Part II: Examples in the Alps

INTEGRATION OF MONITORING SYSTEMS
CORVARA LANDSLIDE (SOUTH TYROL)

By: Alessandro Corsini *
(DSCG – UniMoRe)

Partnership
Province of BZ (RIP.11, RIP.30, RIP32)
Municipality of Corvara in Badia
DSCG - UniMoRe
IRPI-CNR Padua
EURAC-Bz

Data & figures acknowledgements
Dr. M. Mulas (DSCG - UniMoRe)
Dr. G. Marcato (IRPI-CNR Padua)
Dr. G. Chinellato (EURAC-Bz)

** Associate Professor Engineering Geology*
Department of Chemical and Geological Sciences
University of Modena and Reggio Emilia
alessandro.corsini@unimore.it

Site location

Site location

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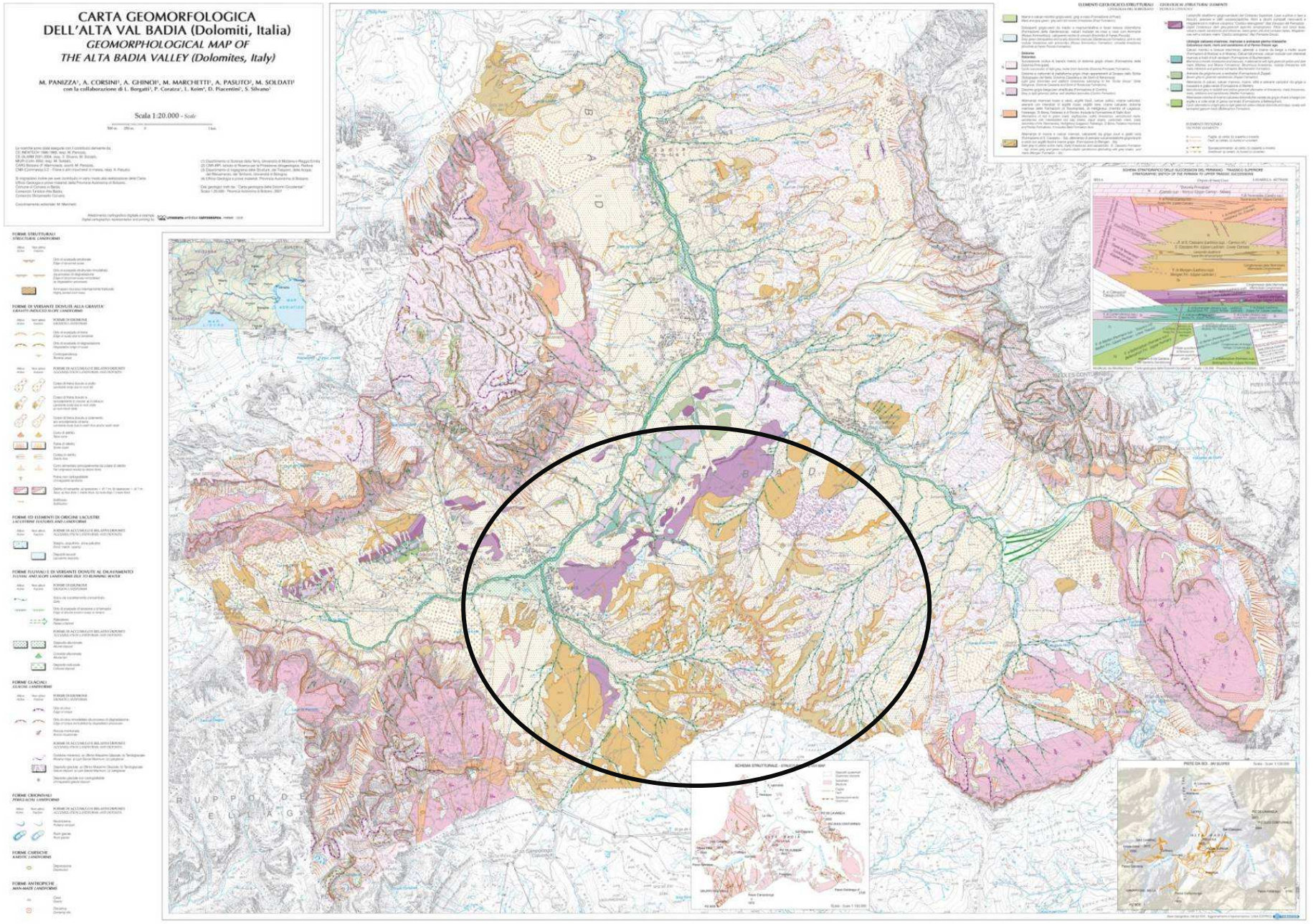
Geological & Geomorphological setting



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Hazard & Risk

today

mid XX century

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Hazard & Risk

Holocene slope evolution

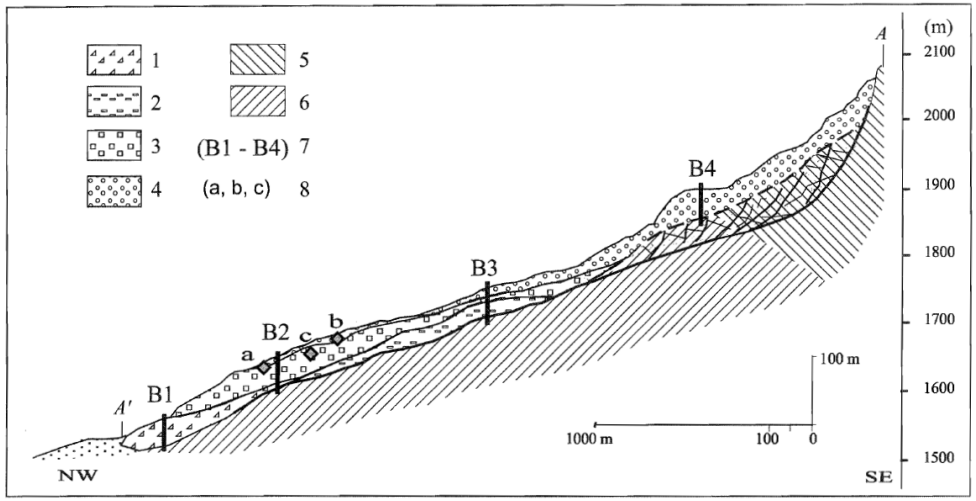

FIG. 5 - Interpreted chronological cross section of the Corvara landslide. Legend: 1 - events ca. 10.000 cal. yr BP (provenance Cianaciai: Arlara landslide; see fig. 3); 2 - events ca. 9000 cal. yr BP (provenence Freines; see fig. 3); 3 - events ca. 5000-4000 cal. yr BP (provenance Freines and Bicocca; see fig. 3); 4 - events ca. 3000-2000 cal. yr BP (provenance Bicocca; see fig. 3); 5 - La Valle Formation; 6 - S. Cassiano Formation; 7 - boreholes (see fig. 3); 8 - tree trunks collected in the Rutorto river scarp (see fig. 3).

ALESSANDRO CORSINI (*), MAURO MARCHETTI (*) & MAURO SOLDATI (*)

HOLOCENE SLOPE DYNAMICS IN THE AREA OF CORVARA IN BADIA (DOLOMITES, ITALY): CHRONOLOGY AND PALEOCLIMATIC SIGNIFICANCE OF SOME LANDSLIDES

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Catena 55 (2004) 141–161
CATENA
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Landslides and climate change in the Italian Dolomites since the Late glacial

Mauro Soldati[a,*], Alessandro Corsini[a], Alessandro Pasuto[b]
[a]Dipartimento di Scienze della Terra, Università degli Studi di Modena e Reggio Emilia, Largo S. Eufemia 19, 41100 Modena, Italy
[b]Istituto di Ricerca per la Protezione Idrogeologica (IRPI)—C.N.R., Corso Stati Uniti 4, 35127 Padova, Italy

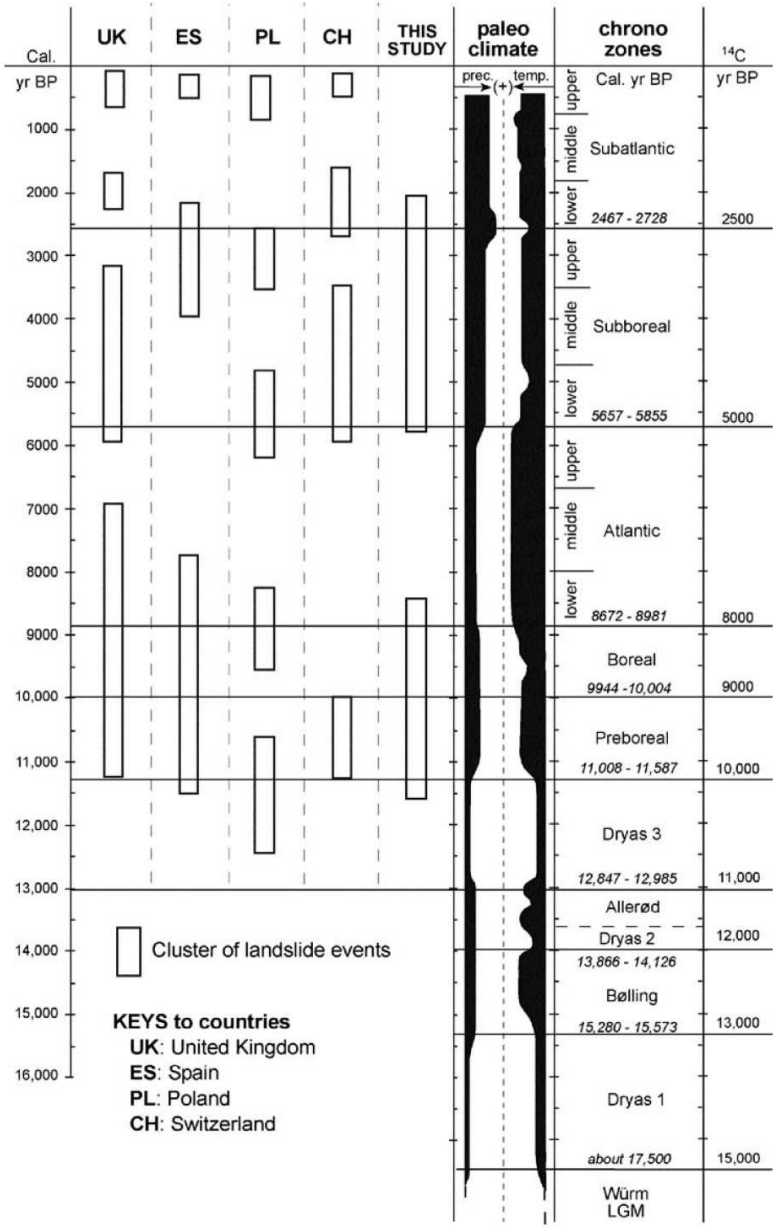

Fig. 6. Temporal distribution of landslide activity since the Late glacial in different parts of Europe and comparison with paleoclimate trends.

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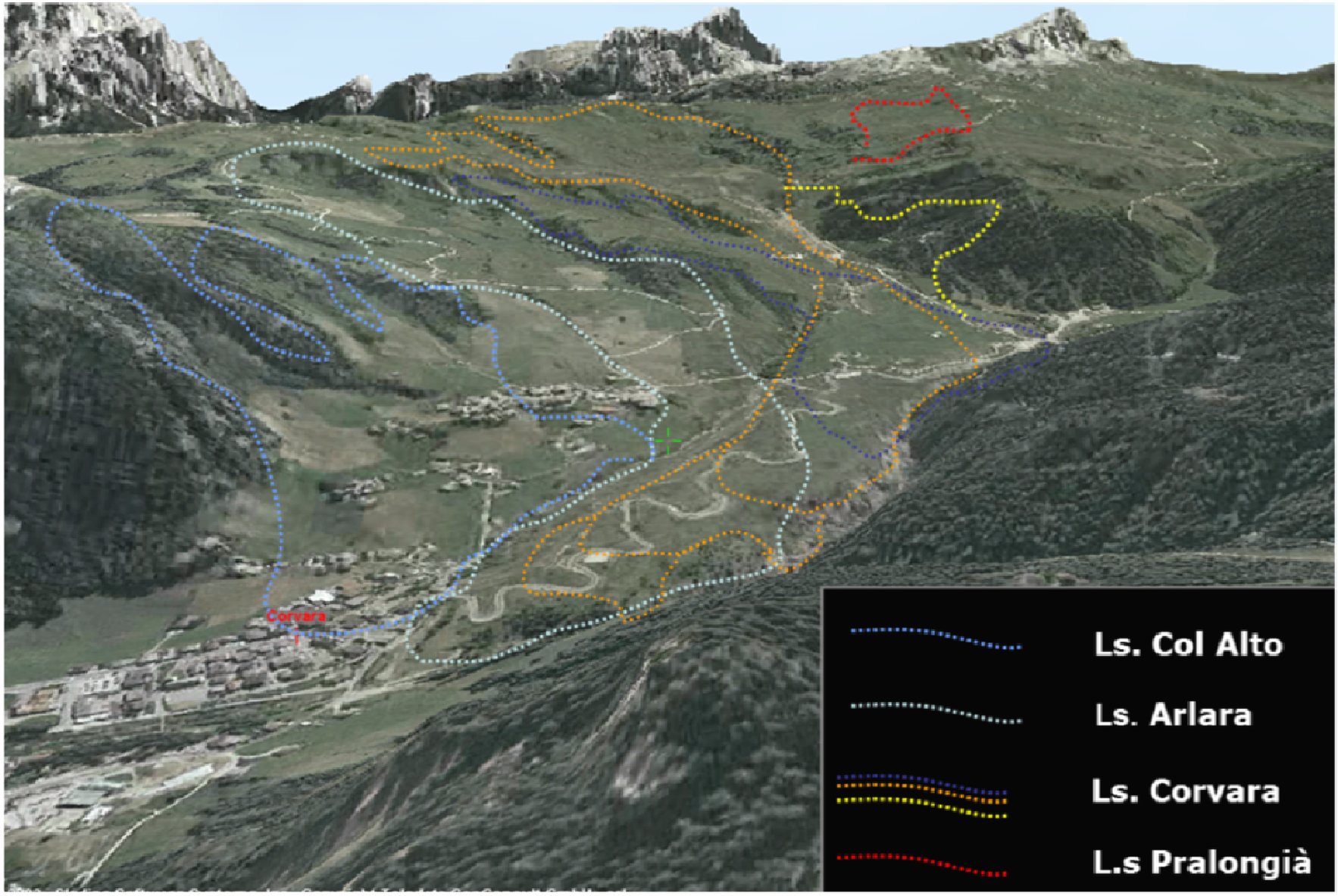
Holocene slope evolution

Radiocarbon dating in Alta Badia; data calibrated with Radiocarbon Calib. Program 4.1 by Stuiver and Reimer (1993), data set by Stuiver et al. (1998)

