Data Report for "Bringing New Tools and Techniques to Bear on Earthquake Hazard Analysis and Mitigation"

During July 2013, IRIS held an Advanced Studies Institute in Santo Domingo, Dominican Republic, that was designed to enable early-career scientists who already have mastered the fundamentals of seismology to begin collaborating in frontier seismological research. Support for participants at the Institute, who were drawn from a dozen different countries of Middle America, was partially funded by NSF award OISE-1242259, with David Simpson as the P.I. and Raymond Willemann and a co-P.I.

This was the first IRIS institute to combine an instructional short course with field work for data acquisition. Student participants broke into small teams to acquire data, and teams rotated among different types of data acquisition so that all of them would have experience with all of the different types of data collection. All of the data acquisition sites were within the Santo Domingo urban area, which is situated on limestone terraces.

We used Trillium compact seismometers owned by Baylor University and Reftek 130 data loggers loaned by PASSCAL under the rules for a RAMP deployment to acquire three-component ambient noise data for Spatial Auto-Correlation (SPAC) analysis at eight arrays, with ten stations at each array location. *Table 1* provides details about the arrays, including date of deployment, instrument serial numbers, and array center locations. Within each array, sensors were placed at the vertices of three nested equilateral triangles – with sizes of 15 meters, 30 meters, and 60 meters on a side – and at the single center point of all three triangles. *Figure 1* shows an example of the array geometry, but the array orientations were not measured and varied from site to site. We recorded for at least an hour at each array location, in each case continuing for 60 minutes beyond the top of the hour after deployment was completed to ensure synchronized data files at the ten sites of the array. Work at the SPAC arrays was supervised by Jay Pulliam of Baylor University.

We also used Trillium compact seismometers owned by Baylor University and Reftek 130 data loggers loaned by PASSCAL under the rules for a RAMP deployment to acquire three-component ambient noise data for Horizontal to Vertical Spectral Ratio (HVSR) analysis at 61 individual sites that lie along six sub-parallel profiles and at selected points between the profiles. The profiles are oriented approximately north-south, perpendicular to the shoreline along the south side of Santo Domingo. *Figure 2* shows the locations of stations along the profiles. *Table 2* provides details about the HVSR sites, including date of deployment, instrument serial numbers, and profile numbers. The HVSR data acquisition was carried out by two teams working independently, each with two sets of instrumentation. We recorded for approximately 30 minutes at each site. One team was supervised by Michael Schmitz of FUNVISIS, Venezuela; the other team was supervised by Carlos Huerta of the University of Puerto Rico, Mayagüez.

We used a DALink III 24-channel recorder and RTC 4.5 Hz vertical geophones from Optim to acquire ambient noise data for Refraction Microtremor (ReMi) analysis at 11 sites, with supplementary data for active-source Multi-channel Spectral Analysis of Surface Waves (MASW) analysis at three of them. The geophones were spaced at 10 meters, generally along a straight line, but along a gently curving road at site "Sur 3". The orientation of the lines were not measured, and are known only approximately. *Table* 3 provides details about each line. At first we recorded 24 channels of data, but after a connector broke at "Este 4" on one of the 12-channel geophone cables, we recorded only 12 channels. At each location, we used a 12-pound sledge hammer for ten untimed strikes at a distance of ten meters from each end of the line to enhance data for ReMi analysis. At the sites selected for MASW analysis, after the ReMi data acquisition and without moving the geophones, we also struck ten times, timed using a hammer trigger, with the 12-pound sledge hammer adjacent to each of the 12 or 24 geophones. Work at the geophone lines was supervised by John Louie of the University of Nevada, Reno, and Travis West of Optim; at least one of them was at each site, but each of them was absent for some of the sites.

Figure 3 shows an aerial view of Faro a Colon, with the SPAC sites numbered and the approximate locations of the geophone lines drawn. *Figure 4* shows and aerial view of Herrera Airport and the Subsidence Area, with the center points of the geophone lines marked by stars. *Figure 5* shows a map of the SPAC arrays and geophone lines at Mirador del Sur. *Figure 6* shows an aerial view of the geophone lines Este 3 and Este 4.

The results showed that teams quickly learned to collect high-quality data for each method of analysis. SPAC and refraction microtremor analysis each demonstrated that dispersion relations based on ambient noise and from arrays with an aperture of less than 200 meters could be used to determine the depth of a weak, disaggregated layer known to underlie the fast near-surface limestone terraces on which Santo Domingo is situated, and indicated the presence of unexpectedly strong rocks below. All three array methods concurred that most Santo Domingo sites has relatively high V_S30 (average shear velocity to a depth of 30 m), generally at the B-C NEHRP hazard class boundary or higher. HVSR analysis revealed that the general pattern of resonance was short periods close to the coast, and an increase with distance from the shore line. In the east-west direction, significant variations were also evident at the highest elevation terrace, and near the Ozama River. In terms of the sub-soil conditions, the observed pattern of HVSR values, departs form the expected increase of sediment thickness close to the coast.

