GNSS single-frequency devices at OGS: *LZER0* a cost-effective prototype.

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Low cost single frequency GNSS (Global Navigation Satellite Systems) receivers, usually developed for the mass market or for hobby use, recently (Eyo et al. 2014), gained more importance in surface or near surface process monitoring. Some studies have investigated the accuracy of single-frequency GPS receivers for landslide monitoring (Eyo et al. 2014, Squarzoni et al. 2005, Janssen et al. 2003). The big challenge in landslide monitoring is how to reduce the monitoring costs and the prospect of losing the equipment during a landslide event. Even precise GNSS real-time positioning techniques, RTK (Hu et al. 2003), can benefit from cost-effective single-frequency devices.

Centro di Ricerche Sismologiche (CRS) of Istituto Nazionale di Oceanografia e di Geofisica Sperimentale OGS has gained experience in the single-frequency GNSS systems since 2015, when the CRS staff started to monitor a landslide near the Tolmezzo municipality (central Friuli, Cazzaso village, Zuliani et al. 2016). The landslide monitoring system, called SENDAS (and now DEDALOS), implements single-freequency GNSS devices to measure, with a centimetre precision, the surface displacements caused by the landslide. In 2015 CRS, thanks to the gained expertise, has started to develope and test its proprietary cost-effective GNSS device both for post-processing and real-time applications. Up to now 4 prototypes have been produced:

- **LONE** built in 2015 made of a Raspberry Pi B+, a NVS NV08-CSM L1 GNSS receiver and a Tallysman TW2410 GNSS antenna (Fig. 1)
- 2 naked prototypes used for continuous developping and based on Raspberry Pi Zero W and u-blox M8T GNSS receiver (Fig. 2)
- **LZER0** built in 2016 made of a Raspberry Pi Zero W, a u-blox M8T GNSS receiver and a Tallysman TW4721 GNSS antenna (Fig. 3)

The GNSS elaboration running on the raspberry is performed with two packages:

- **RTKLIB** 2.4.3
- BKG Ntrip Client (**BNC**)