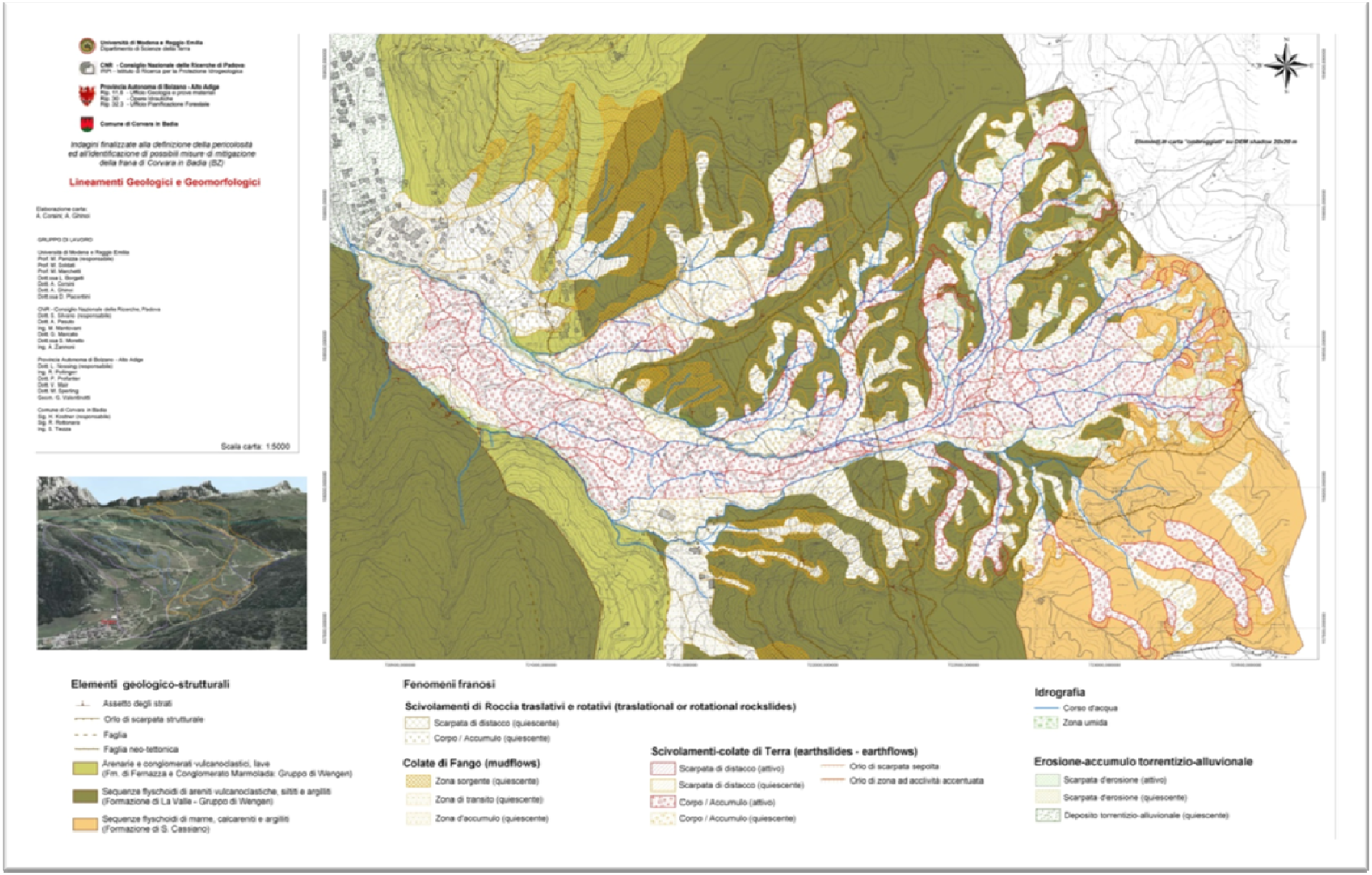
ID	Landslide name	Landslide type	Sample code	Sample type	Site of collection	Depth (m)	Conventional age (^{14}C year BP)	Calendar age 2σ (cal year BP)	Paleoclimatic significance
(A)									
12	Corvara	rotational rock slide–earth flow	B-112032	wood	borehole (C1)	25.70	8820 ± 50	10,152–9632	high
12	Corvara	rotational rock slide–earth flow	B-112033	wood	borehole (C1)	26.40	8560 ± 90	9709–9334	high
12	Corvara	rotational rock slide–earth flow	B-112031	organic sediment	borehole (C3)	22.70	7920 ± 70	9009–8543	low
12	Corvara	rotational rock slide–earth flow	B-154704	wood	borehole (C6)	69.70	8020 ± 60	9030–8650	high
12	Corvara	earth flow	Ki-9233	wood	borehole (C6)	47.50	5543 ± 72	6471–6199	high
12	Corvara	earth flow	Ki-9230	wood	borehole (C6)	19.10	4616 ± 64	5575–5052	high
12	Corvara	earth flow	B-112029	wood	borehole (C2)	7.50	4260 ± 70	5025–4575	high
12	Corvara	earth flow	B-112030	wood	borehole (C2)	20.00	4260 ± 70	5025–4575	high
12	Corvara	earth flow	Ki-9234	tree trunk	erosion scarp	8.00	3888 ± 64	4513–4094	high
12	Corvara	earth flow	B-105976	tree trunk	erosion scarp	6.00	3830 ± 60	4417–3999	high
12	Corvara	earth flow	B-105977	tree trunk	erosion scarp	4.50	2860 ± 60	3207–2792	high
12	Corvara	earth flow	B-93975	tree trunk	erosion scarp	5.00	2490 ± 60	2750–2352	high
12	Corvara	earth flow	B-112034	wood	borehole (C4)	37.40	2260 ± 50	2351–2129	high
13	Arlara	rotational rock slide–earth flow	B-105975	tree trunk	erosion scarp	3.5	6870 ± 50	7789–7592	high

M. Soldati et al. / Catena 55 (2004) 141–161

Holocene slope evolution



State of activity



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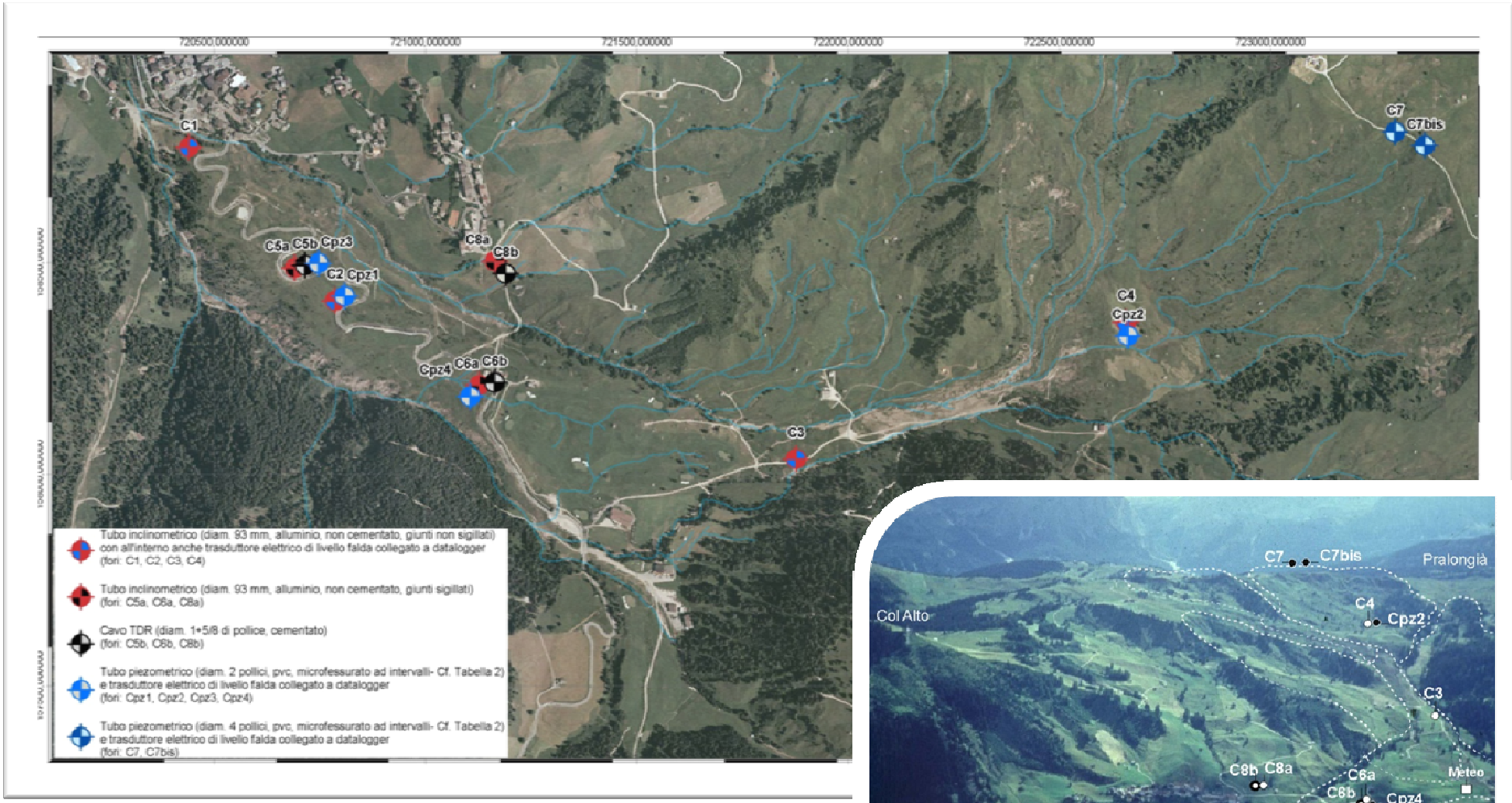
Boreholes monitoring 1997-2006



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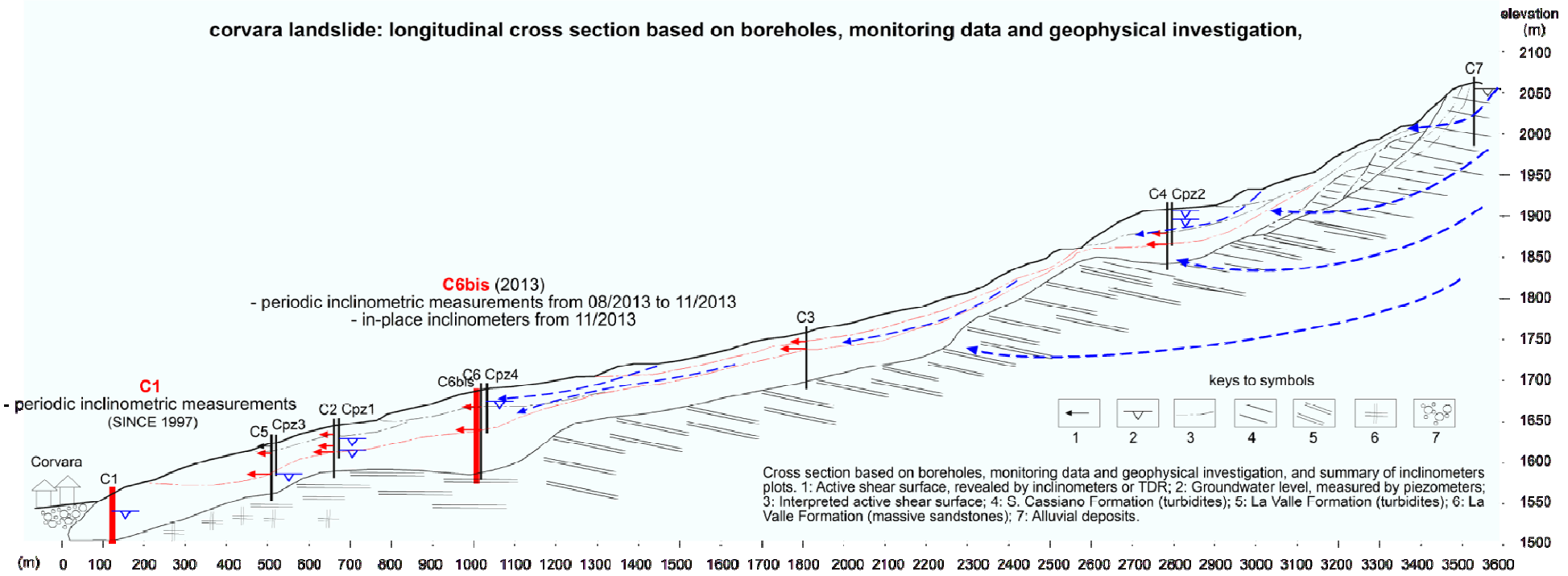
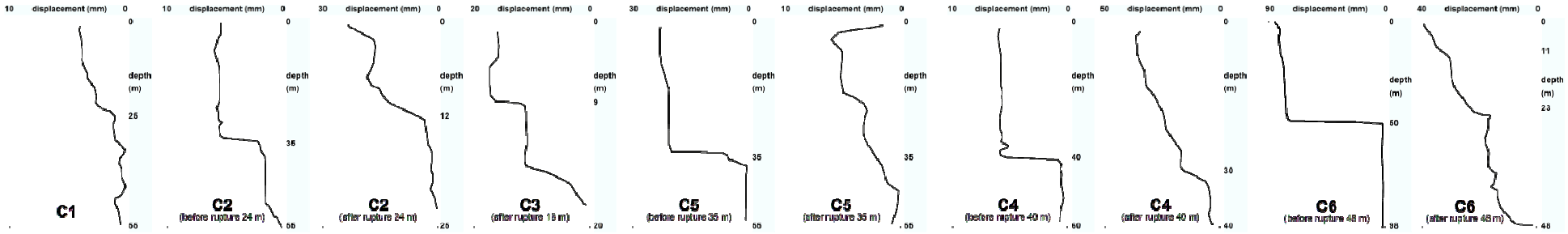
Boreholes monitoring 1997-2006



SINTHESIS OF PERIODIC INCLINOMETRIC MEASUREMENTS 1997 - 2004



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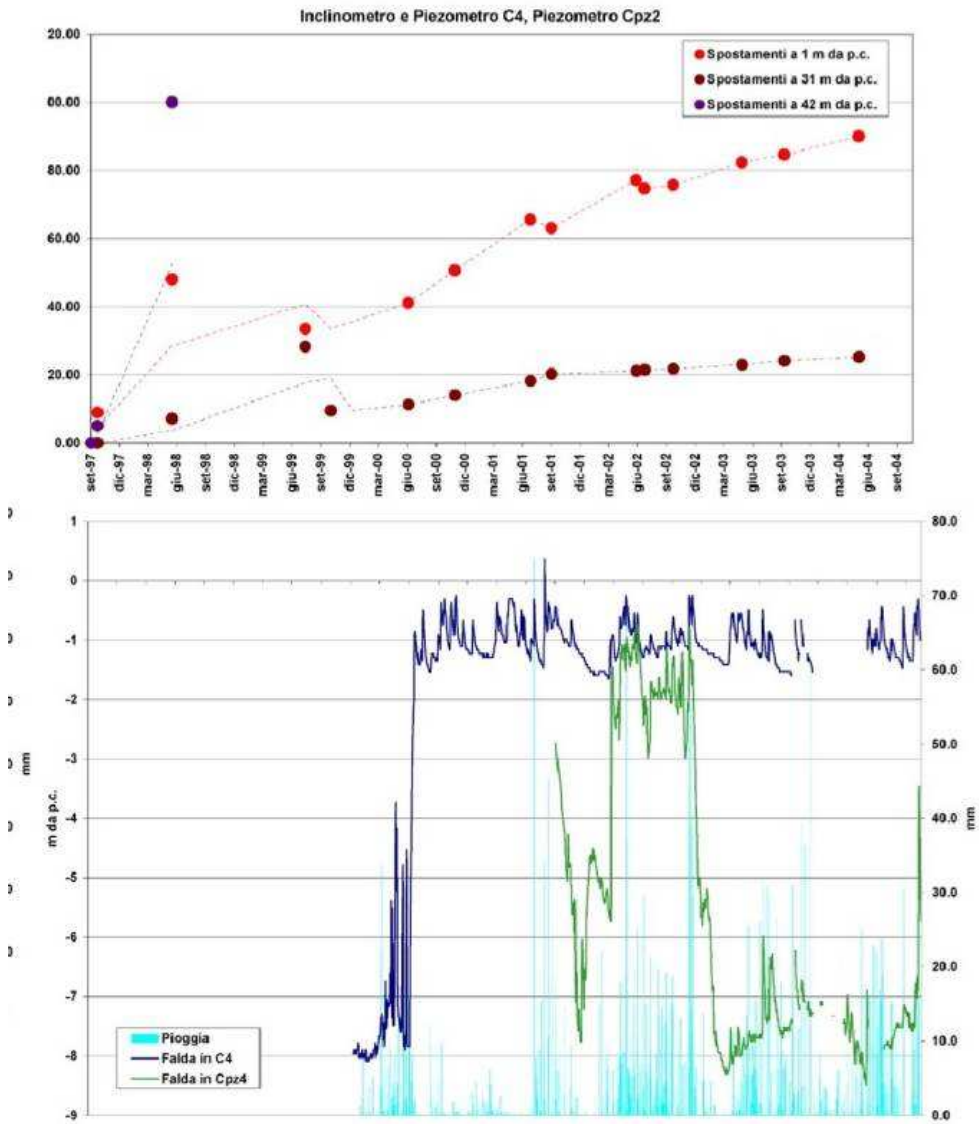
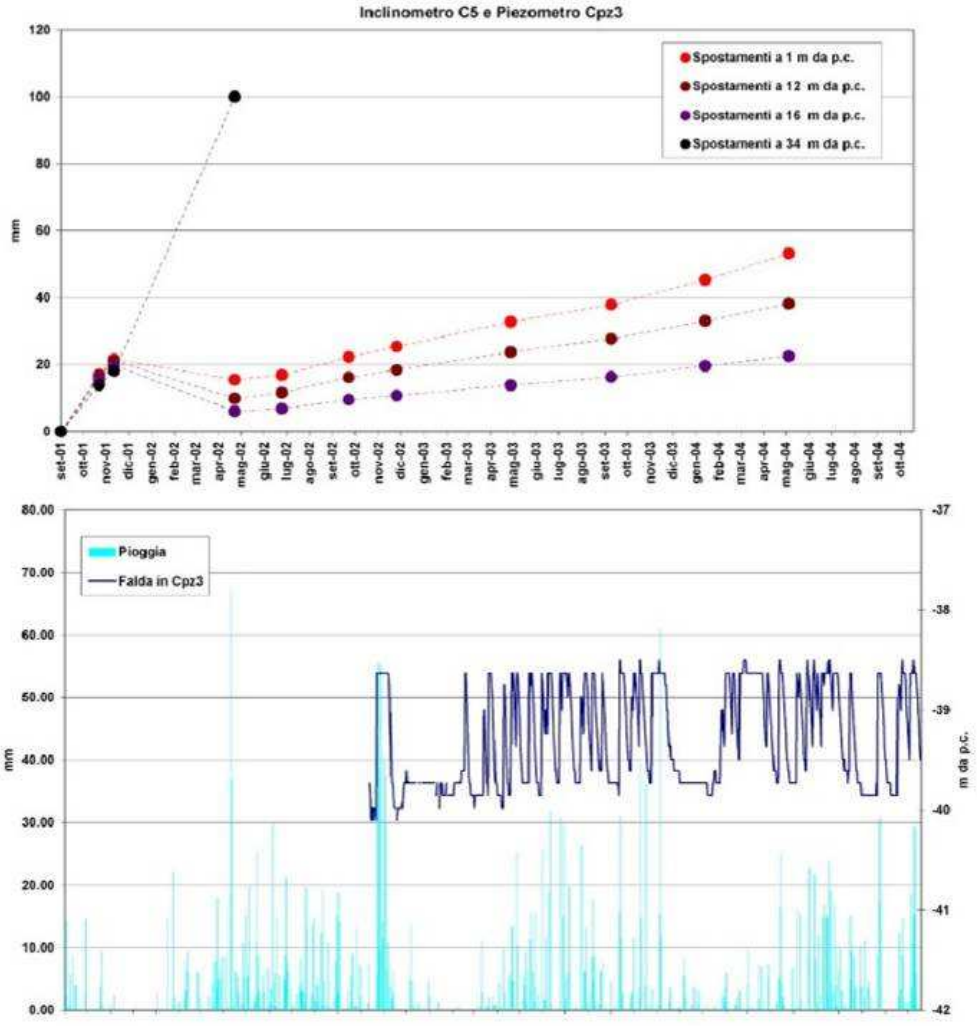
Boreholes monitoring 1997-2006





