0.0258,	-0.1176, -0	.0072, -0.568	31, -0.4695.	0.0238,	0.2228, -0.6	481, 0.2543	, 0.1261,	-0.0197, 0.2637.	-0.1321,
0.4251, 0.0647, 0.0923, 0.3694	, 0.2032,	0.3776,	0.3921, 0.7	701, 0.5940,	0.3039,	0.2618,	0.3538, 0	.1894, 0.478	1, 1.0522,	1.0297,	0.9890, 0.2	202, 0.2093	, 0.2427,	-0.2193, 0.0633,	0.2440,
1825, -0.0385, 0.4358, 0.330	0, 0.4128,	0.2776,	-0.7135, 0.	1259, -0.2733	3, -0.7305	, 0.2247,	0.4232,	1.6182, 0.59	0.4830,	1.0708,	-0.1458, 1.	2877, 1.139	8, -0.2136,	-0.3718, -0.0434,	-0.3375

Sentinel-1 wide Coverage: the Napoli Bay area

Stable InSAR analyses require at least two-three years of data, especially for the removal of Atmospheric artefacts that are quite severe for Sentinel IW Interferograms

Sentinel-1: a Small Baseline constellation

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Sentinel-1 SBAS results on the Napoli Bay area: Preliminary Results

descending orbits

Atmospheric artefacts are difficult to be removed (very large swath, wider beams, etc ...)

Accurate estimates require a (stable) population of more than three years, thus facilitating the removal of all the disturbances affecting Sentinel-1 Deformation Time-Series

LOS <-6 cm/year

07 October 2014 – 06 April 2017

81 SLC

NEW DATA ARE NEEDED FOR ASSESSING THE QUALITY OF ACHIEVED RESULTS AND MAKE THEM MORE STABLE !!!!

>6

Radiometric Calibration of di SAR Images

Algorithm development

Radiometric Calibration of the SAR Images: A New Formulation

SAR image analysis

Investigate the soil consumption effects through the analysis of the detected reflectivity changes and of the retrieved surface displacements

- sigma naught (σ⁰) maps: SAR images have to be properly radiometrically calibrated (including the effect of topography) and geocoded.
- Multitemporal analysis of the σ⁰ variation
- Vegetation consumption, vegetation mortality, soil alteration

An Example: VH Sigma Naugth Difference Maps

Darker areas correspond to an area affected by fires in Sardinia. Similar analyses will be provided for the monitoring of the backscattered signal variations <u>in urban scenarios</u>