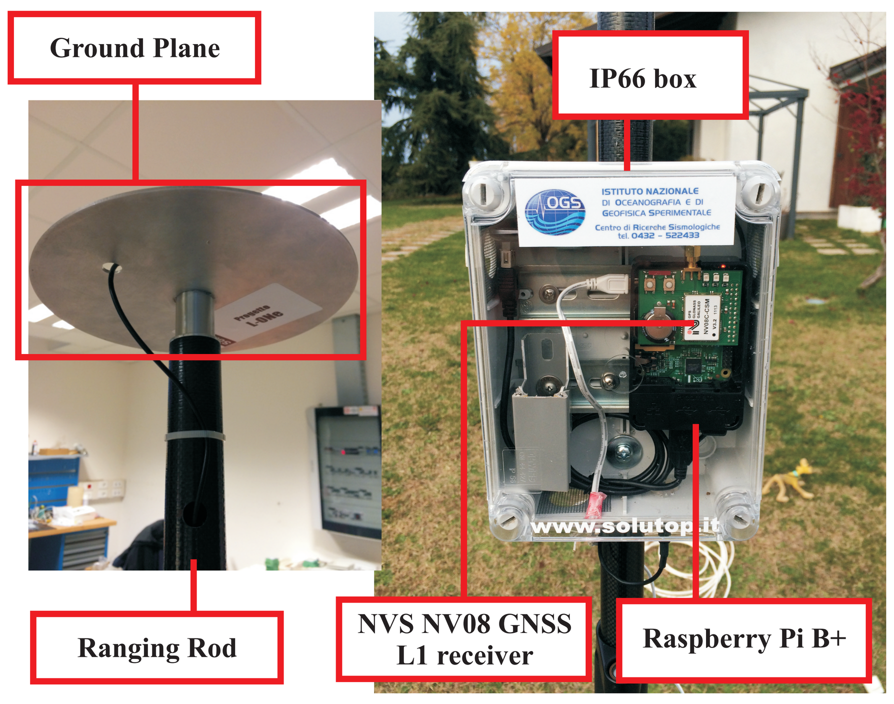

Fig. 1: LONE single-frequency GNSS prototype, developed in 2015 and made of: a Raspberry Pi B+, a NVS Nv08-CSM GNSS L1 receiver, a Tallysman TW2410 GNSS antenna. Power supply is realized with a 2200mAh USB power bank and connectivity is enabled by a GPRS USB modem and by the raspberry internal ethernet port. All the components are included inside an IP66 box. The Tallysman antenna has been coupled with a metallic ground plane to reduce multipath signals from the ground.