SPAC Arrays

Date	UNIQUE ID	Deployment	Position	Reftek #	Inst. #	GPS #	Field Notes	Data File to Use	Data?	Chan Ok? 1	2	3	QAQC Notes	Location of Center Station W	N	Elev
20130718	MS101	Mirador del Sur 1	1	9461	449	3263		170000005_00290BB2	Y	Y	N	N	Ch. 2 and 3 flat. Ch 1 clips at end	-69.9813	18.43545	58
	MS102		2	929B	428	1940		170000005_00245AFE	Y	N	N	N	Chs. Only good after 1900 seconds			
	MS103		3	9492	1052	2570		170000005_00255A80	Y	Y	Y	Y	ch. 2 looks really noisy			
	MS104		4	92B0	1055	1783	Chan 3 Issue	170000005_0029A02C	Y	Y	Y	Y				
	MS105		5	925D	410	1892		170000000_00251282	Y	Y	Y	Y	Good data only after 600 seconds			
	MS106		6	92DD	1053	1405		170000000_00269864	Y	Y	Y	Y				
	MS107		7	9452	482	1082	chans 2,3 flat after recording	170000000_00266718	y	Y	Y	Y				
	MS108		8	92B2	1045	1090		170000000_00281478	Y	Y	N	Y	Ch 2. Clipped at - values for almost entire record			
	MS109		9	92F0	447	1118	Horiz. Chans Flat	170000000_002BB092	Y	Y	N	N	Ch 1. looks suspect as well			
	MS110		10	92E3	459	1806	Chan 3 Issue. Chan 2 dead after recording	?	N	N	N	N	NO DATA			
20130718	MS201	Mirador del Sur 2	1	92B2	459	1090	bad chan 2	140000005_002166F0	Y	Y	Y	Y	All chans. Look very noisy	-69.98035	18.435733	43
	MS202		2	92B0	428	1783		140000005_0025F2C4	Y	Y	Y	Y				
	MS203		3	92F0	449	1118	bad chan 3	1400000010_0022D44F	Y	Y	N	N	Ch. 1 may be unusable. Strange drift			
	MS204		4	9452	1045	1082		140000000_002F3500	Y	N	N	N	Ch. 3 clipped. Chs. 1 and 2 have lots of noise, may not be usable			
	MS205		5	9461	1053	3263		140000005_0026DD1A	Y	Y	Y	Y				
	MS206		6	92DD	482	1405		140000005_002A563E	Y	Y	Y	Y				
	MS207		7	92E3	1052	1806		140000005_0024F36A	Y	Y	N	Y	all chans. Look very noisy			
	MS208		8	925D	410	1892		140000005_002CC310	Y	Y	Y	Y				
	MS209		9	929B	1055	1940		140000005_0027E926	Y	Y	Y	Y				
	MS210		10	9492	447	2570		140000000_002CE818	Y	Y	Y	Y				

SPAC Arrays

Date	UNIQUE ID	Deployment	Position	Reftek #	Inst. #	GPS #	Field Notes	Data File to Use	Data?	Chan Ok? 1	2	3	QAQC Notes	Location of Center Station W	N	Elev
20130719	FC101	Faro a Colon 1	1	925D	1049			140000005_00257470	Y	N	N	N	lots of instrument noise in chs. 1 and 3			
	FC102		2	92F0	1051			140000010_0024DB41	Y	Y	Y	Y				
	FC103		3	92B2	410			140000000_0024273C	Y	Y	Y	Y				
	FC104		4	929B	447			140000005_0023B2D4	Y	Y	Y	Y	lots of long period noise			
	FC105		5	92E3	1045			?	N	N	N	N	NO DATA	-69.869933	18.478267	37
	FC106		6	9492	1055			140000005_00204B94	Y	Y	Y	Y				
	FC107		7	9461	482			140000005_00228B52	Y	Y	Y	Y				
	FC108		8	92DD	1053			140000005_00202FEC	Y	Y	Y	Y	substantial noise in Chs. 2 and 3			
	FC109		9	92B0	1052			140000005_00216C40	Y	Y	Y	Y				
	FC110		10	9452	428			140000000_00237E18	Y	Y	Y	Y	lots of long period noise			
20130719	FC201	Faro a Colon 2	1	925D	1049			170000005_0036EE80	Y	Y	N	Y	ch. 1 is probably unusable. Very noisy			
	FC202		2	9492	1055			170000005_0036EE80	Y	Y	Y	Y	All chans very noisy			
	FC203		3	9452	428			170000005_0036EE80	Y	Y	Y	Y				
	FC204		4	92DD	1045			170000000_0036EE80	Y	Y	Y	Y	large spike at 1350s			
	FC205		5	92E3	1053		BE CAREFUL, ONLY USE SECOND HOUR, sensor was incorrectly placed originally		N	N	N	N	RAW DATA IS THERE, DIDN'T GET CONVERTED?	-69.868317	18.479633	0
	FC206		6	929B	410			170000005_0036EE80	Y	Y	Y	Y	might work, but large spike in the middle			
	FC207		7	9461	482			170000005_0036EE80	Y	Y	Y	Y	might work, but large spike in the middle			
	FC208		8	92B0	1052			170000000_0036EE80	Y	Y	N	N	Chs. 2 and 3 very noisy			
	FC209		9	92B2	447			170000000_0036EE80	Y	Y	Y	Y				
	FC210		10	92F0	1051			170000020_0036EE80	Y	Y	Y	Y				

