

Integrated surveying system for landslide monitoring, Valoria Landslide (Appennines of Modena, Italy)

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Summary

prediction and prevention of landslide risk through the utilization of integrated surveying systems

Boschi di Valoria landslide, located on Appennines of Modena in the Northern Italy, which relatively large size, about 1.6 square km

Integrated Automatic Total Station, looking at 45 reflectors
GPS master station, reference for three rovers on the landslide.
a bi-dimensional clinometer to monitor "local" disturbing effects
geotechnical sensors (inclinometers and piezometers)

Instruments:

alert system

GIS for landslide risk management

Test in progress
- interferometric survey (IBIS system)
-New Automatic total station Leica TM30

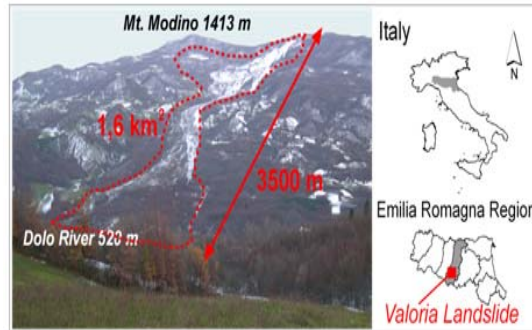


Fig. 1- Location map and panoramic view of the Valoria landslide in February 2006

Boschi di Valoria Landslide is an **ancient large-scale active earth** landslide - multiple **reactivation** phases in the last 60 years; high potential for further development, both in the **upper** landslide zone and in the **toe** area

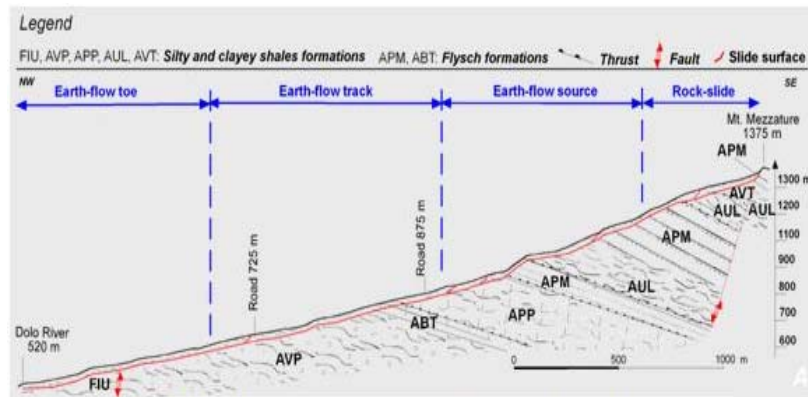
The surface monitoring of the landslide needs both GPS and robotic station systems because of its relatively **large size** (about 1.6 km²: 3.5 km long and 0.7 km wide (**points not in view**)) to create a prevention model.

Risk for:

damaged roads and endangered houses during a sequence of reactivations

Dolo river: it is located at the toe of the slide and in case of event, the overflow of water could isolate entire small villages.

In addition to that, the possible retrogression of the rear scarps could cause relevant **damage to infrastructure**.



Cross section of the Valoria landslide

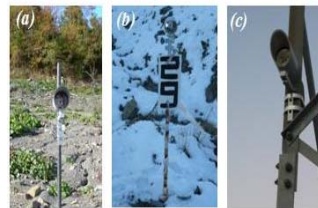
- In the slope, these rocks are deformed by overthrusts and faults.
- thickness between 5 and 40 m



- robotic station (*TCA2003 Leica*) and of a double frequency GPS receiver (*GMX902 Leica*) with an antenna *AX1202 Leica*.
- bi-dimensional clinometer (*Nivel 220 Leica*)
- remote control at university and Authority for hydrological risk monitoring.



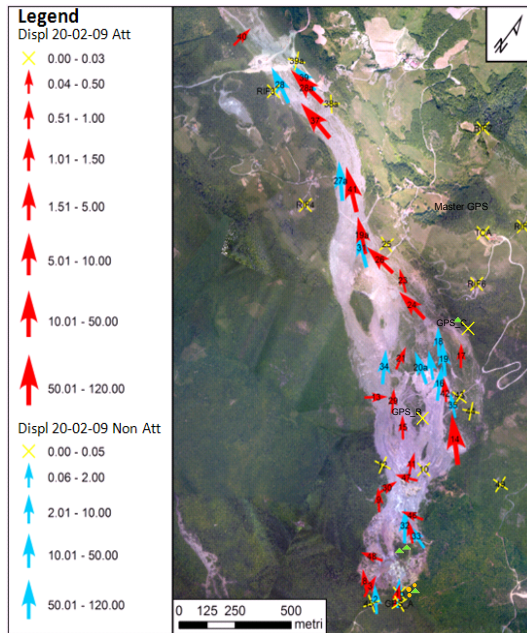
*Example of GPS benchmark –
periodic survey
fixed in the soil for 1.5-2 m*