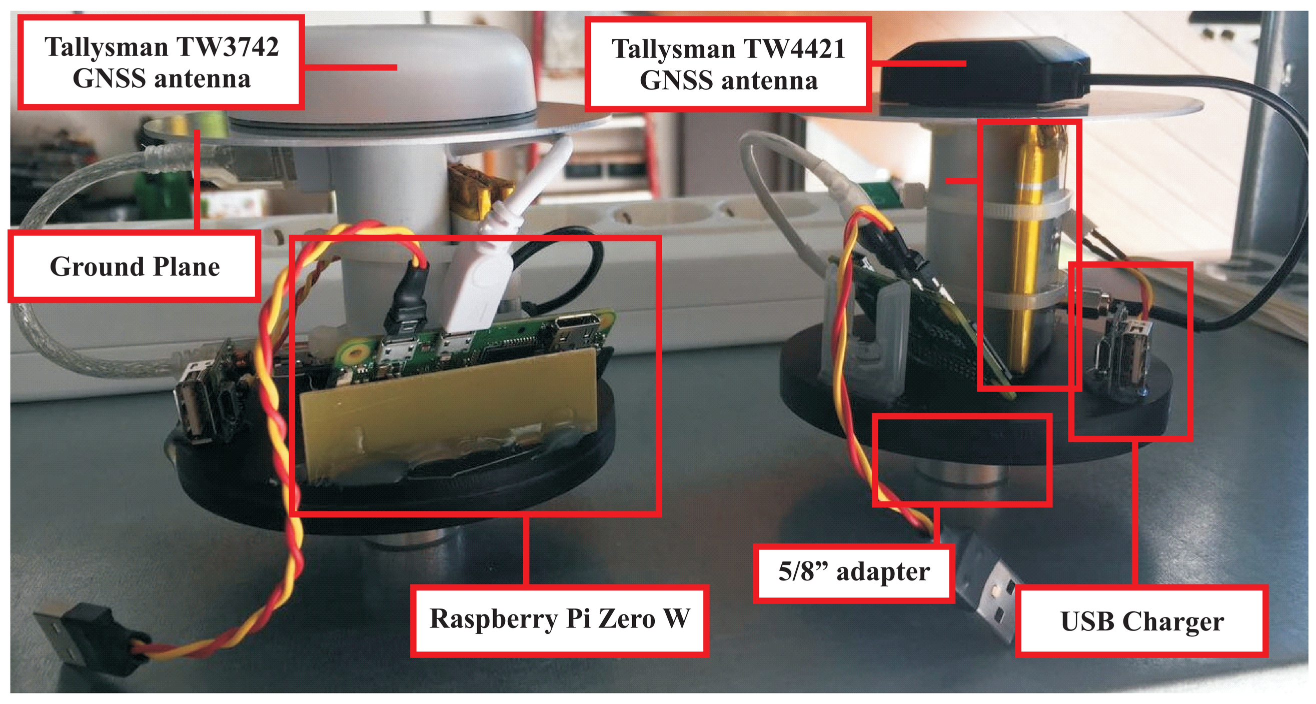

Fig. 2: 2 LZER0 naked versions. Both of them are made with a Raspberry Pi Zero W, a USB version of a u-blox M8T GNSS receiver, a Tallysman (TW3742 or TW4421) GNSS antenna, an aluminum ground-plane, a battery recharger unit (grabbed from USB power banks), a 2000mAh LiPo battery. Those versions are ongoing prototypes and recently they have been updated with a couple of 3DR UHF radios to implement a GNSS Master-Rover link. A plastic support holds all the components together and a 5/8" aluminum adapter is inserted at the bottom to use the device with a ranging rod. The prototypes run different RTKLIB modules (mainly str2str and rtkrcv) to capture, elaborate and provide GNSS data and final coordinates. Connectivity is ensured by the Raspberry WiFi module linked to external WiFi hot-spot which is usually provided by a tablet able to reach 3G or 4G/LTE networks.

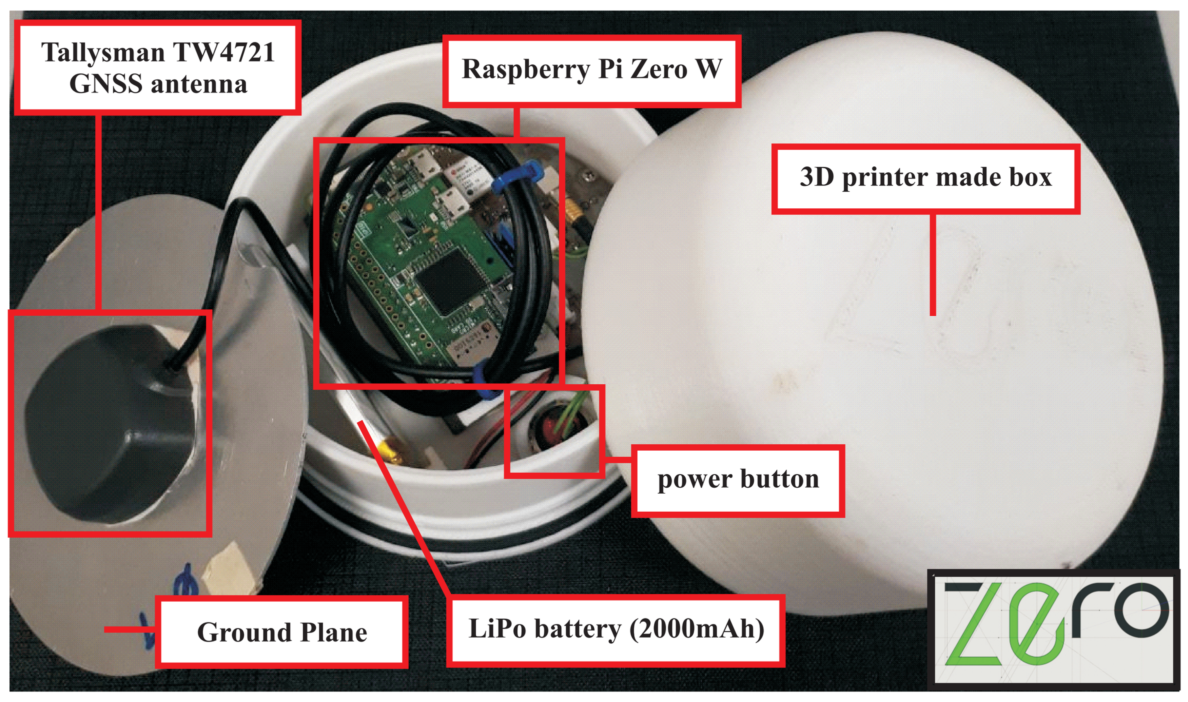

Fig. 3: LZER0 stable version. All the components are included inside a box built with a 3D printer. As the naked version (see beside figure) this LZER0 is made of a Raspberry Pi Zero W but the M8T u-blox GNSS receiver is mounted on a circuit board developed by the CRS staff. The board also includes the battery charge circuitry and a PIC microcontroller to safely shutdown the Raspberry from an external button. Inside the box a 2000mAh LiPo battery is included, the GNSS antenna adopted is a Tallysman TW4721 coupled with an aluminum ground-plane . At the bottom of the box you can find a power off button, a microusb connector for recharging, 2 status leds and a 5/8" thread to couple the device with a ranging rod.