SPAC Arrays

Date	UNIQUE ID	Deployment	Position	Reftek #	Inst. #	GPS #	Field Notes	Data File to Use	Data?	Chan Ok? 1	2	3	QAQC Notes	Location of Center Station W	N	Elev
20130719	FC301	Faro a Colon 3	1	92F0	1051			190000000_003014B1	Y	Y	Y	Y	chs. 2 and 3 have long period bg signal			
	FC302		2	92B2	432			190000000_002D2A76	Y	Y	Y	Y				
	FC303		3	9492	1055			190000005_002E1350	Y	Y	Y	Y				
	FC304		4	92E3	1053			190000005_002ECBA6	Y	Y	Y	Y	ony good after 800 seconds			
	FC305		5	9461	447			190000005_0031B974	Y	Y	Y	Y		-69.866983	18.4791	38
	FC306		6	929B	92B0			190000005_002F99E6	Y	Y	Y	Y				
	FC307		7	92B0	1052			190000005_002E5C20	Y	Y	Y	Y	chs. 2 and 3 have long period bg signal			
	FC308		8	9452	1045			190000000_003035EA	Y	Y	Y	Y				
	FC309		9	92DD	428			190000005_002EFD1A	Y	Y	Y	Y	chs. 2 and 3 have long period bg signal			
	FC310		10	925D	1049		Bad Ch. 2	190634000_00277356	Y	Y	N	Y	ch. 1 is probably unusable			
20130720	HA101	Herrera Airport 1	1	92B0	482		Use 11AM START TIME FOR ALL. Most sensors were turned off at 09:15 start time.	150000005_0024EA32	Y	Y	Y	Y				
	HA102		2	92DD	1045			150000000_002D5F28	Y	Y	Y	Y				
	HA103		3	9452	447			150000005_002658A4	Y	Y	Y	Y				
	HA104		4	92B2	1051			150000005_0023FD66	Y	Y	Y	Y				
	HA105		5	9492	410		ch. 2 dead at start only	150000000_0028D688	Y	Y	Y	Y	large spike at 600 sec	-69.96875	18.472033	67
	HA106		6	9461	459			150000005_002CA646	Y	Y	N	Y	ch. 2 clipped			
	HA107		7	92F0	1052			150000005_00278792	Y	Y	Y	Y				
	HA108		8	9891	1055		Ch 2. dead at end of exp.	150000000_002ED196	Y	Y	Y	Y				
	HA109		9	92B8	428			150000005_002B71CC	Y	Y	Y	Y				
	HA110		10	929B	449			150000005_00233656	Y	Y	Y	Y				

SPAC Arrays

Date	UNIQUE ID	Deployment	Position	Reftek #	Inst. #	GPS #	Field Notes	Data File to Use	Data?	Chan Ok? 1	2	3	QAQC Notes	Location of Center Station W	N	Elev
20130720	HA201	Herrera Airport 2	1	92B0	482			180000005_001F6508	Y	Y	Y	Y		-69.969117	18.47065	68
	HA202		2	9461	1051			180000000_00285F82	Y	Y	Y	Y				
	HA203		3	92B8	410			180000000_00204D38	Y	Y	Y	Y				
	HA204		4	9492	1052			180000000_00212BFE	Y	Y	Y	Y				
	HA205		5	9891	1055			180000000_00253A82	Y	Y	Y	Y				
	HA206		6	925D	403		switched out DAS? Two collocated sensors?	180000000_0026B6F0	Y	Y	N	Y	All chs. Have spike at 2300 sec			
	HA211		6	9452	459		switched out DAS? Two collocated sensors?	180000000_0025F652	Y	N	N	Y	ch. 1 clipped for half the record, ch. 2 dead			
	HA207		7	92B2	447			180000005_00223918	Y	Y	Y	Y				
	HA208		8	92DD	1045			180000005_00276FFA	Y	Y	Y	Y				
	HA209		9	929B	428			180000000_0024708E	Y	Y	Y	Y	chs. 2 and 3 have long period bg signal			
	HA210		10	92F0	449			180000005_00233A0C	Y	Y	Y	Y				
20130721	UA101	UASD Soccer Field	1	92B2	482			160000000_001BA8BE	Y	Y	Y	Y		-69.914183	18.461933	19
	UA102		2	925D	428			160000005_001DCD9C	Y	Y	Y	Y				
	UA103		3	929B	410			160000000_001D40FC	Y	Y	Y	Y				
	UA104		4	92F0	1051			160000000_001C9896	Y	Y	Y	Y				
	UA105		5	9452	1055			160000005_001E4D30	Y	Y	Y	Y				
	UA106		6	9492	447			160000000_001FCD40	Y	Y	Y	Y				
	UA107		7	92DD	449			160000005_001F1B20	Y	Y	Y	Y				
	UA108		8	9891	1051			160000005_0021DE32	Y	Y	Y	Y				
	UA109		9	92B0	403			160000005_00212BF4	Y	Y	N	Y				
	UA110		10	92B8	1045			160000000_002083AC	Y	Y	Y	Y				