Reflectors with special mount



GPS rover



Localization of topographic and geotechnical instruments on Valoria Landslide. Continuous system architecture. Movement vectors of prisms and GPS on the landslide: blue arrows - displacements of lost prisms and red arrows - displacements of active reflectors. Rif1, Rif2, Rif3, Rif4, Rif5, Rif6 are reference reflectors. GPS_A, GPS_B, GPS_C are rovers GPS. Extensometers are indicated with a orange circle and borehole instruments (piezometers and inclinometers) with a green triangle.

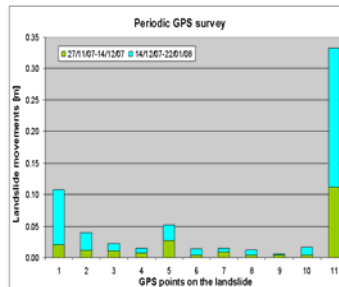
Periodic surveys

three periodic GPS campaigns from November 2007 until January 2008
Fast static surveys a logging rate of 1 second

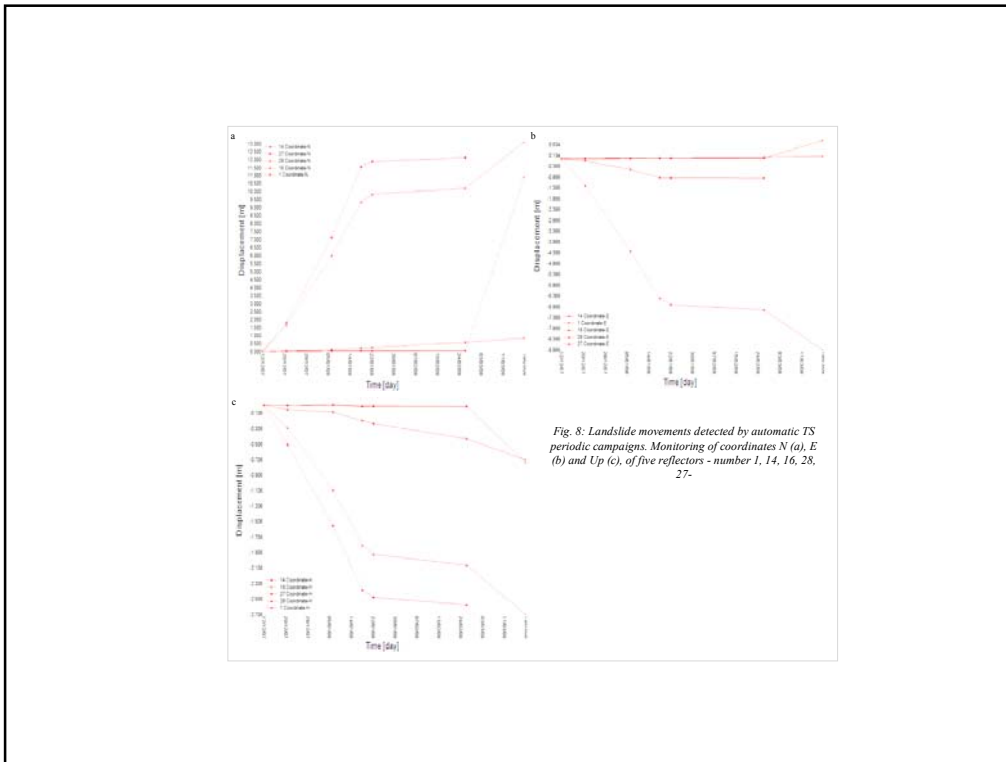
seven periodic surveys with the automatic total station TCA2003 from December 2007 to February 2008 every two weeks
The robotic station measured about 45

precision:
repeatability of 5 mm per day in movement detection

Landslide movements: $ \Delta $ in [m]		
GPS point ID	27/11/2007-14/12/2007	14/12/2007-22/01/2008
1	0.0200	0.0873
2	0.0106	0.0284
3	0.0100	0.0117
4	0.0076	0.0071
5	0.0270	0.0241
6	0.0041	0.0095
7	0.0095	0.0054
8	0.0036	0.0082
9	0.0036	0.0020
10	0.0040	0.0122
11	0.1123	0.2206