Linux shell scripts have been written to combine the RTKLIB and BNC features and to redirect GNSS data for simultaneous elaborations.Third parties software called SmartRTK has been adopted to collect LZER0 real-time results and to show them into a geomatic environment running on an Android Tablet. As we have the full control of the FReDNet RTK engine (Zuliani et al. 2018) we created specific RTK access points (called mount-points) to be used with LZER0 in real-time. The mount-points are VRASP0, VRASP1, VRASP2 and VRASP4, which enable 4 different VRS at various distances from the rover (0 km, 1 km, 2 km, 3 km and 4 km). With the support of a I.T.G. Marinoni student we used LZER0 to measure 2 benchmarks belonging to the Istituto Geografico Militare IGM and part of the IGM95 network with well known coordinates. The comparison between the known coordinates and the LZER0 measures is reported in tables Tab. 1 and Tab. 2. The tables include LZER0 coordinates calculated using a post-processing (PP) approach with GNSS data collected by LZER0 within a 30 min session sampled at 1 s and LZER0 RTK coordinates taken in real time. Furthermore, repeatability tests have been made on a single benchmark (installed on the roof of the CRS venue in Udine) to test both reliability and performance of the system (see Fig. 4). LZER0 is still a prototype to be improved and developed but inexpensive and easy to command, useful for research and teaching activities.