Table 2, page 1. Instrument serial numbers (sensor, recorder, GPS antenna), profile and site number location of ambient noise measurements in Santo Domingo, Dominican Republic.

Profile/site	Sensor Trillium Compact s/n	Recorder/GPS s/n	Julian day, (2013)
P1/01	1049	949A-1030/NA	199
P1/02	1046	92F1-130/NA	199
P1/03	N/A	N/A	199
P1/04	1046	N/A	199
P1/05	1049	92F1-130/NA	199
P1/06	1050	949A-130/NA	199
P1/07	1046	92F1-130/NA	199
P1/08	1046	92F1-130/NA	199
P2/01	01051	950C/1714	199
P2/02	486	9282/1815	199
P2/03	01051	950C/NA	199
P2/04	486	9282/1815	199
P2/05	01051	N/A	199
P2/06	486	9282/NA	199
P2/07	N/A	N/A	199
P2/08	486	9282/1815	199
P5/01	486	950C/1815(1714)	200
P5/02	403	9282/1815	200
P5/03	486	950C/1714	200
P5/04	403	9282/1815	200
P5/05	403(486)	950C/1714	200
P5/06	403(486)	9282/1815	200
P5/07	486	950C/1714	200; Site repeated= site 03
P6/01	1046	92F1-130/1006	200
P6/02	1050	949A-130/1008654	200
P6/03	1046	92F1-130/1006	200
P6/04	1050	949A-130/1008654	200
P6/05	1046	92F1-130/NA	200
P6/06	1050	949A-130/NA	200
P6/07	1046	NA/NA	200
P6/08	1050	949A-130/NA	200

Table 2, page 2. Instrument serial numbers (sensor, recorder, GPS antenna), profile and site number location of ambient noise measurements in Santo Domingo, Dominican Republic.

Profile/site	Sensor Trillium Compact s/n	Recorder/GPS s/n	Julian day, (2013)
P3/01	001053	9282/NA	201
P3/02	00486	950C/NA	201
P3/03	001053	9282/NA	201
P3/04	00486	950C/NA	201
P3/05	001053	9282/1815	201
P3/06	00486	950C/1714	201
P4/01	1050	92F1-130/NA	201
P4/02	1046	949A-130/NA	201
P4/03	1050	92F1-130/NA	201; No site ID (plaza espania)
P4/04	1046	949A/NA	201
P4/05	1050	92F1/NA	201
P4/06	1046	949A/NA	201
P4/07	1050	92F1/NA	201
P4/08	1046	949A-130/NA	201
P4/09	1046	92F1/NA	201
P4/10	1050	949A-130/NA	201
P4/11	1046	92F1/NA	201
P4/12	1050	92F1-130/NA	201
P1-P2/01	1053	9282/1714	202
P1-P2/02	0485	950C/1815	202
P1-P2/03	1053	9282/1815	202
P1-P2/04	486	950C/1714	202
P3-P4/01A	1050	92F1-130/NA	202
P3-P4/02	1050	92F1-130/NA	202
P3-P4/01B	1046	949A/NA	202
P3-P4/03	1046	949A-130/NA	202
P3-P4/04	1050	92F1-130/NA	202
P3-P4/05	001046	949A/1815	202
P3-P4/06	1050	92F1-130/NA	202
P3-P4/07	1046	949A-130/NA	202

P#-P#/##: sites between profiles/site number, N/A: Info. not available on field notes, P#/##: profile number/site number. Information here described as it appears in the field notes.