Landslide displacements detected with GPS periodic surveys

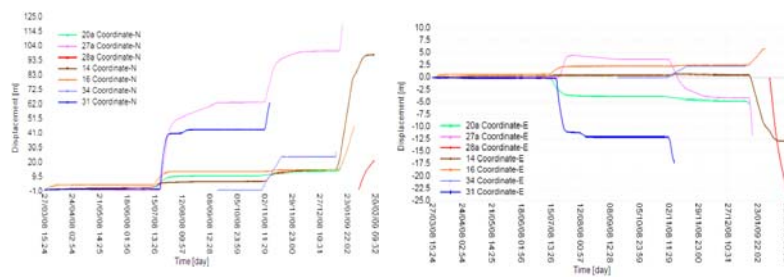


Continuous measurements

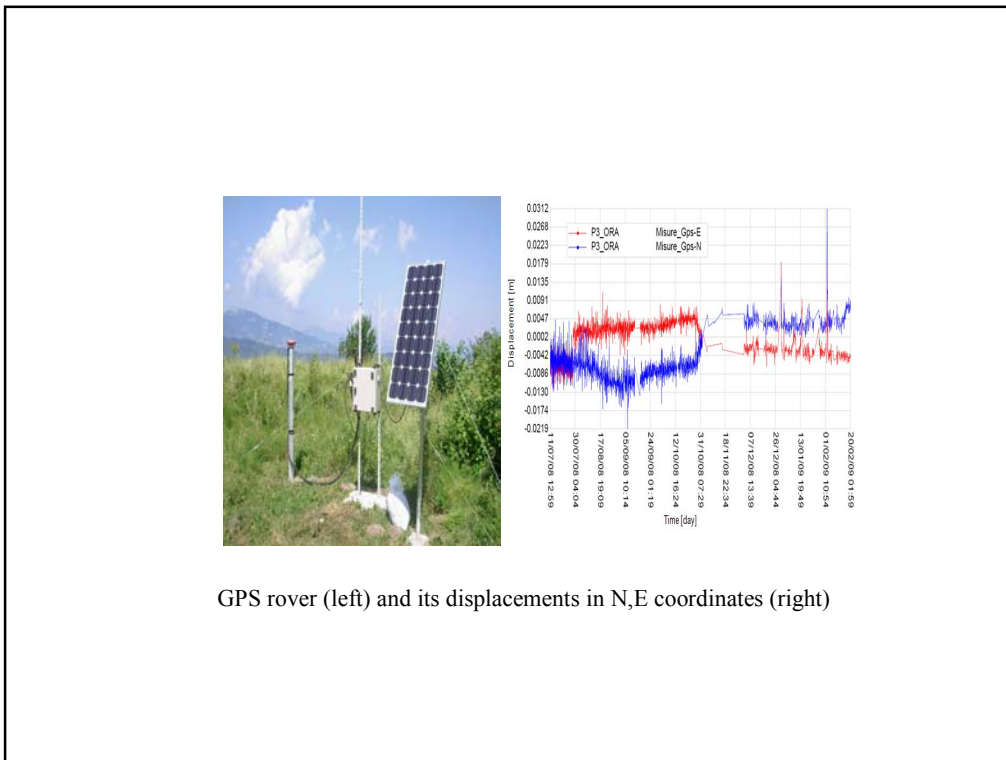
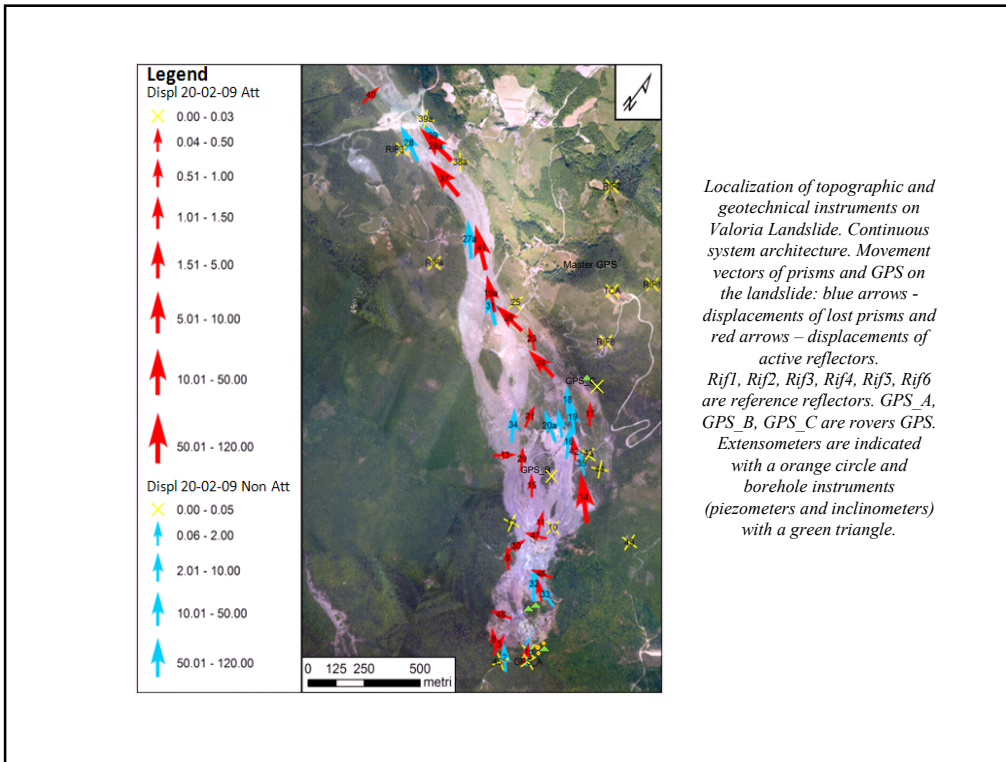
The robotic station measures about 45 reflectors every three hours (complete cycle- three layers)