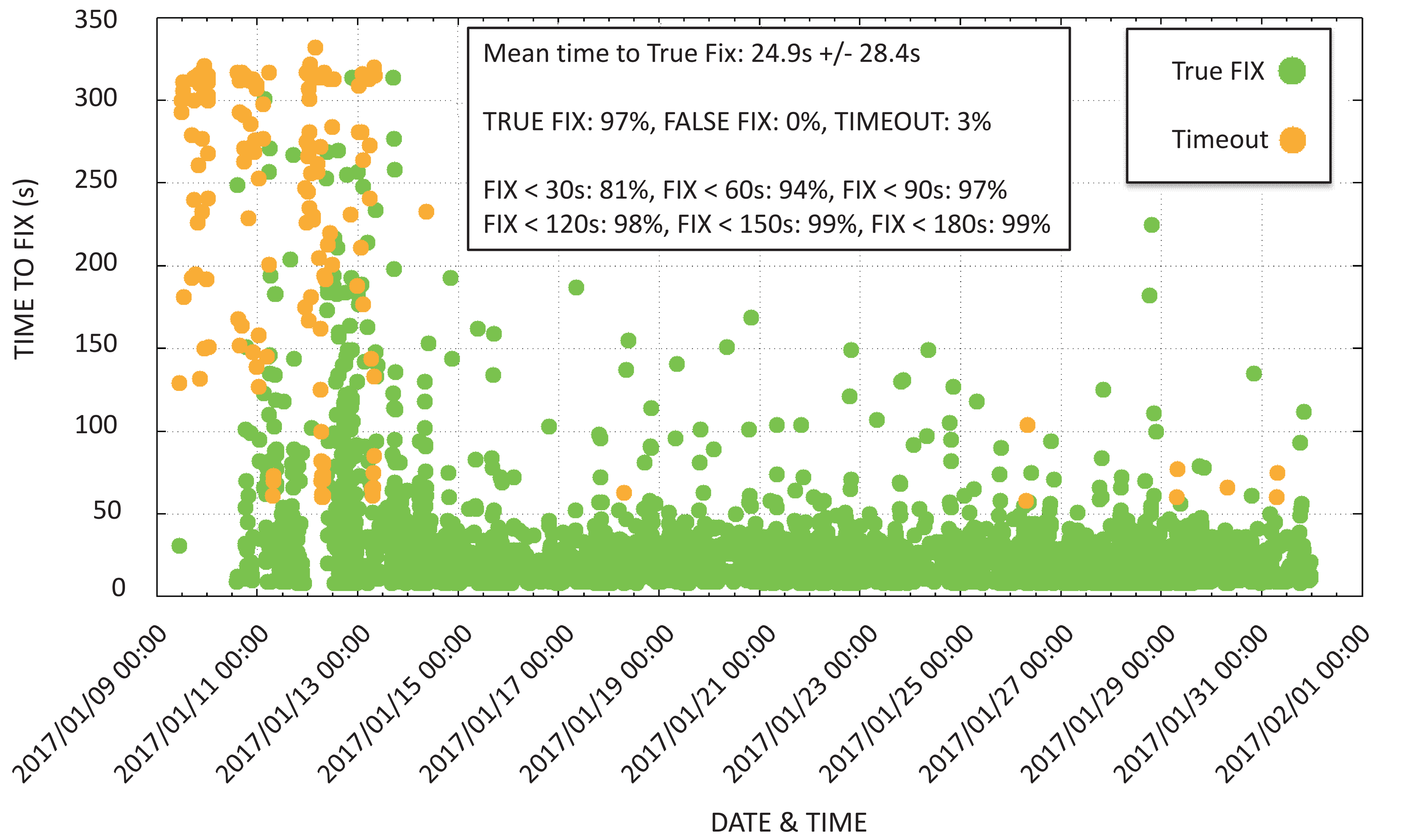

Fig. 4: A Linux tcsh script has been written to repeatedly check the RTK engine inside LZER0. LZER0 during the tests is fixed on a benchmark with well-known coordinates. Every dot represents a single test where LZER0 is forced to restart its *rtkrcv* module and to reach a final solution within a given timeout. Timeout is 5min and includes not only the RTK search algorithm but also the connection to the RTK service (available on the remote server). A green dot is a FIX status representing a correct solution found within the timeout and matching the benchmark coordinates. The yellow dot represents an incomplete solution because of the reached timeout. No false FIX is present. False FIX usually appears when a solution is reached within the timeout but it does not match the right coordinates of the given benchmark. Some statistics are given about the time needed to reach a correct solution.

TYPE	NORD [m]	EST [m]	H. ELL. [m]
IGM reference	5097336.565	356202.294	120.466
LZER0 POST-	5097336.578	356202.349	120.543
DIFF.	-0.013	-0.055	-0.077
IGM reference	5097336.565	356202.294	120.466
LZER0 RTK	5097336.572	356202.327	120.525
DIFF.	-0.007	-0.033	-0.059

Tab. 1: IGM 025705 in Campoformido (UD) is an IGM benchmark used as references for the first LZER0 test. The Reference Frame used is ETRF2000 (2008.0), plane coordinates are UTM 33 and the quote is the ellipsoidal height of the benchmark. Differences between the reference coordinates and the LZER0 results (both post–processing mode and real-time RTK) are taken into account. LZER0 RTK coordinates are the average of 5 measures; each of them is taken after the reboot of the RTKLIB module rtkrcv. LZER0 POST-PROC coordinates are the result of a post-processing procedure performed with the software Topcon Tools Ver.8.2.3. The Master station is CODR 14 km faraway and belongs to FReDNet. For the calculus a 30 min session of GNSS data, sampled at 1 s, has been used.

TYPE	NORD [m]	EST [m]	H. ELL. [m]
IGM reference	5084917.016	368909.649	71.181
LZER0 POST-	5084917.015	368909.651	71.256
DIFF.	0,001	-0,002	-0,075
IGM reference	5084917.016	368909.649	71.181
LZER0 RTK	5084917.113	368909.598	71.346
DIFF.	-0.097	0.051	-0.165

Tab. 2: IGM 040801 in Palmanova (UD) is an IGM benchmark used as references for the second LZER0 test. The Reference Frame used is ETRF2000 (2008.0), plane coordinates are UTM 33 and the quote is the ellipsoidal height of the benchmark. Differences between the reference coordinates and the LZER0 results (both post–processing mode and real-time RTK) are taken into account. LZER0 RTK coordinates are the average of 5 measures; each of them is taken after the reboot of the RTKLIB module *rtkrcv.* LZER0 POST-PROC coordinates are the result of a post-processing procedure performed with the Topcon Tools Ver.8.2.3 from Topcon. The Master station is UDI1, 15 km faraway and belonging to FReDNet. For the calculus a 30 min session of GNSS data, sampled at 1 s, has been used.