Table 3. Geophone Deployments

ReMi Data	Location	Time GMT	Emplacement	Orientation	Supervisor	Corresponding SPAC site
Sur_1_ReMi	-69.9817617, 18.4355133, 0	2013.199.14:33:28	Spike in Soil	East-West	Louie, West	Mirador del Sur 2
Sur_2_ReMi	-69.9797349, 18.4354966, 0	2013.199.16:54:46	Spike in Soil	East-West	Louie, West	Mirador del Sur 1
Sur_3_ReMi	-69.9779783, 18.4356966, 0	2013.199.17:59:00	Tripod on Pavement	East-West	Louie, West	-----
Este_1_ReMi	-69.8696949, 18.478349, 0	2013.200.12:34:08	Tripod on Pavement	East-West	West	Faro a Colon 1 and 2
Este_2_ReMi	-69.8670166, 18.4790733, 0	2013.200.13:58:11	Spike in Soil	East-West	West	Faro a Colon 3
Este_3_ReMi	-69.8603399, 18.4797766, 0	2013.200.17:10:36	Tripod on Pavement	East-West	West	-----
Este_4_ReMi	-69.8621333, 18.4793249, 0	2013.200.18:37:31	Tripod on Pavement	North-South	West	-----
Herrera_Airport_1_ReMi	-69.9690983, 18.4706333, 0	2013.201.12:44:14	Tripod on Pavement	North-South	Louie, West	Herrera Airport 2
Herrera_Airport_2_ReMi	-69.9688199, 18.4720499, 0	2013.201.17:08:37	Tripod on Pavement	North-South	Louie, West	Herrera Airport 1
Subsidence_Area	-69.9584939108, 18.4735468262, 0	No Information	Tripod on Pavement	North-South	Louie, West	-----
UASD_Soccer_Field_ReMi	-69.914183, 18.461933, 0	No Information	Spike in Soil	East-West	Louie	UASD Soccer Field

MASW Data	Location	Time GMT				Corresponding SPAC site
Este_2_MASW	-69.8670266, 18.4790499, 0	2013.200.14:33:40	Spike in Soil	East-West	West	Faro a Colon 3
Herrera_Airport_1_MASW	-69.9691133, 18.4706549, 0	2013.201.13:30:19	Tripod on Pavement	North-South	Louie, West	Herrera Airport 2
UASD_Soccer_Field_MASW	-69.914183, 18.461933, 0	No Information	Spike in Soil	East-West	Louie	UASD Soccer Field

Figure 1. Each SPAC array was nested triangles with side lengths of 15 m, 30 m, and 60 m, plus a center element common to the three triangles.

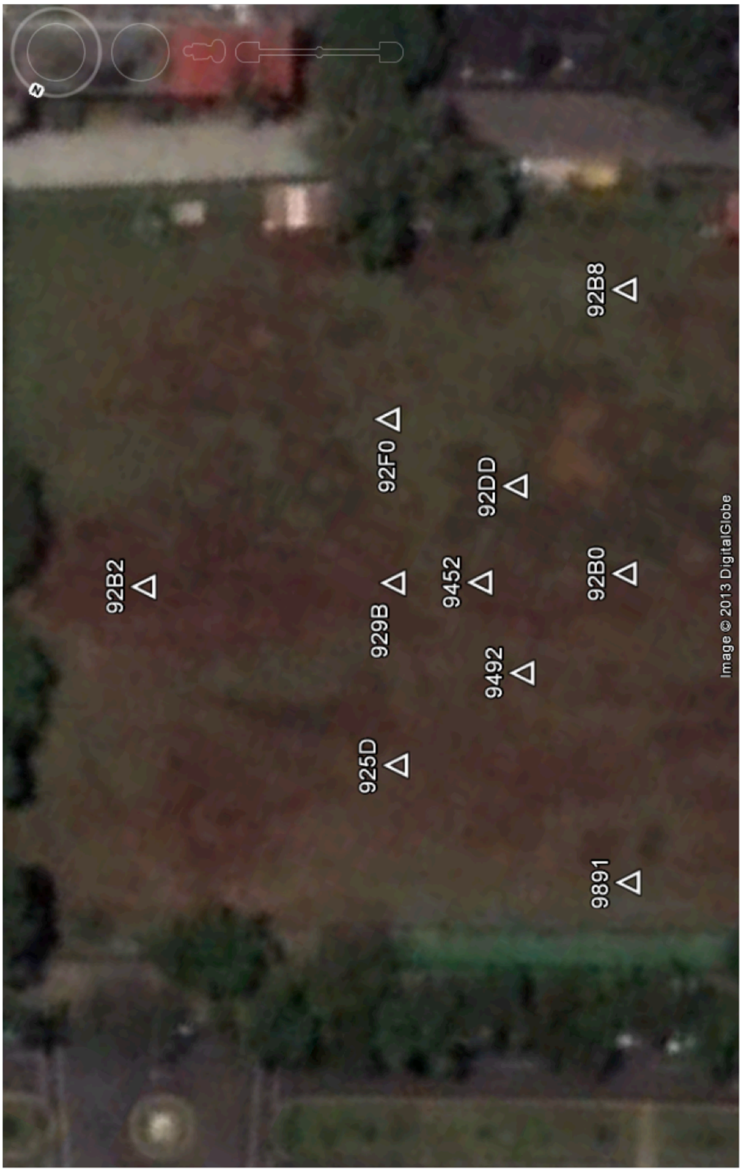

Figure 2. Sixty-one HVSR sites lie along six sub-parallel profiles and at selected points between the profiles.