GPS network is composed by the master GPS, located at Aree Vecchie, which is the reference station, and three single frequency GPS rovers, located in the landslide

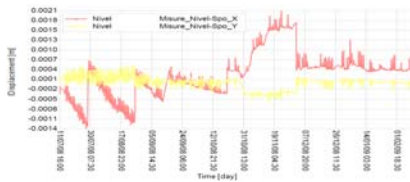
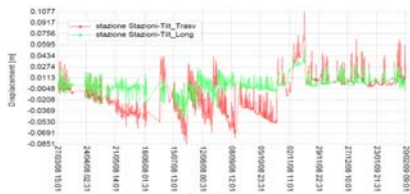
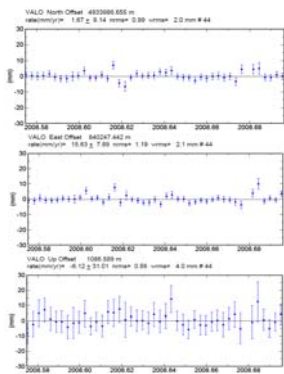
precision:
repeatability 3 mm per day in three coordinate movement detection



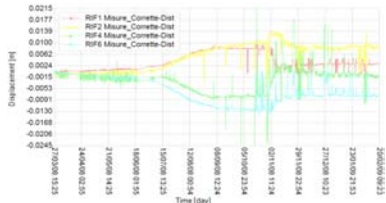
• Landslide movements by automatic TS during continuous measurements. Monitoring of coordinates N (left), E (right) of the most interesting reflectors.



Stability of master station



Tilt of robotic station (up) and measurements of bi-dimensional clinometer (bottom)



Variation in time of the distance from the robotic station and reference reflectors **Testo**

The cyclic movement of master station seems to be perfectly elastic, so it should not disturb data analysis and results interpretation

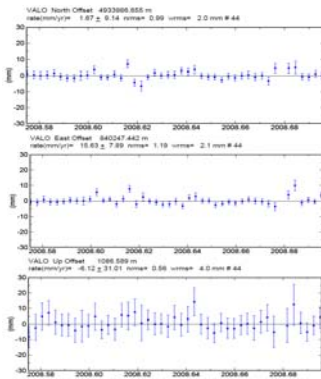
GPS master station in ITRF

-absolute coordinate- accuracy

- local stability

GPS data of the master permanent station, VALO, were archived and then processed in daily sessions (*Gamit/Globk* software) with respect to the EUREF permanent station, MOPS, located about at 50 km far away. GPS data archive computed was only 1.5 months long. VALO coordinates were computed and adjusted in the IGS05 reference frame with respect to the nearest EUREF permanent stations and by means of their published coordinates (MOPS, MEDI, PRAT, IENG, MESL).