References:
· Cina A., GPS. Principi, modalità e tecniche di posizionamento. Vol. 1. Celid, 2000.
· Eyo E. E., Musa T. A., Omar K. M., Idris K. M., Bayrak T., Onuigbo I. C., Opaluwa Y. D. (2014), Application of Low-Cost GPS Tools and Techniques for Landslide Monitoring: A Review, Jurnal Teknologi (Sciences & Engineering) 71:4 (2014) 71–78;
· Janssen V., Rizos C. (2003), A mixed-mode GPS network processing approach for deformation monitoring applications. Survey Review. 37(287): 2–19;
· Heunecke O., Glabsch J., Schuhbäck S., Landslide Monitoring Using Low Cost GNSS Equipment – Experiences from Two Alpine Testing Sites. Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA, Aug. 2011, Volume 5, No. 8 (Serial No. 45), pp. 661-669;
· Hofmann-Wellenhof B., Lichtenegger H., Collins J. (2001), "GPS theory and practice." Springer, New York. (2001) 978-3-211-83534-0 (ISBN);
· Hu G.R., Khoo H.S., Goh P.C., Law C.L. (2003), Development and assessment of GPS virtual reference stations for rtk positioning. Journal of Geodesy (2003) 77:292–302, doi:10.1007/s00190-003-0327-4;
· Kaplan E. D., Hegarty C. J. (1996), Understanding GPS: Principles and Applications, Edition Kaplan, Boston Artech House Publisher, 1996;
· Landau H., Vollath U., Chen X. (2002), Virtual reference station systems. Journal of Global Positioning Systems Vol.1, No 2:137-143;
· Malet J.P., Maquaire O., Calais. E. (2002), The use of Global Positioning System techniques for the continuous monitoring of landslides: application to the Super-Sauze earthflow (Alpes-de-Haute-Provence, France) Geomorphology, Volume 43, Issue 1, p. 33-54, doi:10.1016/S0169-555X(01)00098-8;
· O'Keefe K. (09,10/2016), Single versus multiple: how frequencies make a difference in gnss receivers, InsideGNSS, Volume 11 Number 4, September/October 2016;
· Squarzoni C., Delacourt C., Allemand P. (2005), Differential single-frequency GPS monitoring of the La Valette landslide (French Alps). Engineering Geology. 79(3–4) : 215–229;
· Zuliani D., Fabris P., Rossi G. (2018), FReDNet: Evolution of a Permanent GNSS Receiver System. In: Cefalo R., Zieliński J., Barbarella M. (eds) New Advanced GNSS and 3D Spatial Techniques. Lecture Notes in Geoinformation and Cartography. Springer, Cham, First Online: 08 July 2017; DOI: 10.1007/978-3-319-56218-6_10;
· Zuliani D., Ponton C. (2017), Master Thesis "Organizzazione e gestione di un progetto per lo sviluppo di un prototipo GNSS cost-effective per applicazioni topografiche e monitoraggio strutturale LZER0" at the "Politecnico di Milano Graduate School of Business MIP" (Master in Management of Research, Innovation and Technology Master MIT IV edizione);
· Zuliani D, Fabris P, Del Negro E, Bertoni M, Durì G (2016) Il sistema di monitoraggio GNSS di Esri Italia SENDAS: il case history della frana di Tolmezzo (UD), Conferenza Esri Italia, pp 20–21 Aprile 2016 Roma, doi: 10.13140/RG.2.1.3782.6966.