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Boreholes + seismic + geoelectric surveys 1997-2006

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Dipartimento di Scienze della Terra

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IRPI - Istituto di Ricerca per la Protezione Idrogeologica

Provincia Autonoma di Bolzano - Alto Adige
Rip. 11.6 - Ufficio Geologia e prove materiali
Rip. 30 - Opere Idrauliche
Rip. 32.3 - Ufficio Pianificazione Forestale

Comune di Corvara in Badia

Indagini finalizzate alla definizione della pericolosità ed all'identificazione di possibili misure di mitigazione della frana di Corvara in Badia (BZ)

Bilancio di Massa del Corpo di Frana

Elaborazione carta e grafici:
A. Corsini; D. Piacentini; L. Borgatti; S. Moretto

GRUPPO DI LAVORO

Università di Modena e Reggio Emilia
Prof. M. Panizza (responsabile)
Prof. M. Soldati
Prof. M. Marchetti
Dott.ssa L. Borgatti
Dott. A. Corsini
Dott. A. Ghinoi
Dott.ssa D. Piacentini

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Dott. A. Pasuto
Ing. M. Mantovani
Dott. G. Marcato
Dott.ssa S. Moretto
Ing. A. Zannoni

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Geom. G. Valentinotti

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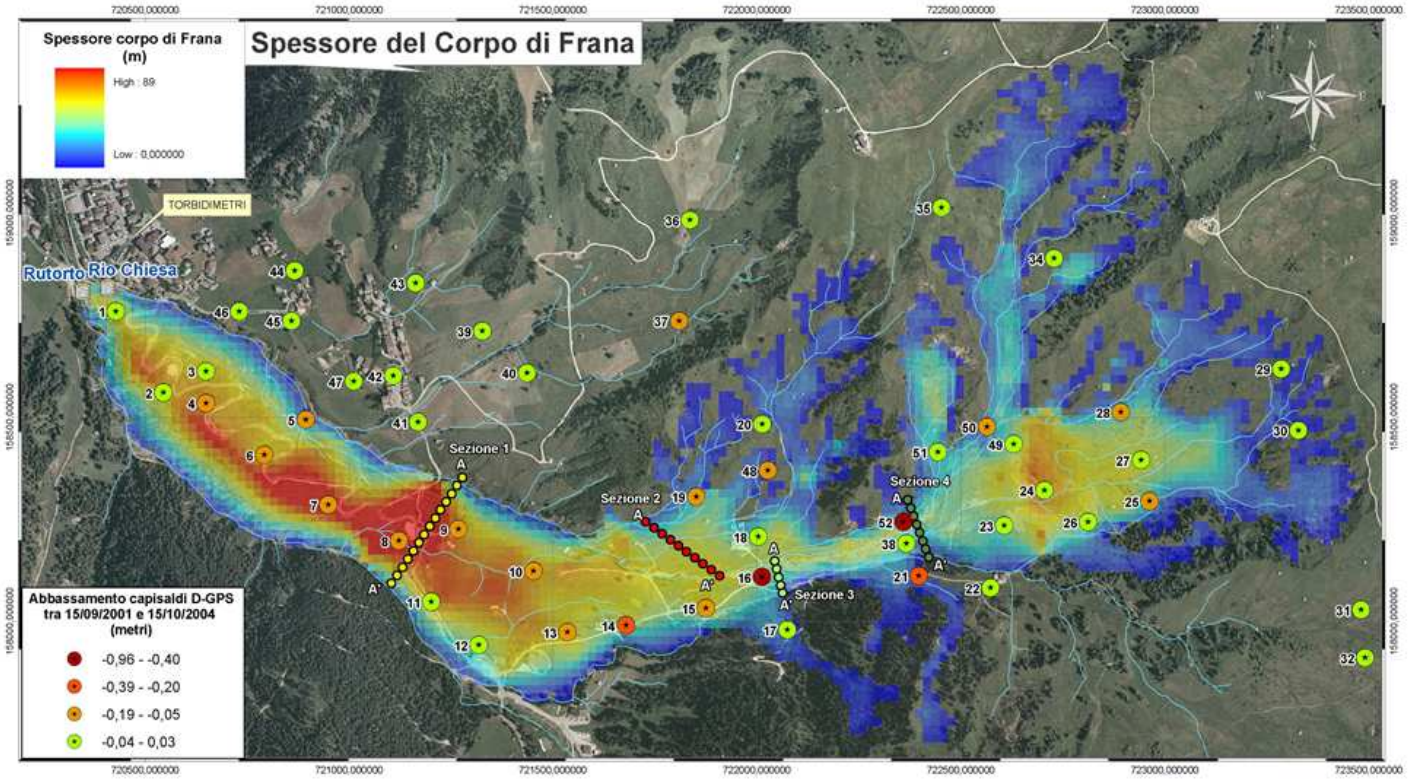

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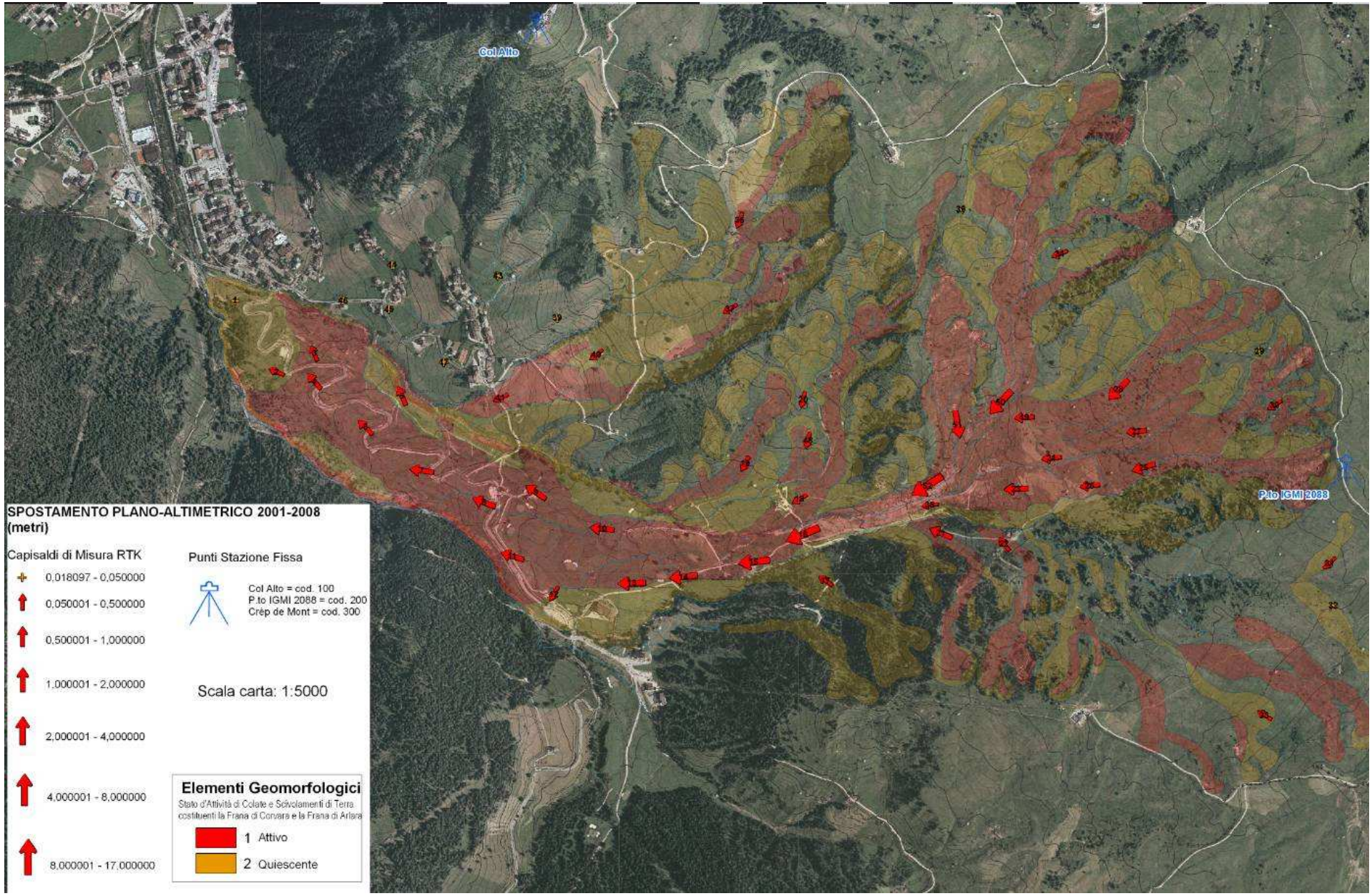
GPS monitoring 1997-2008 [total displacement (m)]



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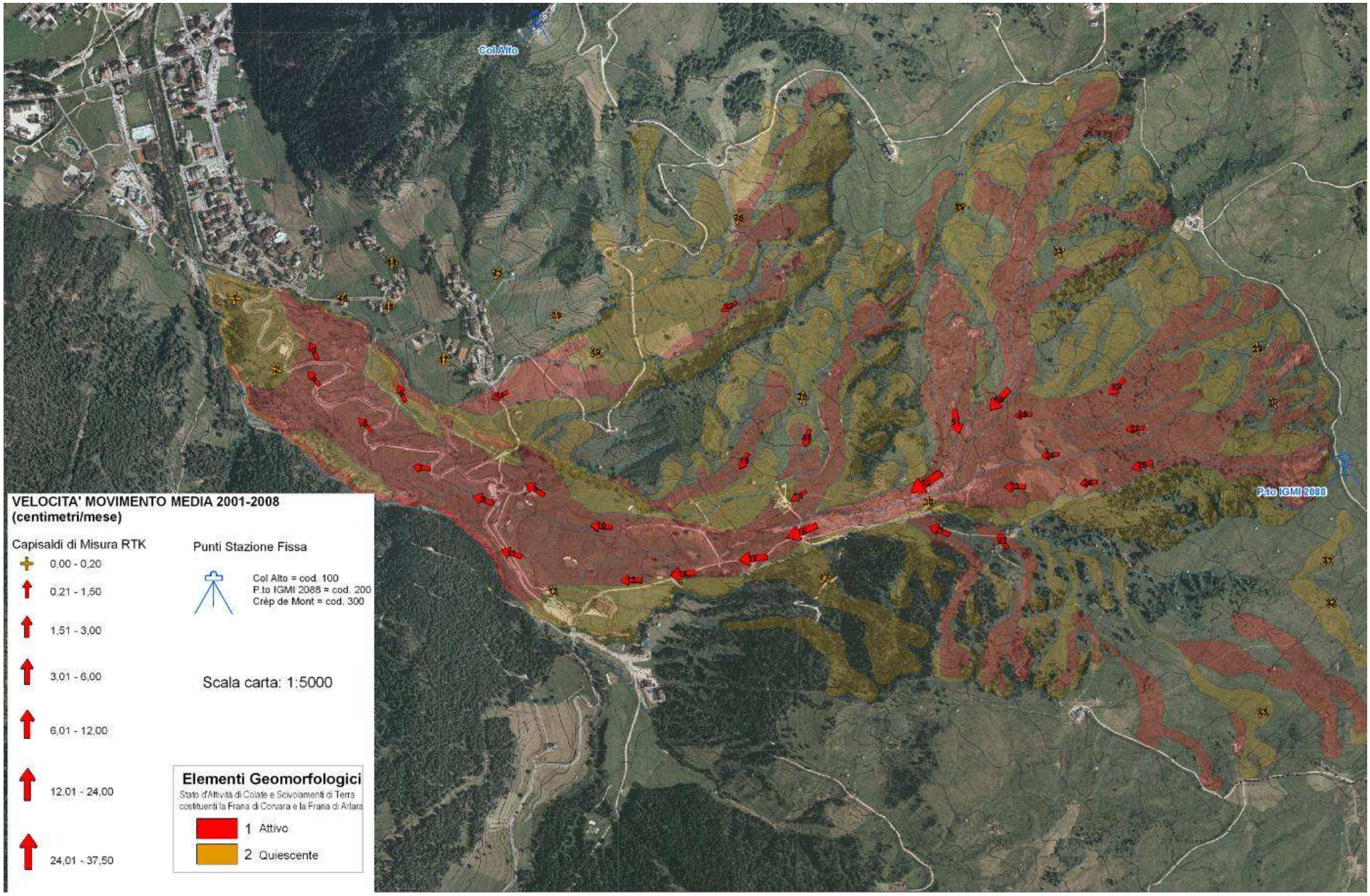
GPS monitoring 1997-2008 [mean velocity cm/month)]