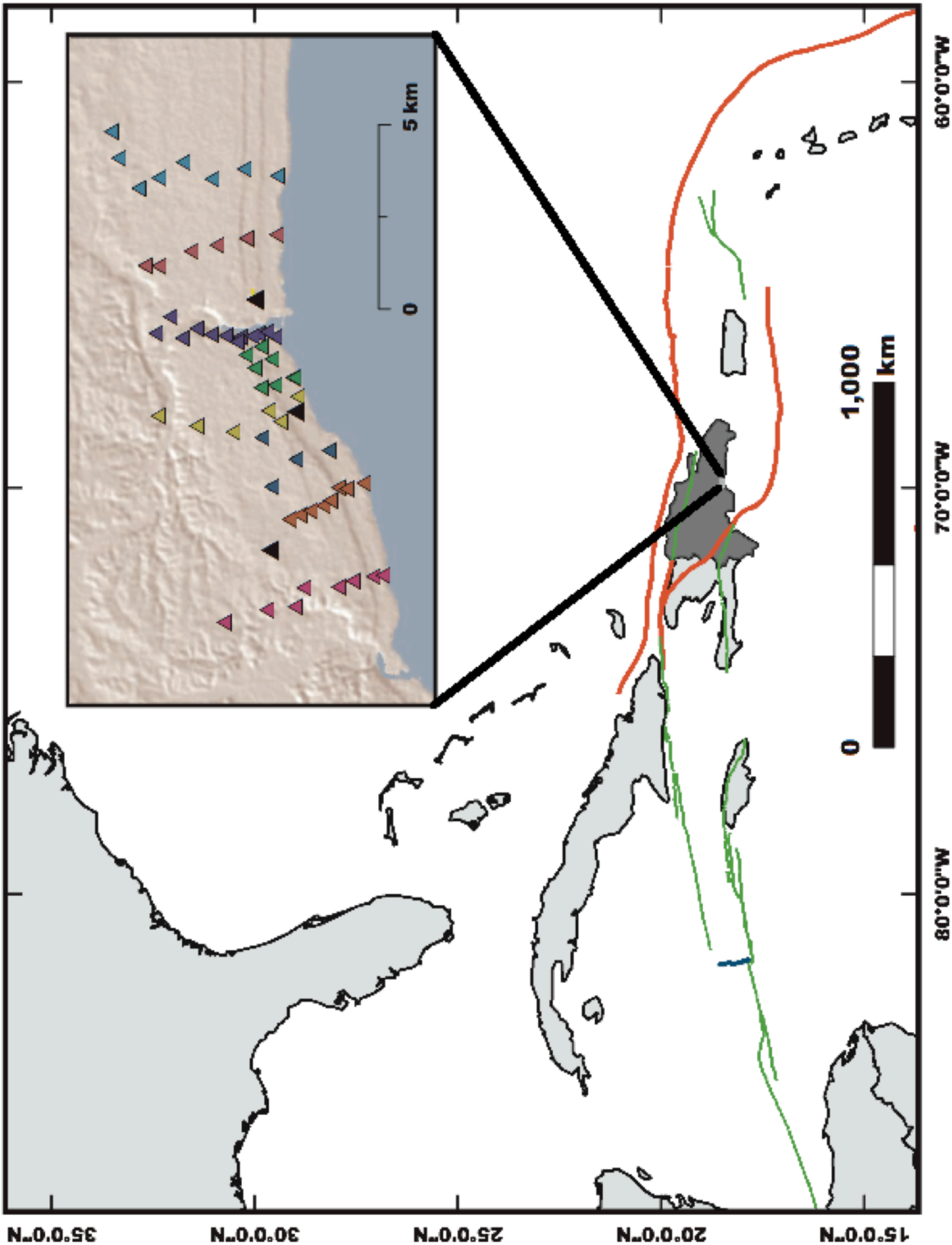

Figure 3. Aerial view of Faro a Colon, with the SPAC sites numbered and the approximate locations of the geophone lines drawn.