In the near future, GPS data are going to be deeply studied and analysed so that it could be possible to find out an explanation to the area movement and compute the displacement velocity.



IBIS - Image by Interferometric Survey

MONITORAGGIO DELLA FRANA DI BOSCHI DI VALORIA (MO)

23-25 Febbraio 2009



landslide upper part

CONFIGURAZIONE E POSIZIONAMENTO

Parametri di Configurazione e Posizionamento

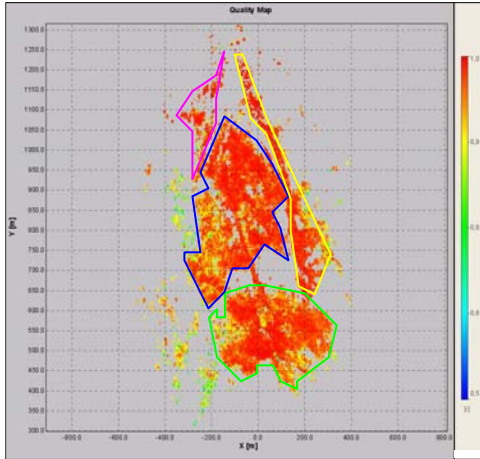
DISTANZA DAL VERSANTE	[m]	450-1300
APERTURA ORIZZONTALE ANTENNE	[grad]	38
RISOLUZIONE IN RANGE	[m]	0.5
RISOLUZIONE IN CROSS-RANGE	[mrad]	4.5
ACQUISIZIONI PER ORA	-	9
DURATA SESSIONE	[ore]	24

Sito di installazione

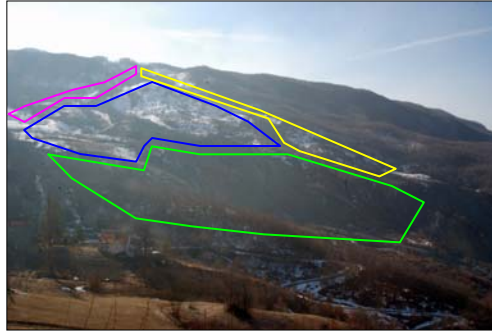


Quality map

Mappa di Qualità



Vista di IBIS-L sul versante



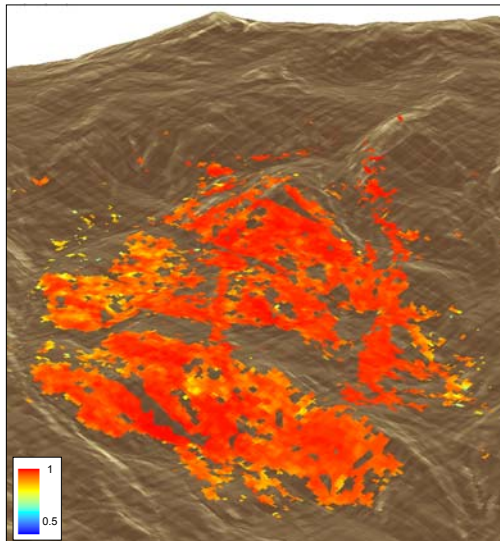
Sezione 1	Blue
Sezione 2	Magenta
Sezione 3	Green
Sezione 4	Yellow

MAPPA DI QUALITÀ

Geocoded Quality Map

Dalla mappa di qualità si evidenziano circa 40000 buoni punti di misura

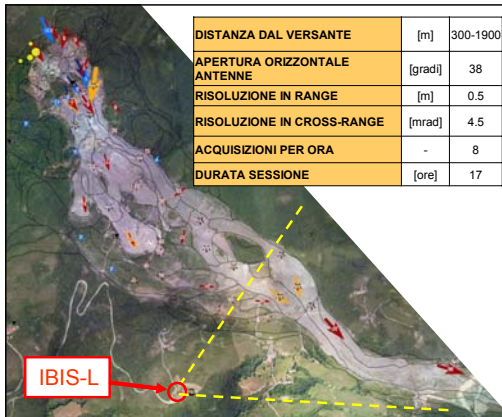
about 40 000 points are good Internal parameter >0.7 due to electromagnetic response