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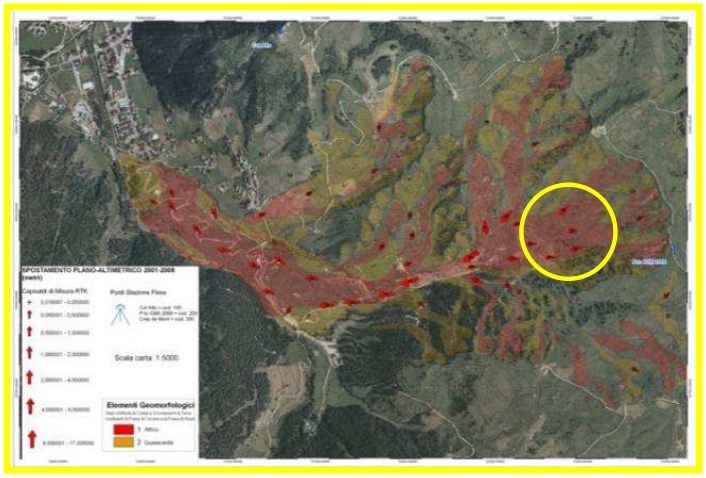
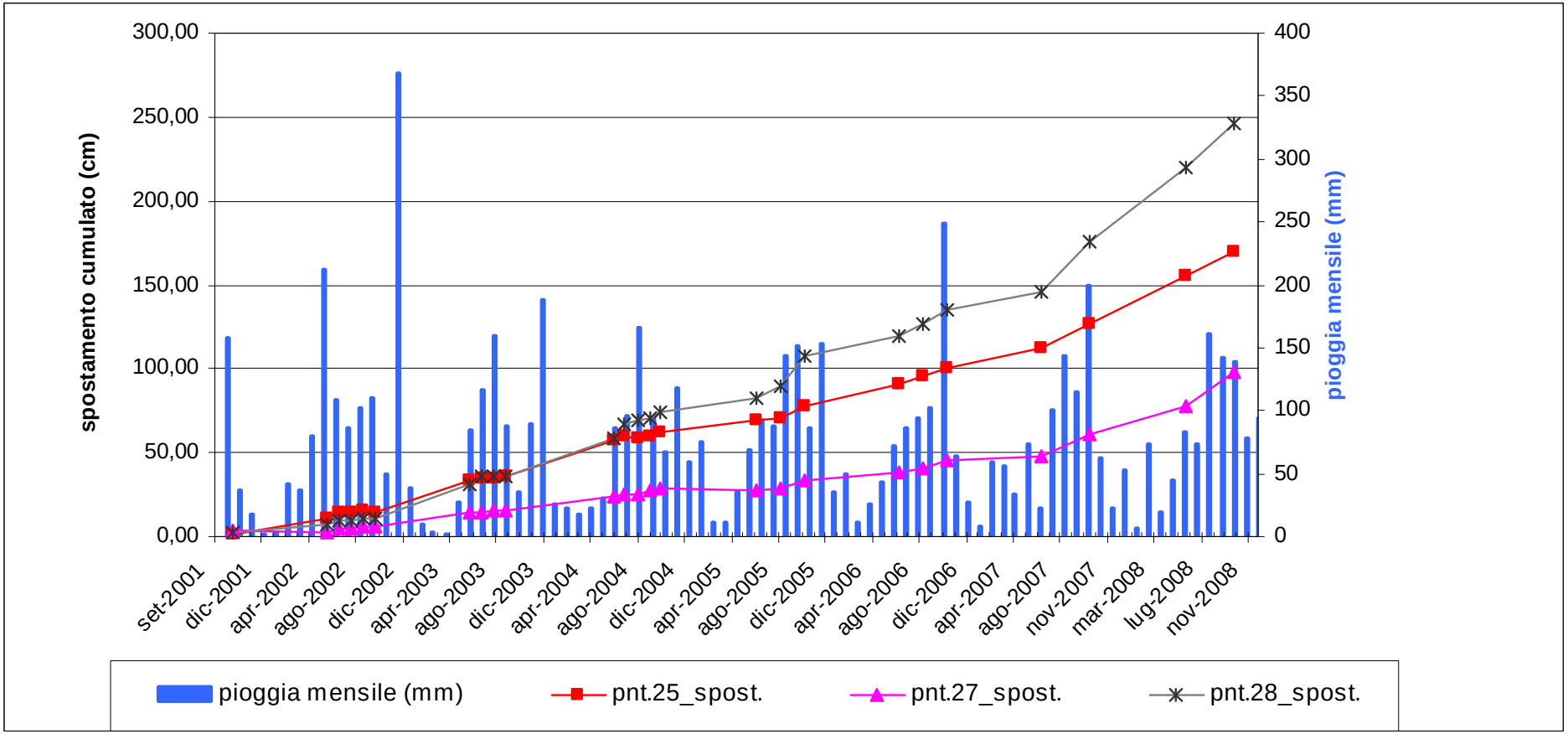
GPS monitoring 1997-2008 [displacement (cm)]



AREA SORGENTE S3:
SETTORE MEDIO-ALTO
Capisaldi n° 25 – 27 – 28



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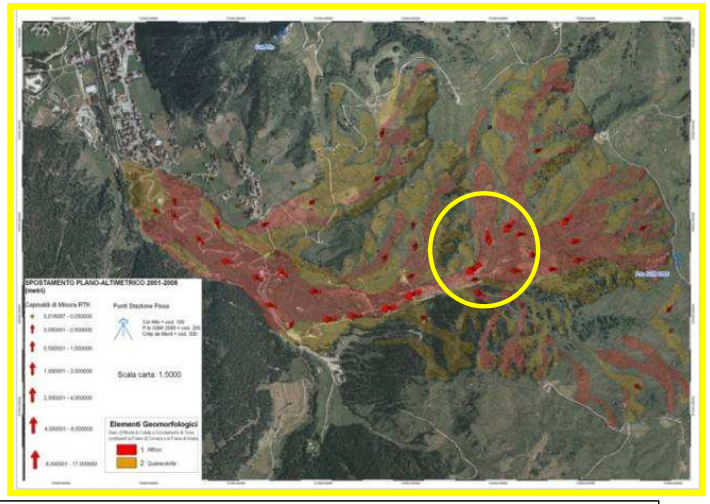
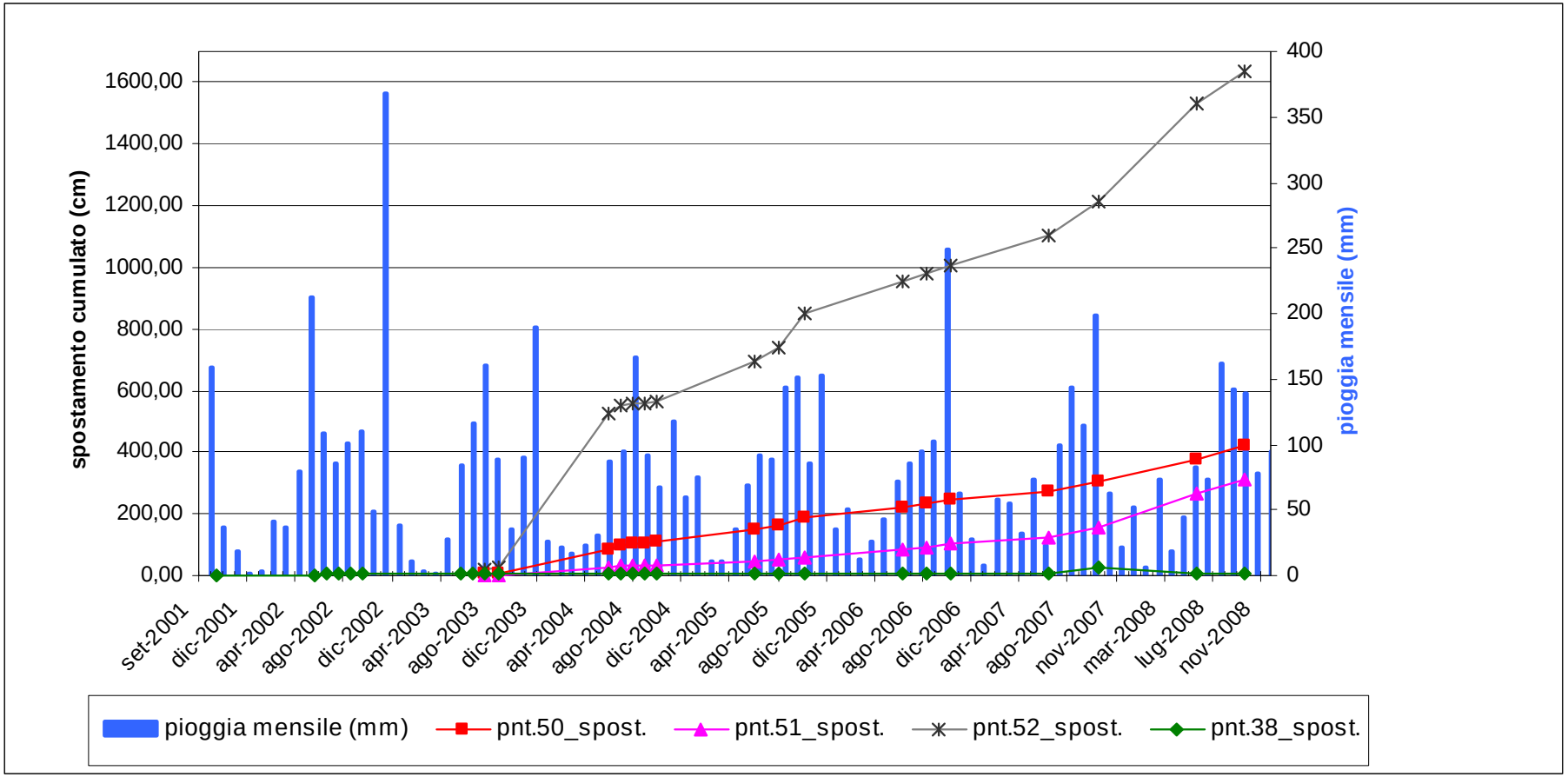
GPS monitoring 1997-2008 [displacement (cm)]



ZONA SORGENTE S2: SETTORE BASSO E ZONA DI TRASPORTO: SETTORE ALTO
Capisaldi n° 38 – 50 – 51 – 52



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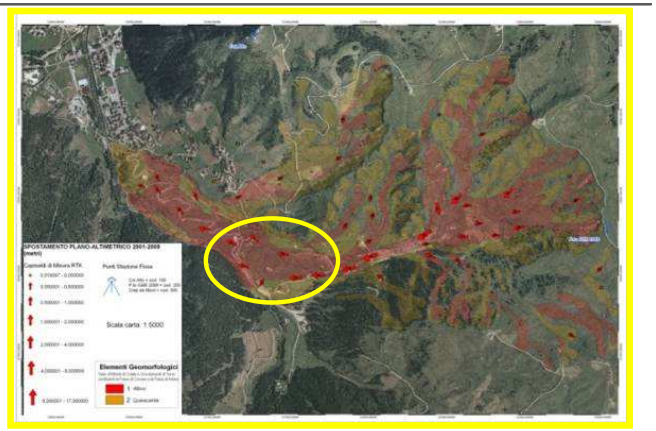
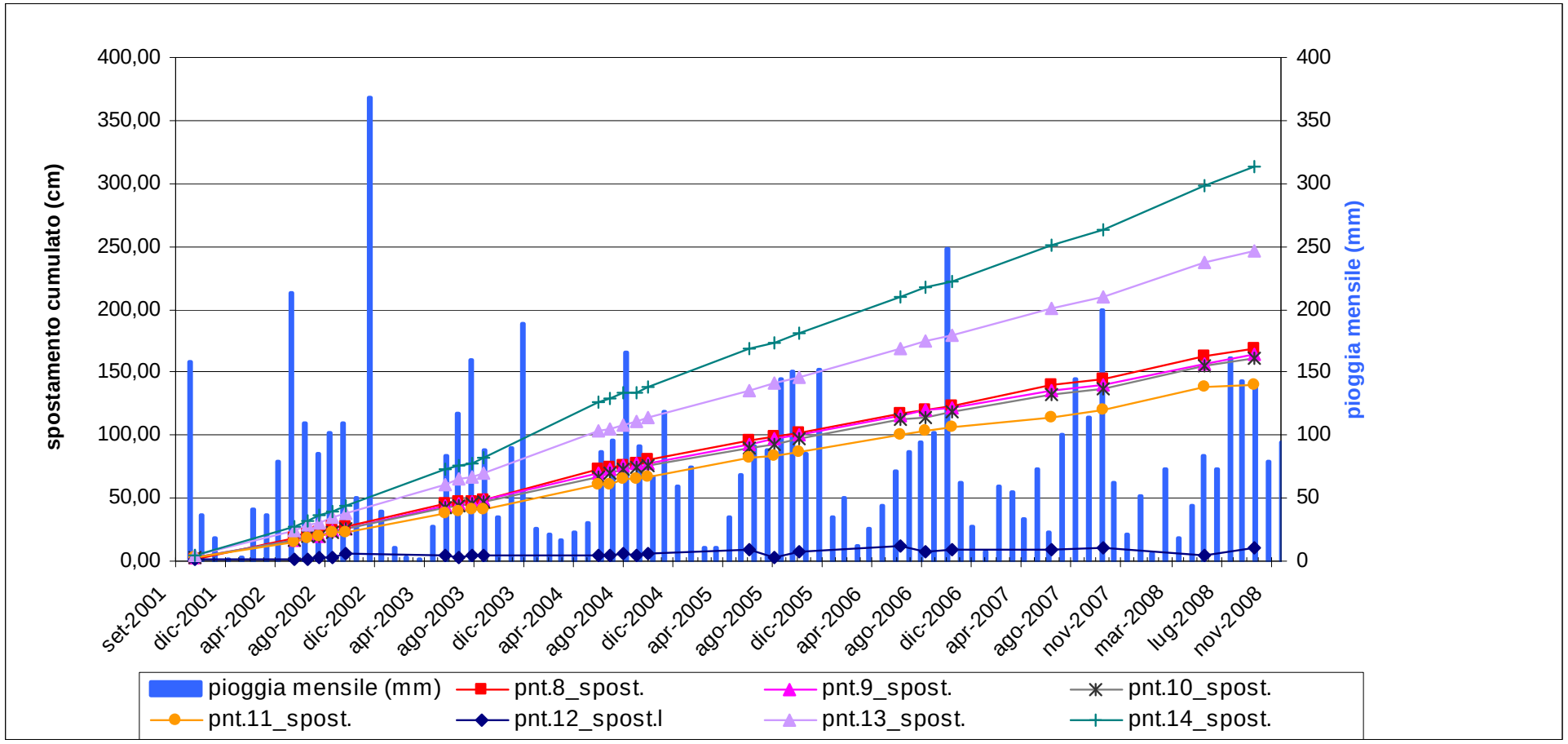
GPS monitoring 1997-2008 [displacement (cm)]



ACCUMULO FRANA:
SETTORE ALTO
Capisaldi n° 8 – 9 – 10 – 11 – 12 – 13 – 14



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SUPPORT OF SATELLITE RADAR TO HAZARD ZONE MAPPING IN THE ITALIAN ALPS

Belitz, K.[1], Corsini, A.[4], Mair, V.[2], Strozzi, T[3], Wegmüller, U. [3], Zilger, J. [1]

[1] Teledata GeoConsult GmbH-srl
Siemenszstraße 19, 39100 Bozen - Bolzano, Italy, Email: k.belitz@td-geoconsult.com
[2] Amt für Geologie und Baustoffprüfung, Autonome Provinz Bozen-Südtirol
Eggentaler Straße 48, 39053 Kardaun - Cardano, Italy, Email: volkmar.mair@provinz.bz.it
[3] Gamma Remote Sensing AG
Thunstraße 130, 3074 Muri BE, Switzerland, Email: wegmuller@gamma-rs.ch
[4] Dipartimento di Scienze della Terra, Università degli Studi di Modena e Reggio Emilia
Largo S. Eufemia 19, 41100 Modena, Italy, Email: allecors@unimo.it

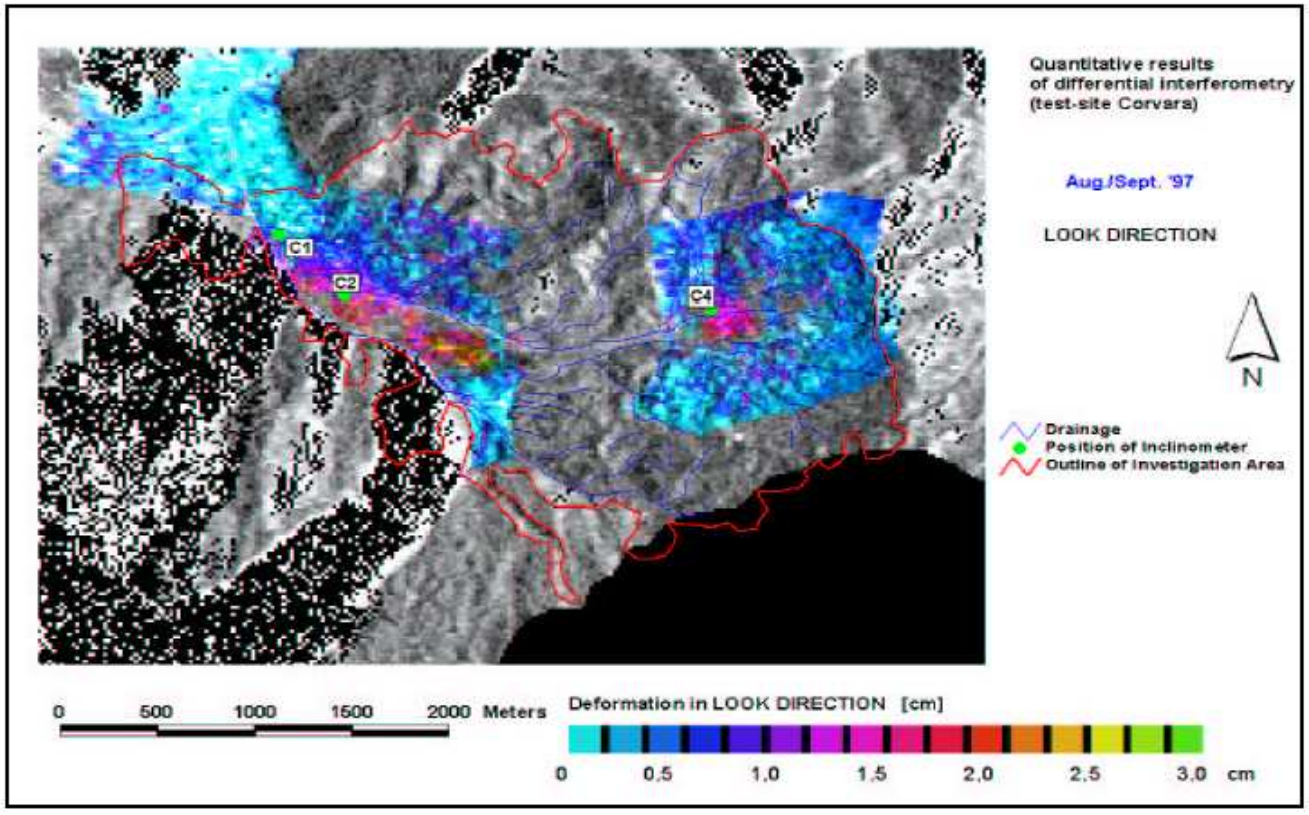

Fig. 4. Quantitative results of DInSAR in look direction, Aug-Sept 1997.