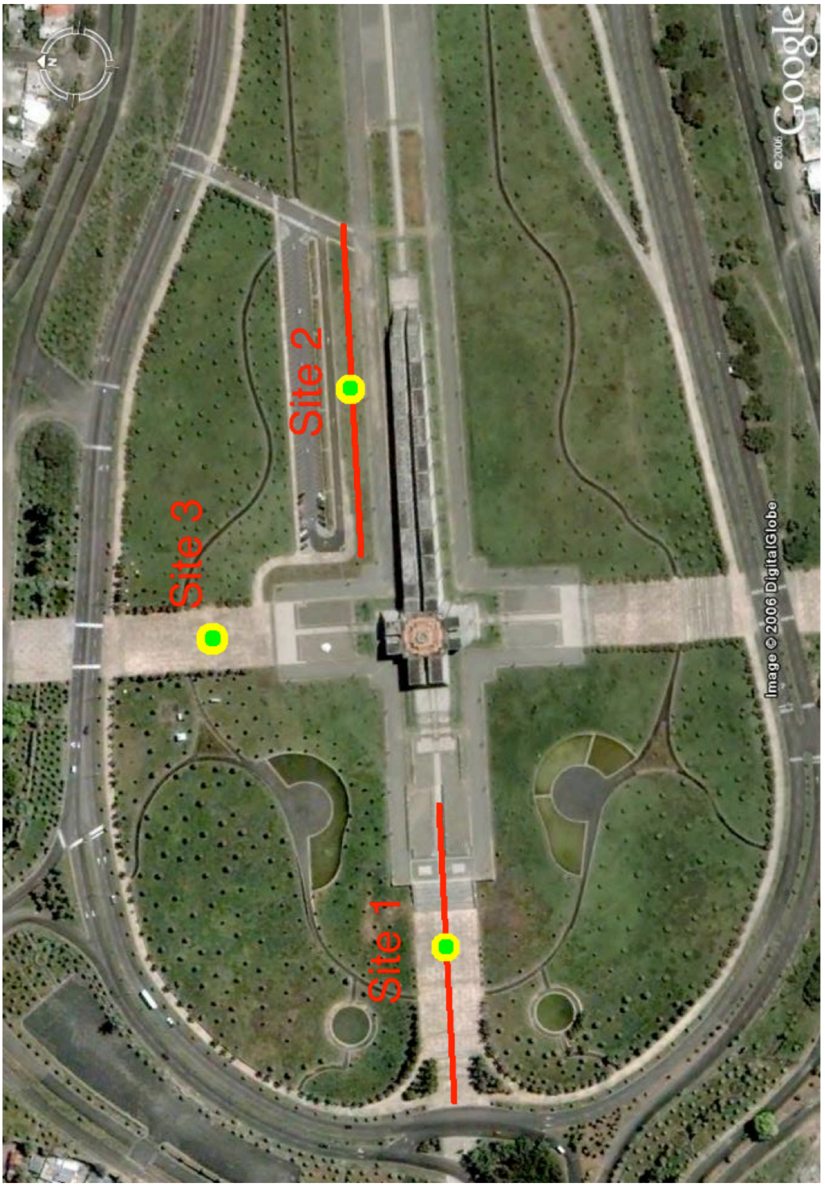

Figure 4. Aerial view of Herrera Airport and the Subsidence Area, with the center points of the geophone lines and the SPAC arrays marked by stars.