Landslide bottom part

CONFIGURAZIONE E POSIZIONAMENTO

Parametri di Configurazione e Posizionamento

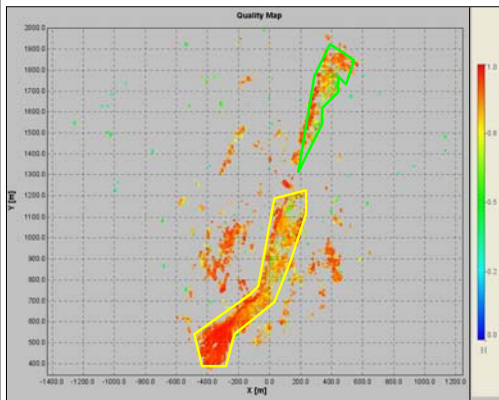


Sito di installazione



Quality Map

Mappa di Qualità



Vista di IBIS-L sul versante

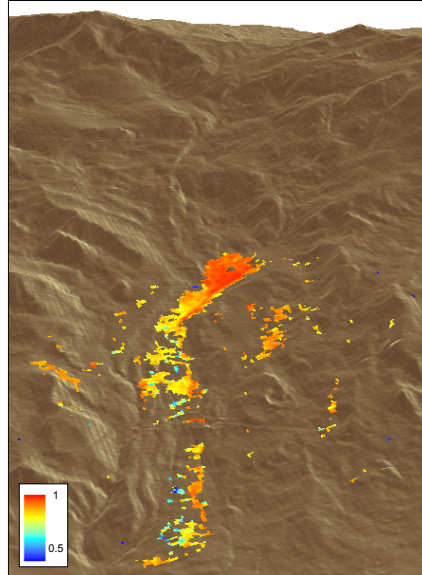


Sezione 1	
Sezione 2	

MAPPA DI QUALITÀ

Geocoded Quality Map

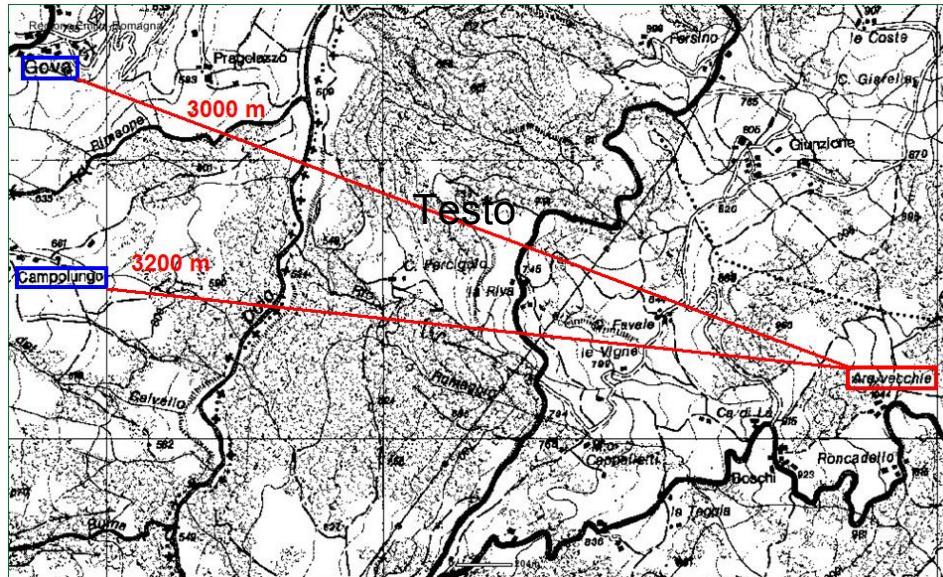
Dalla mappa di qualità si evidenziano circa 40000 buoni punti di misura



New TM30 Leica Automatic Station



very long range EDM



Conclusion

integrated system applied to Valoria landslide it has been possible to observe a big landslide in each part of it, even part of the landslide that are not accessible at all.

study and prediction

Most **significant displacements**, measured by periodic surveys, took place during **autumn 2007** : from **few cm to meter per day** at the toe.

During **2008** movement entity was **less important** than that of 2007, especially during spring and summer time, it should be related to drier climate in last year.

The **stability of station pilaster** used for Robotic instrument was controlled.

precision: monitoring and prevention till to 3 mm per day repeatability

completely automatic remote system : task the evaluation of the risk and to put in state of the **alert** authorities and then the Civil protection

promising test with **interferometry terrestrial radar**

Leica TM30 - accurate and very quick (three times rather than Leica TCA2003)