ERS dataset
(C-band)

Proc. of FRINGE 2003 Workshop, Frascati, Italy,
1 – 5 December 2003 (ESA SP-550, June 2004) 12_belitz

Original Paper

Landslides (2005) 2: 193–201
DOI: 10.1007/s10346-005-0003-2
Received: 4 April 2005
Accepted: 10 June 2005
Published online: 28 September 2005
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Tazio Strozzi · Paolo Farina · Alessandro Corsini · Christian Ambrosi · Manfred Thüring · Johannes Zilger · Andreas Wiesmann · Urs Wegmüller · Charles Werner

Survey and monitoring of landslide displacements by means of L-band satellite SAR interferometry

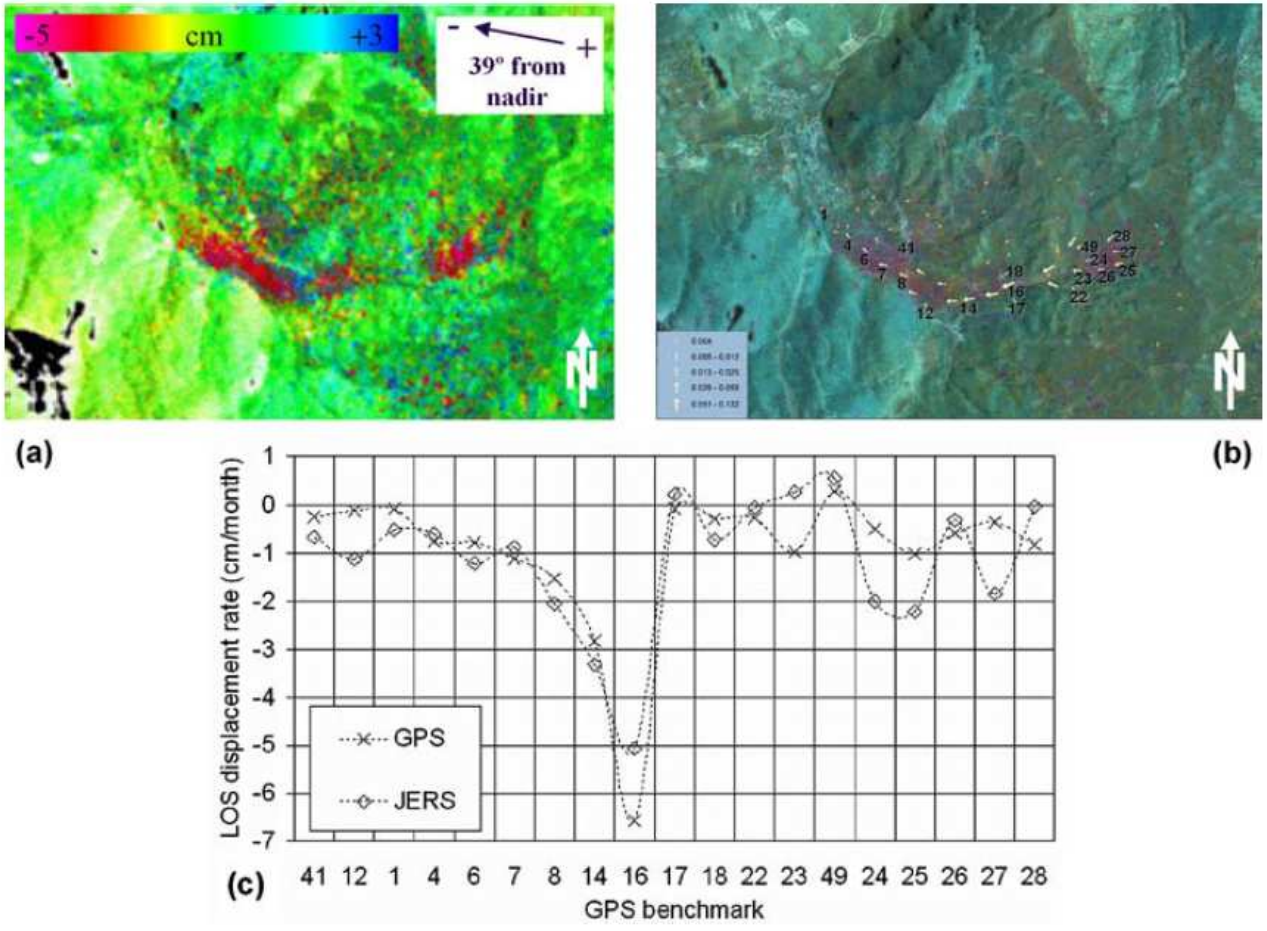


Fig. 2 Corvara in Alta Val Badia. **a** Geocoded JERS displacement map in the line-of-sight direction for the time period 2 July to 28 September 1998 (88 days, 217 m), **b** GPS measurement rates (in meter/month from September 2001 to September 2003) superimposed on the interferogram of Fig. 1a, orthophotograph in the background, **c** Comparison between measurement rates in the JERS line-of-sight (LOS) direction of selected GPS benchmarks and the corresponding pixels in the JERS displacement map of Fig. 2a. See Fig. 2b for the location of the GPS benchmarks

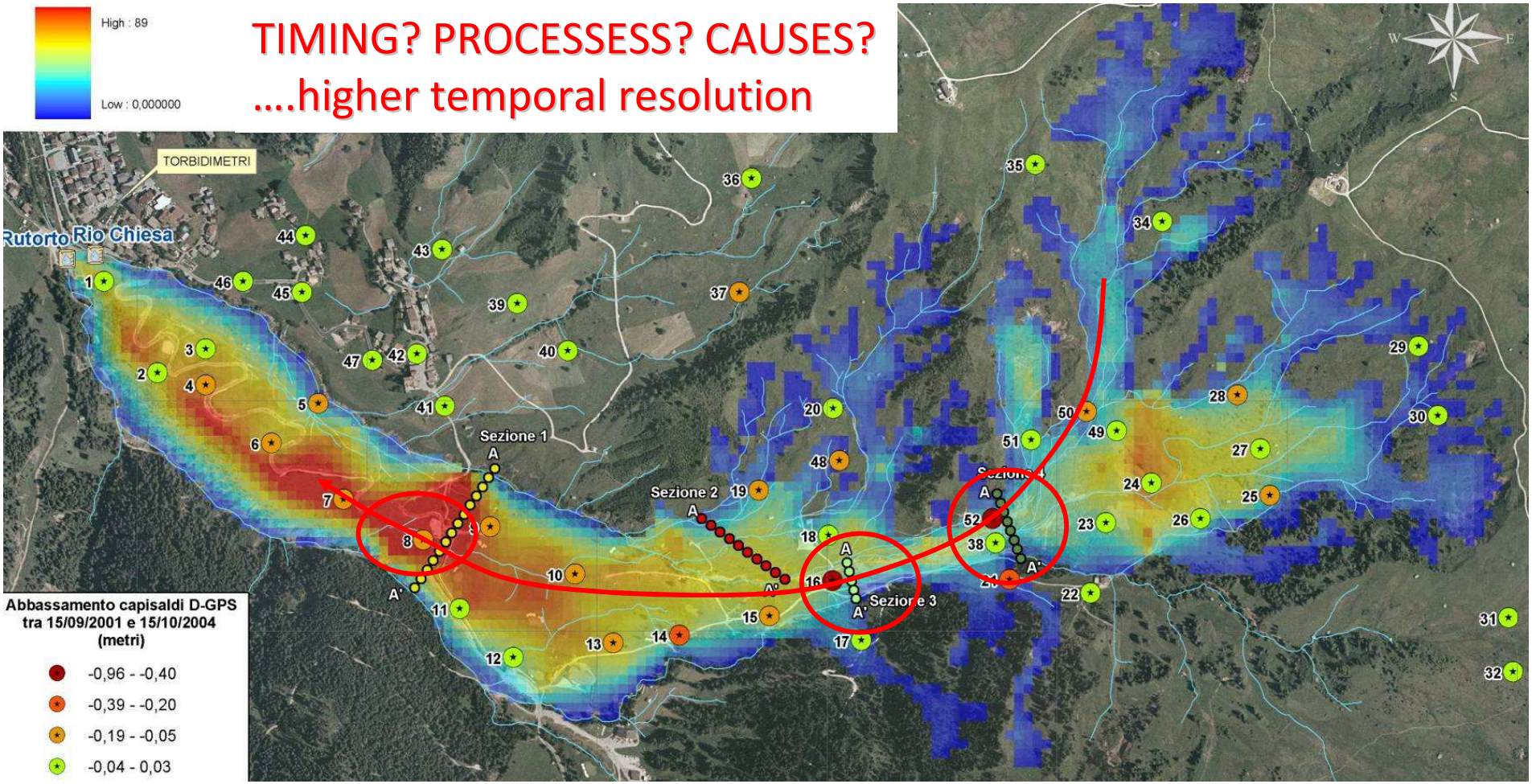
JERS dataset
(L-band)

…was there more to be found out?

Mass balance 1997-2006

ID_SEZIONE	AREA TOTALE (m2)	AREA STIMATA ATTIVA (da inclinometri o altre stime) (m2)	VELOCITA' MEDIA AREA ATTIVA (da dati GPS) (m/anno)	VOLUME TRANSITATO ANNUALMENTE (m3/anno)
4	2349	1174 (stima al 50%)	2,40 (media tra GPS # 52, 51, 50)	2818
3	1900	1555 (da inclinometro C3)	1,68 (GPS # 16)	2612
1	17122	11551 (da inclinometro C6)	0,24 (GPS # 8, 9, 11)	2784

TIMING? PROCESSESS? CAUSES?
….higher temporal resolution



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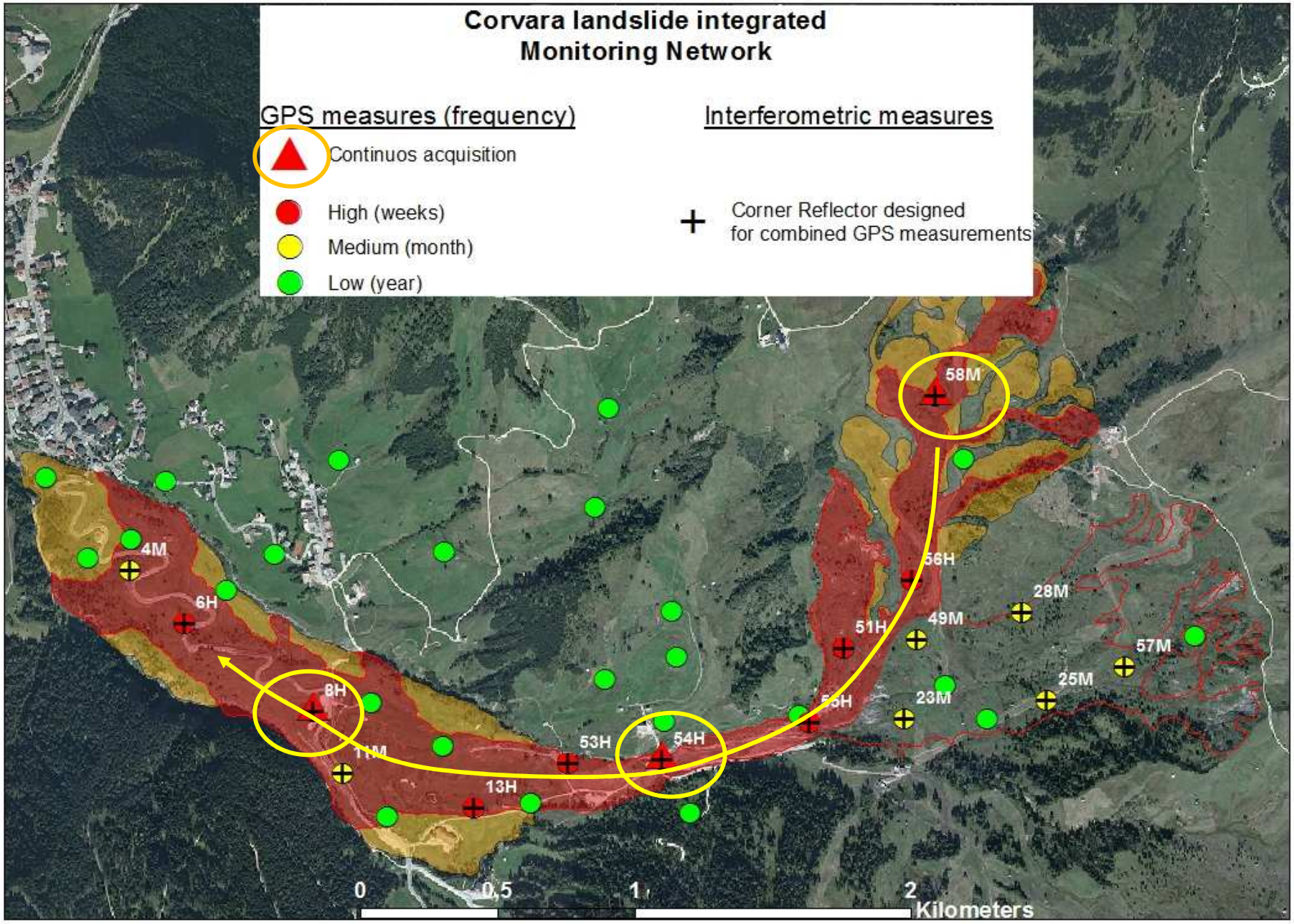
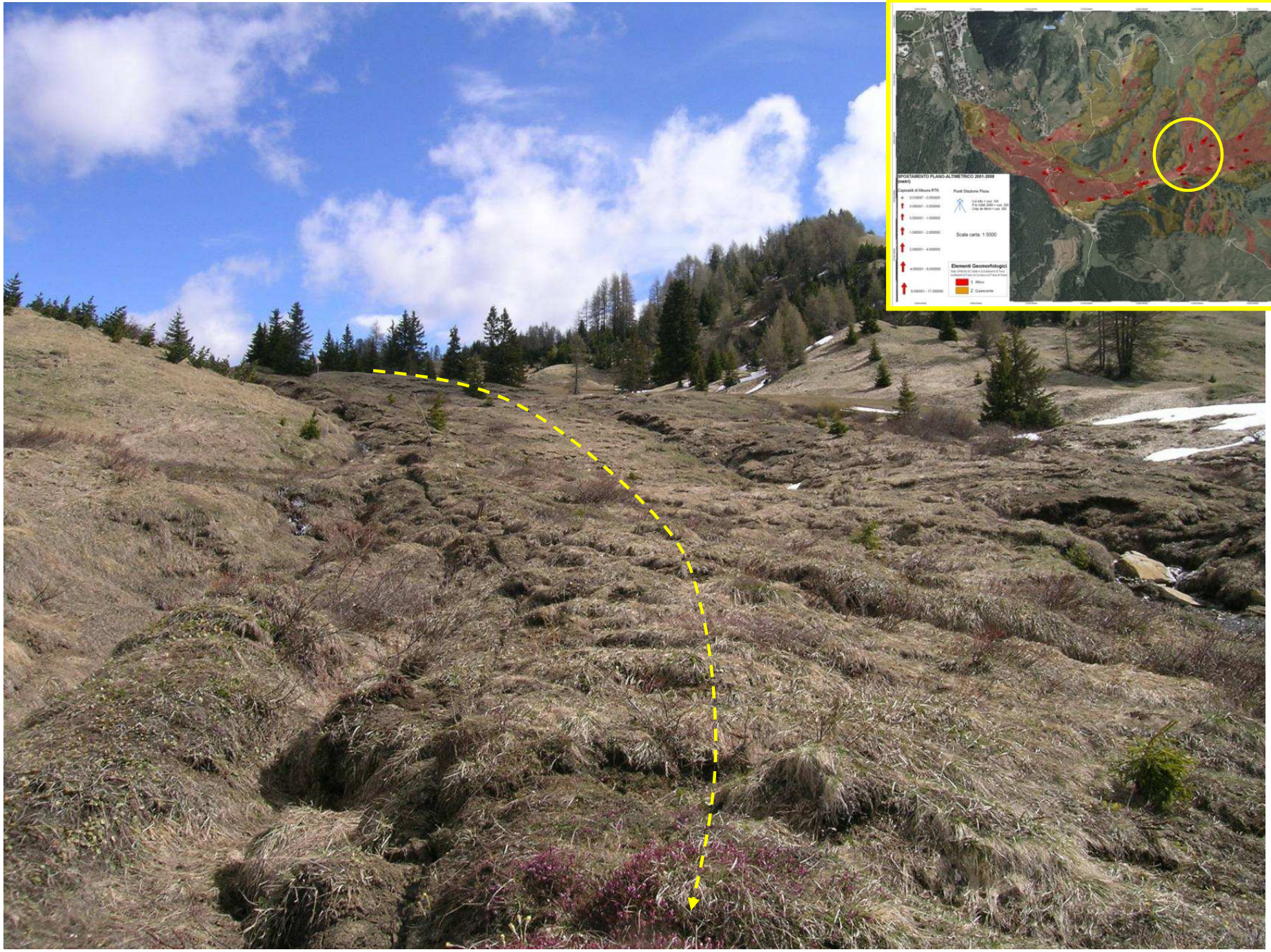
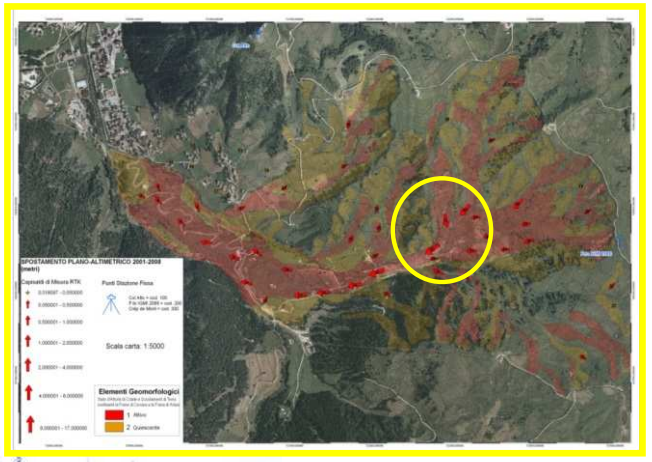
GPS + AR-PS monitoring 2013 to date: operative set-up