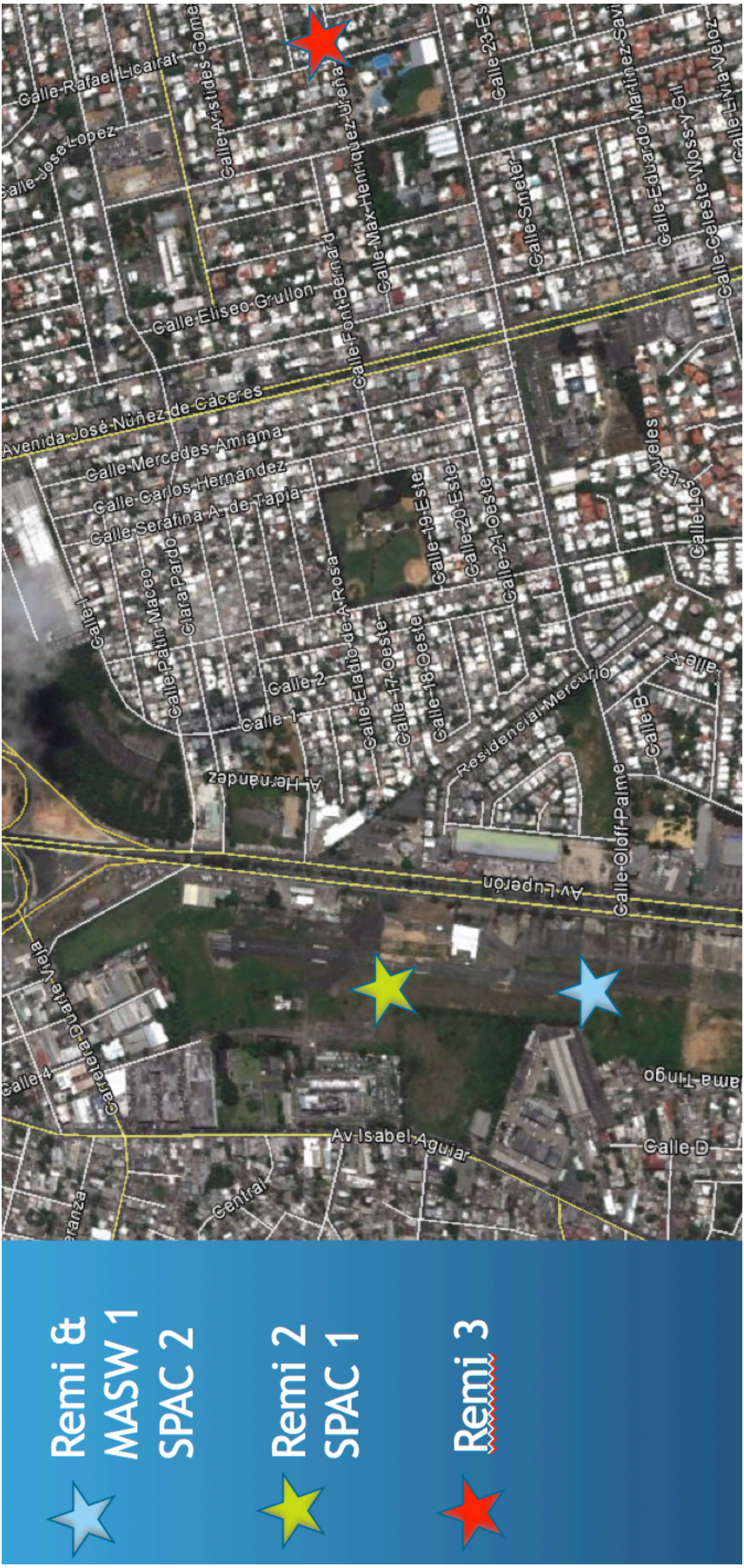

Figure 5. Map of the SPAC arrays and geophone lines at Mirador del Sur.

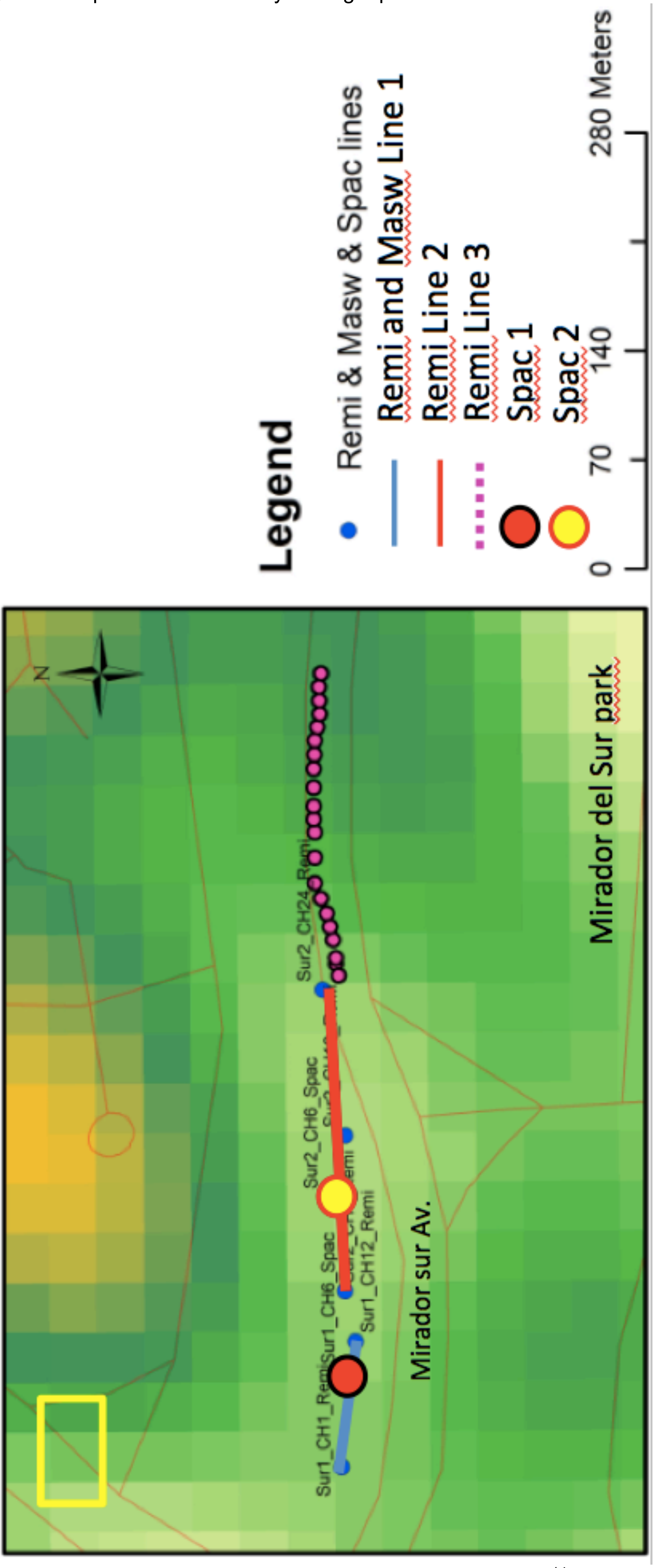

Figure 6. Aerial view of the geophone lines Este 3 and Este 4.