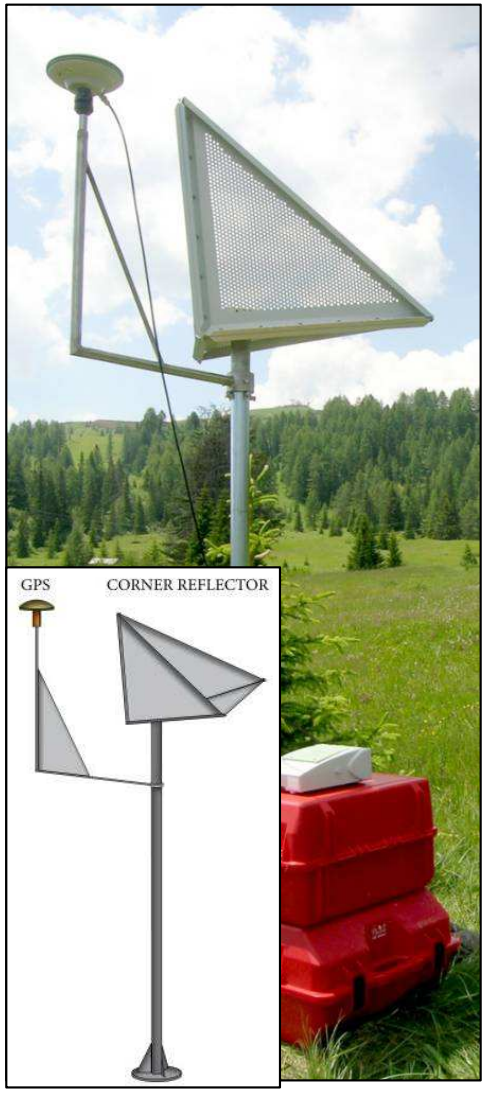

SPOSTAMENTO PLANO-ALTIMETRICO 2001-2008
Scala carta 1:5000
Elementi Geomorfologici


SPOSTAMENTO PLANO-ALTIMETRICO 2001-2008
Scala carta 1:5000
Elementi Geomorfologici

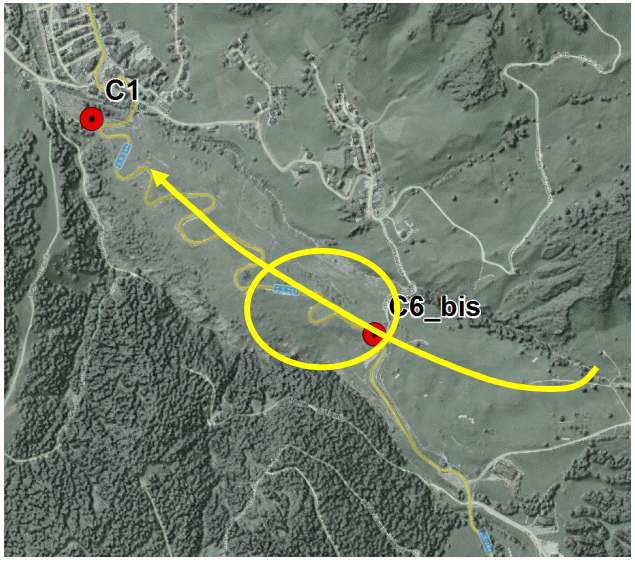
SPOSTAMENTO PLANO-ALTIMETRICO 2001-2008
Scala carta 1:5000
Elementi Geomorfologici
1 Alluv
2 Quiescente


SPOSTAMENTO PLANO-ALTIMETRICO 2001-2008
Scala carta 1:5000
Elementi Geomorfologici
1 Alluvi
2 Quaternario

GPS + AR-PS monitoring 2013 to date: operative set-up



Borehole monitoring 2013 to date



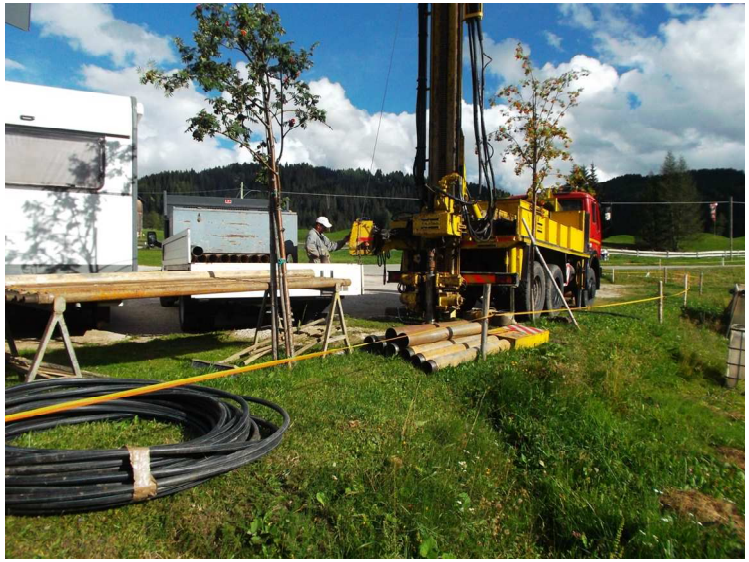


Fig.23 – Costes da l'Ega, cantiere C6 bis. Sullo sfondo l'ubicazione del tubo inclinometrico C6.

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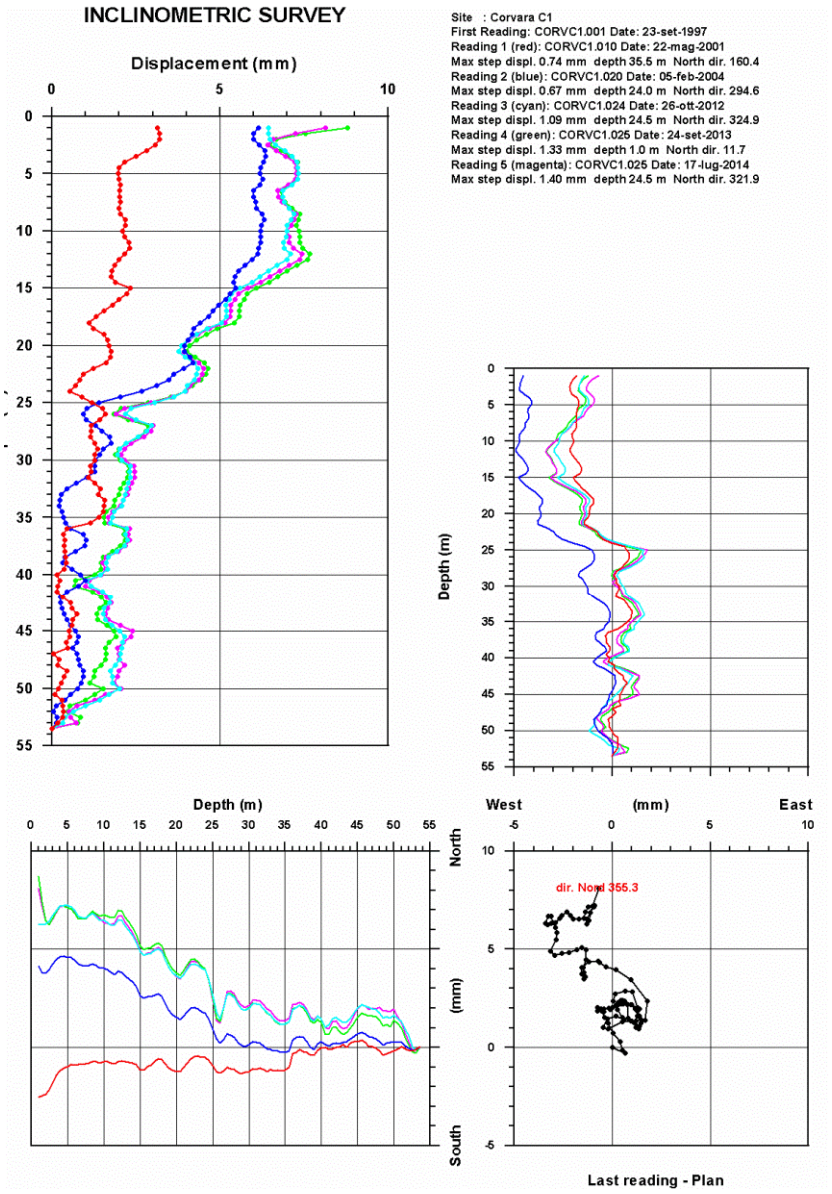
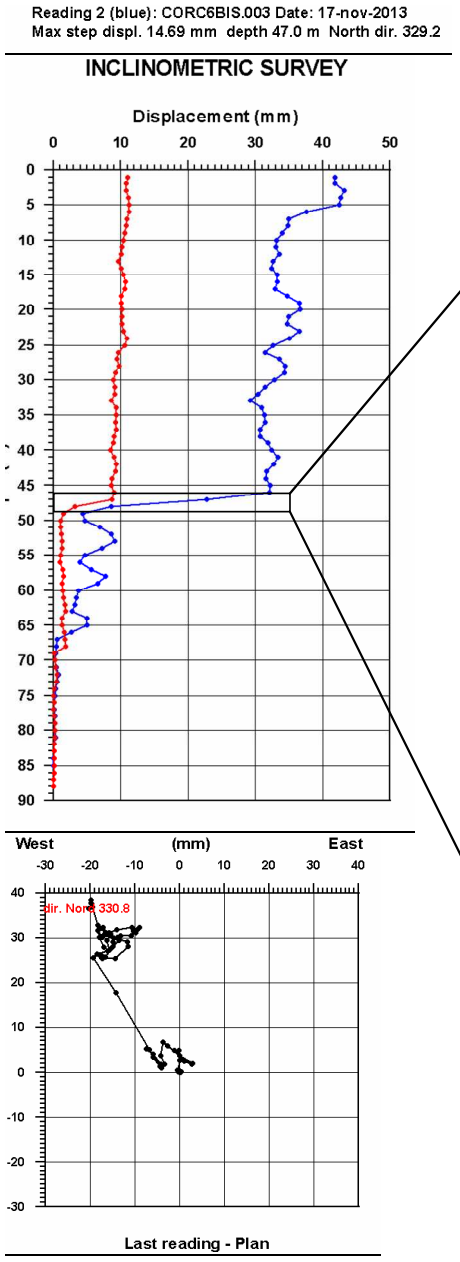
Borehole monitoring 2013 to date: operative set-up

C1 (since 1997)



C6bis (since fall 2013)



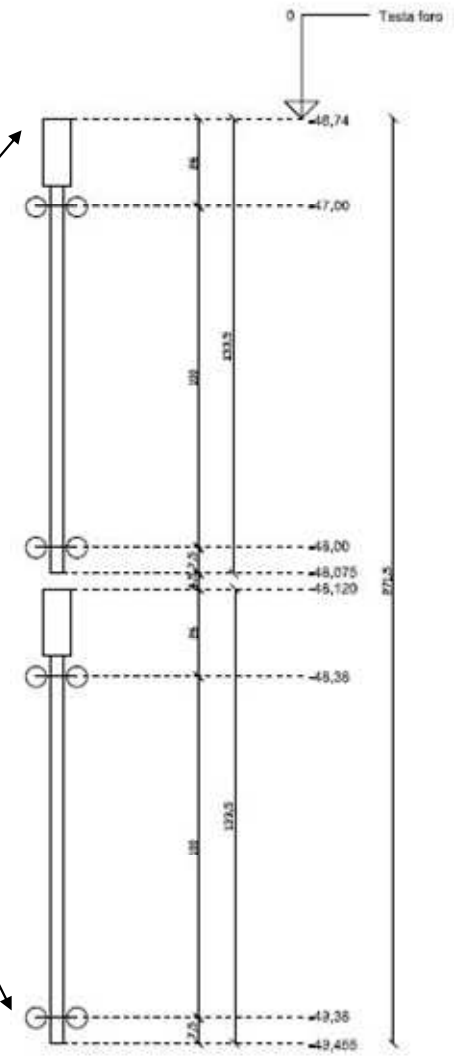


Fig. 26 - Schema di installazione sonde inclinometriche fisse nel tubo C6 bis.

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Borehole monitoring 2013 to date

Fig. 27 - Pozzetto C6 bis. Terminale in acciaio a cui sono ancorate le sonde incliometriche fisse.

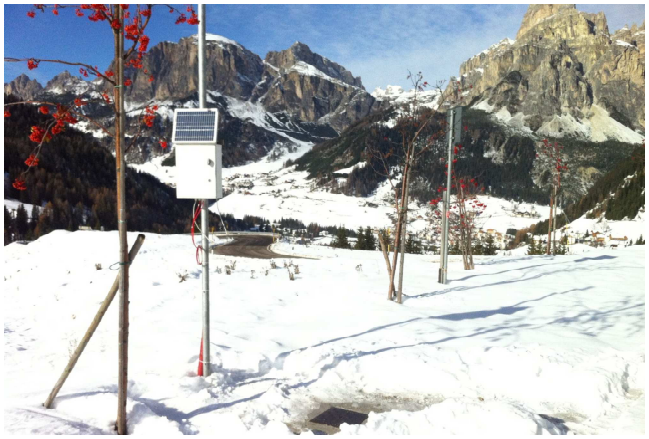
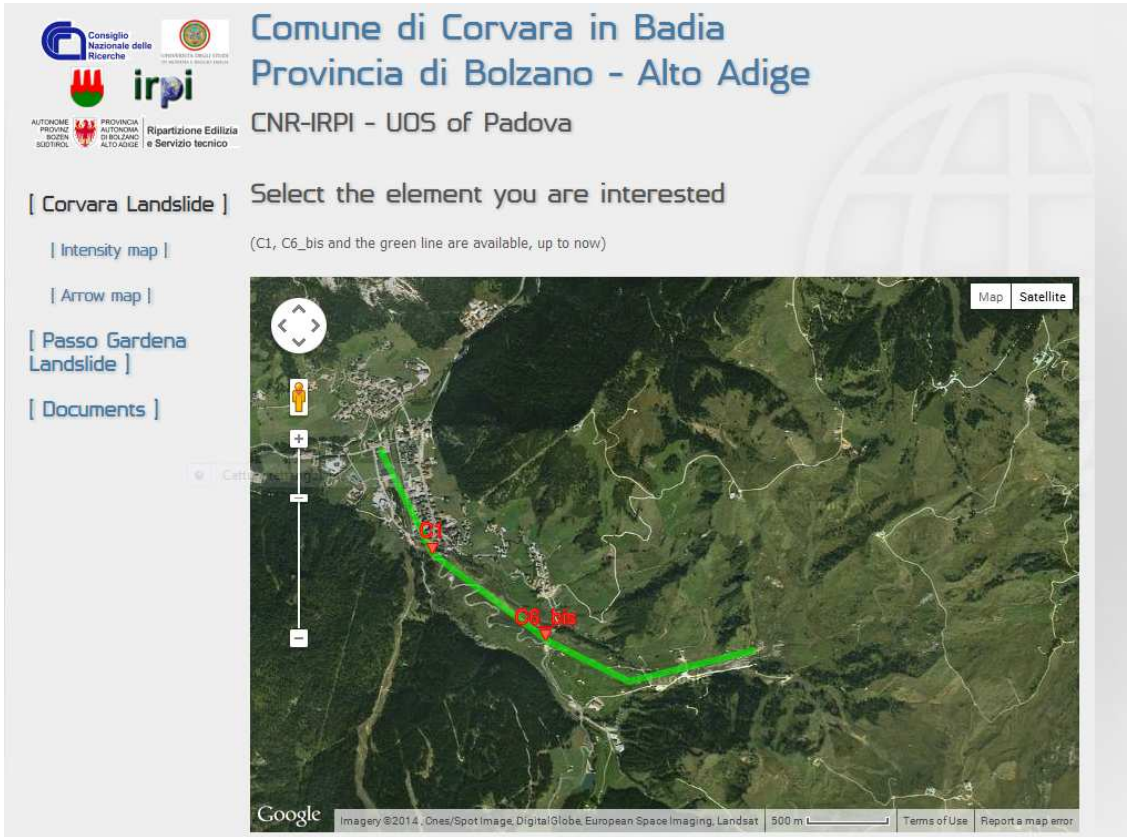
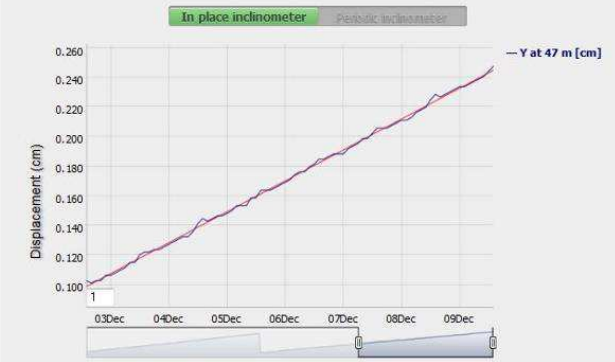


Fig. 28 - C6 bis, unita di acquisizione e trasmissione dati





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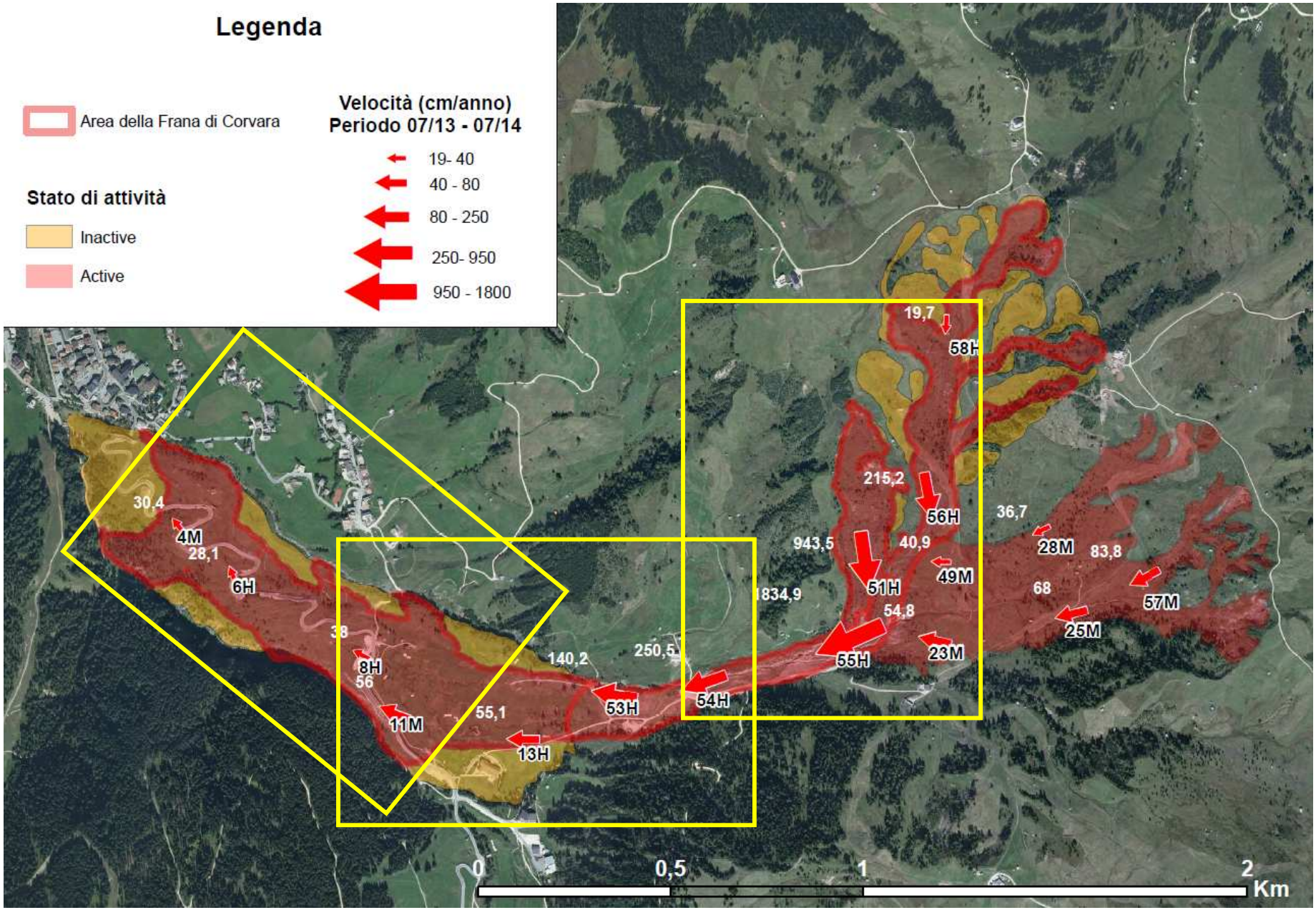
Periodic GPS



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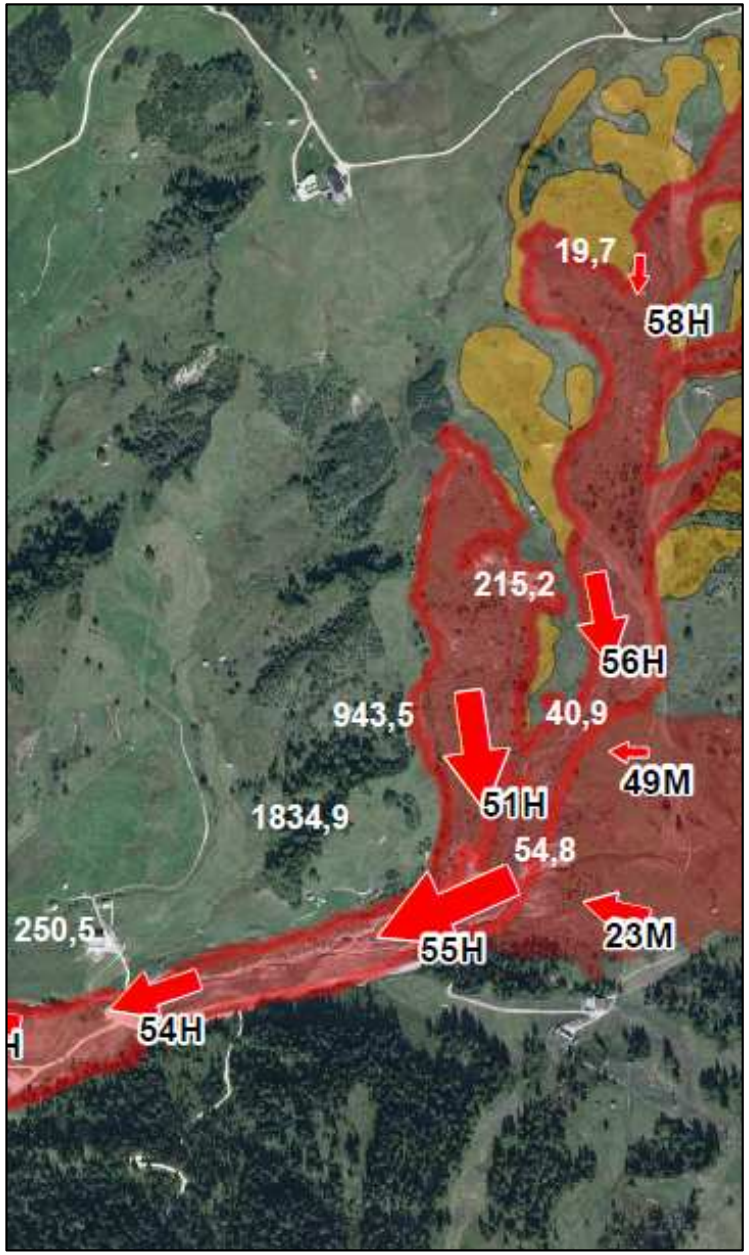
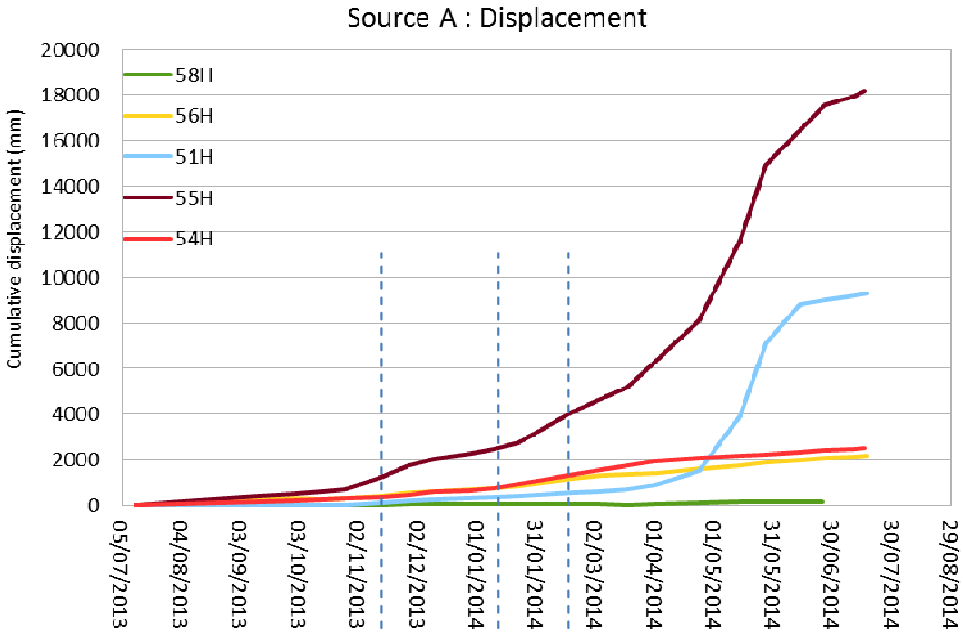
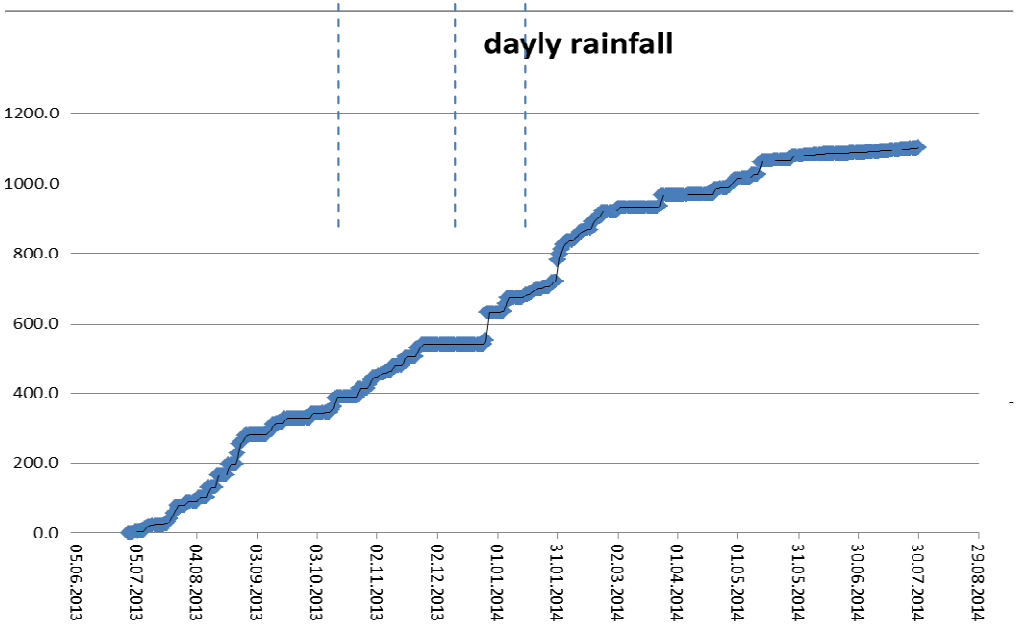
Periodic GPS







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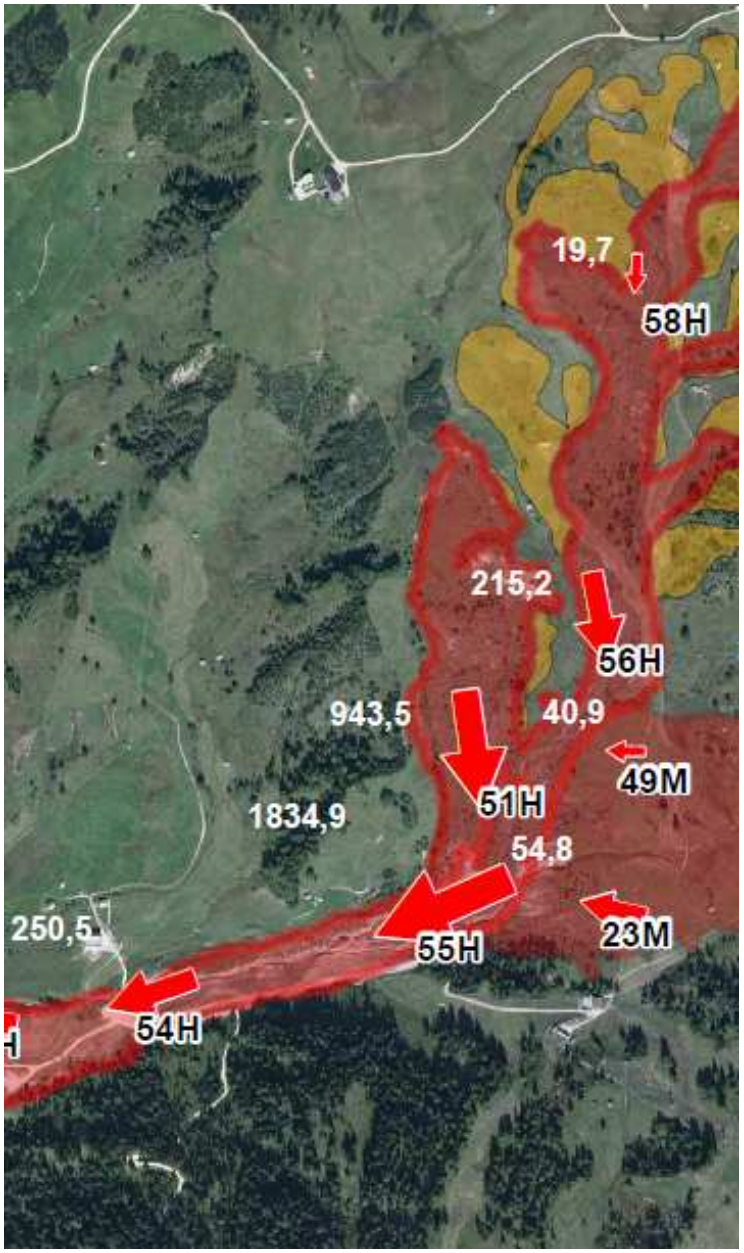
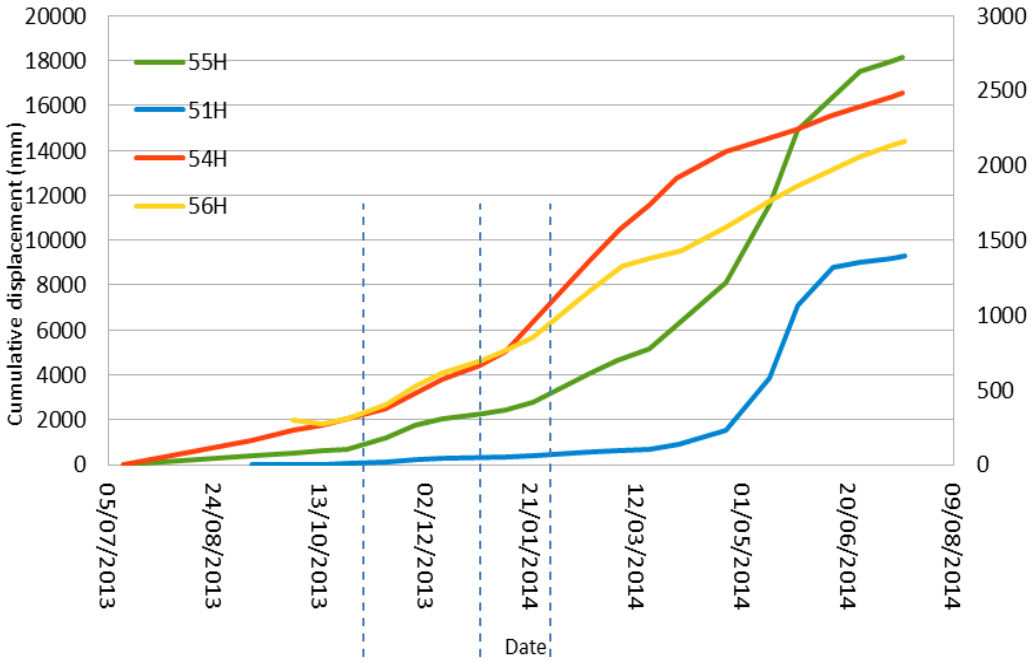
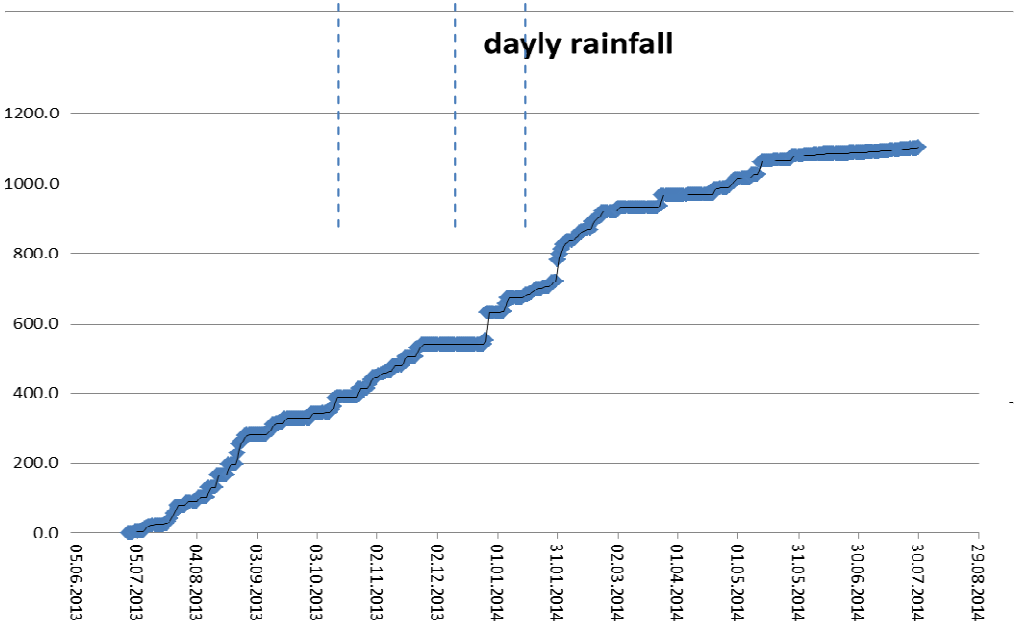
Periodic GPS







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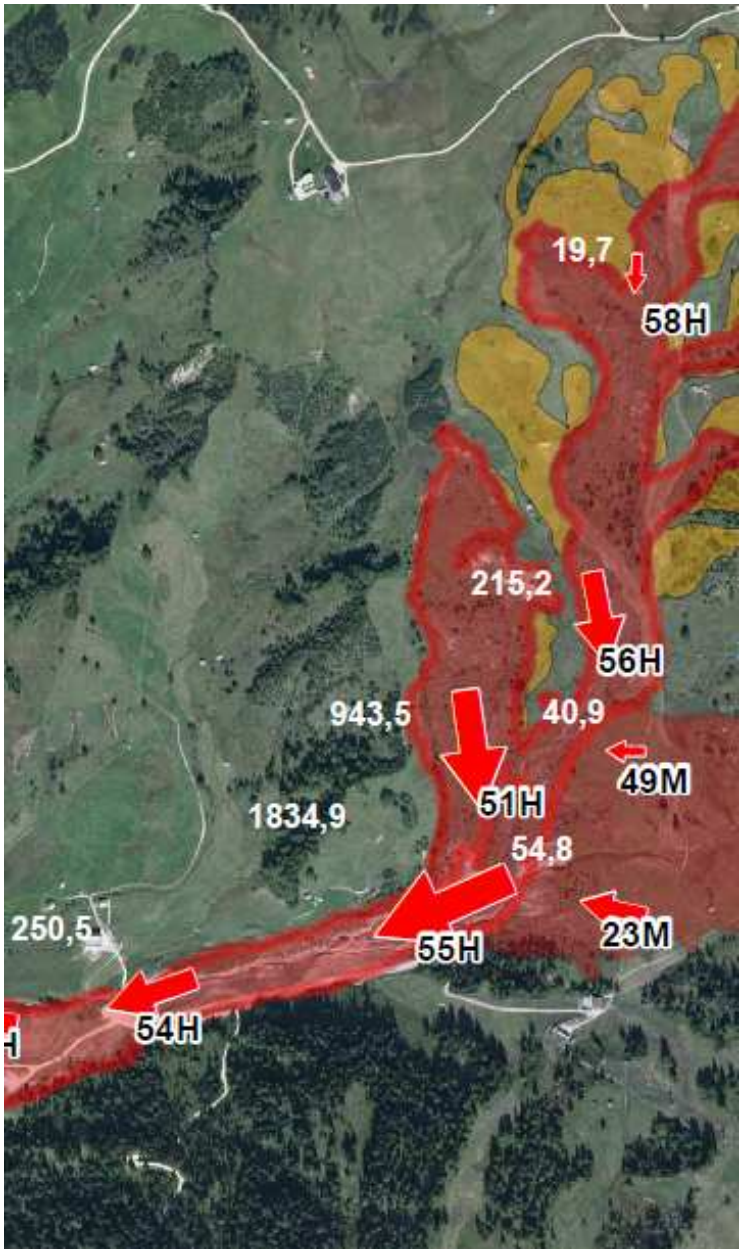
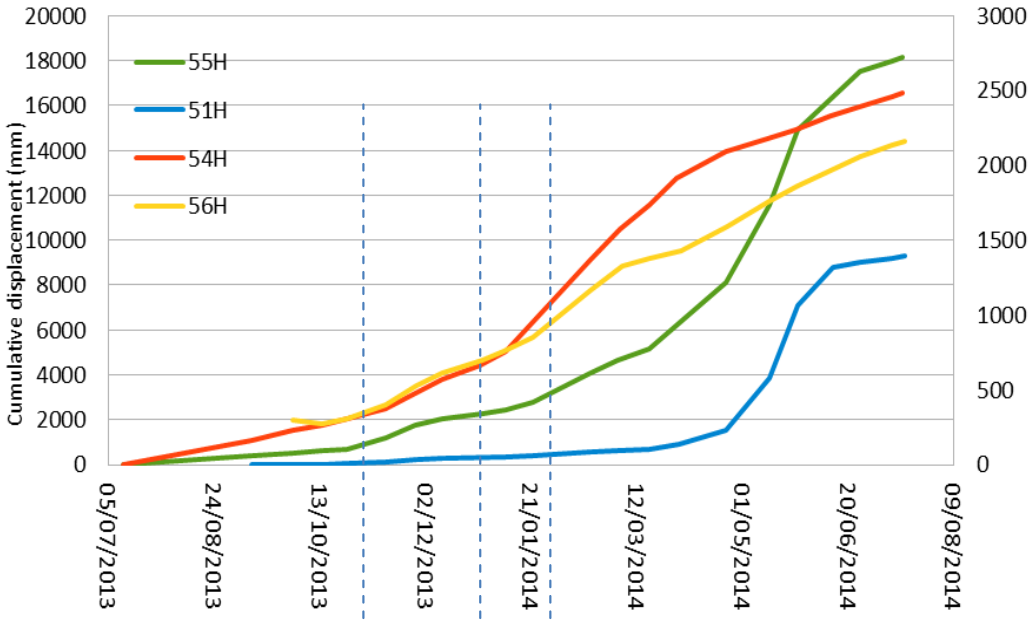
Periodic GPS





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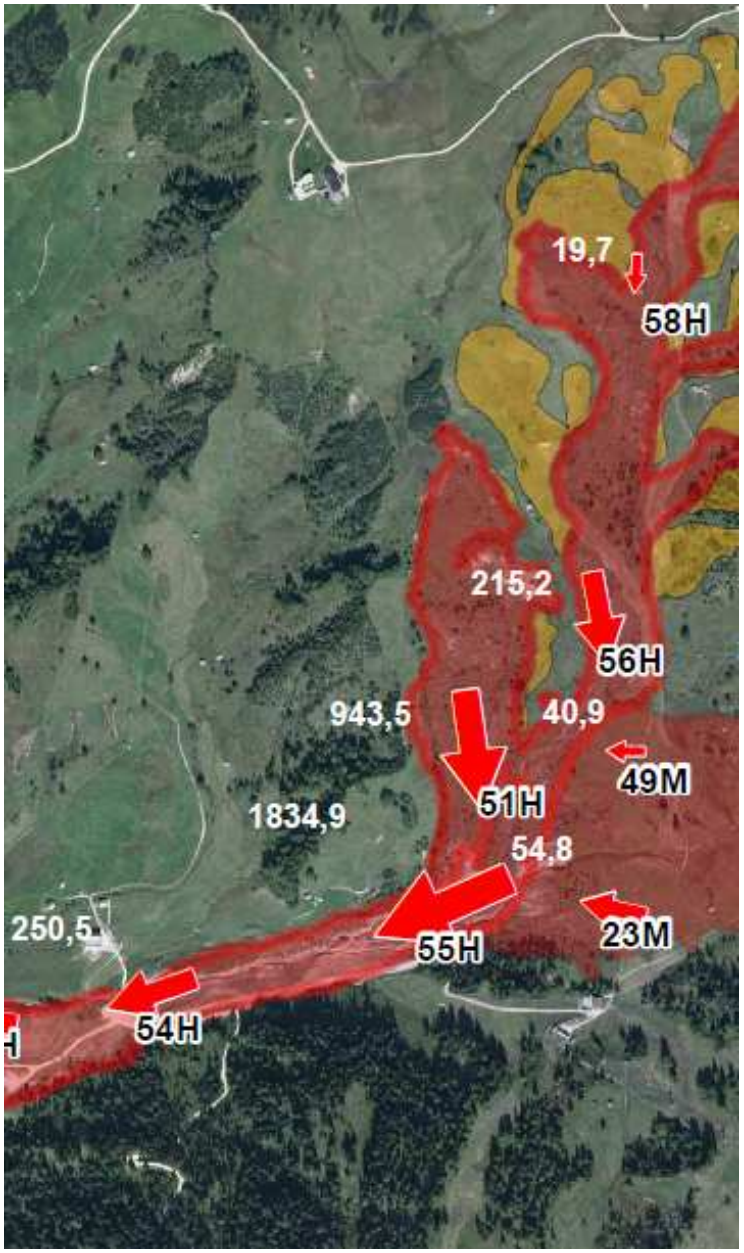
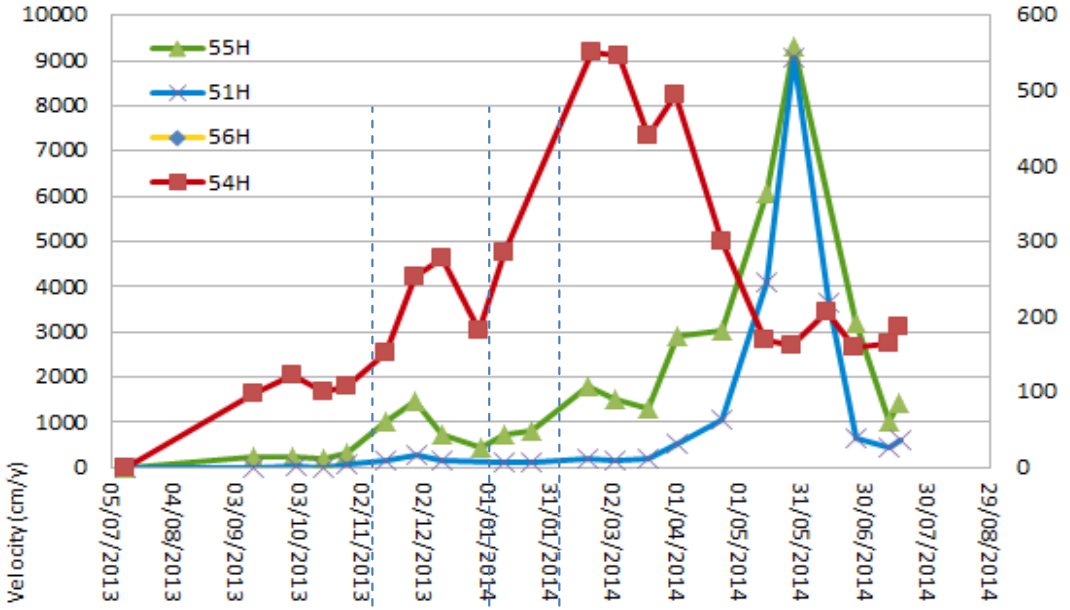
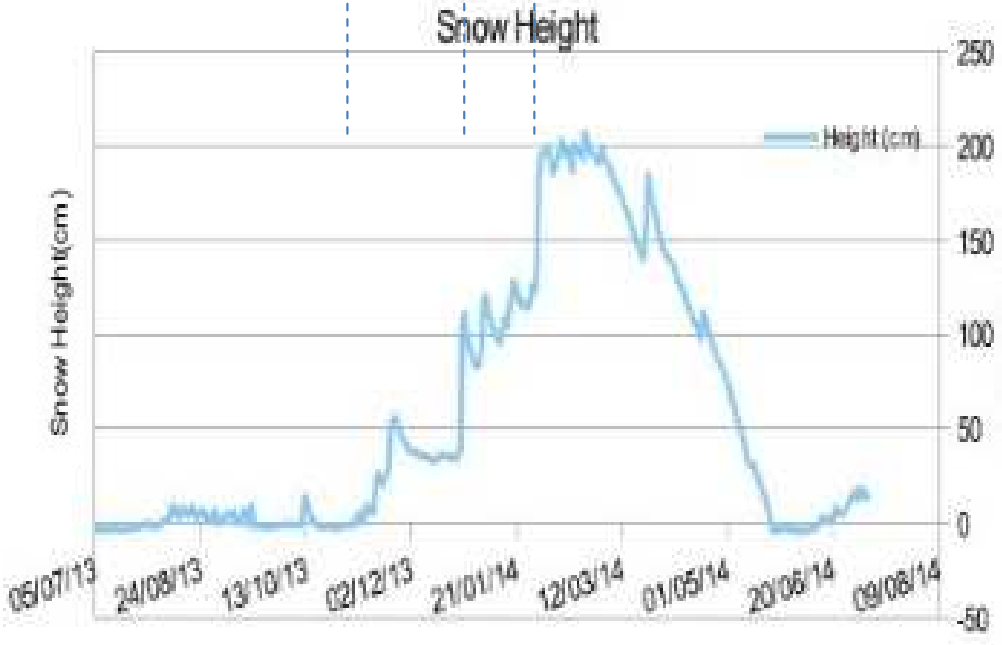
Periodic GPS







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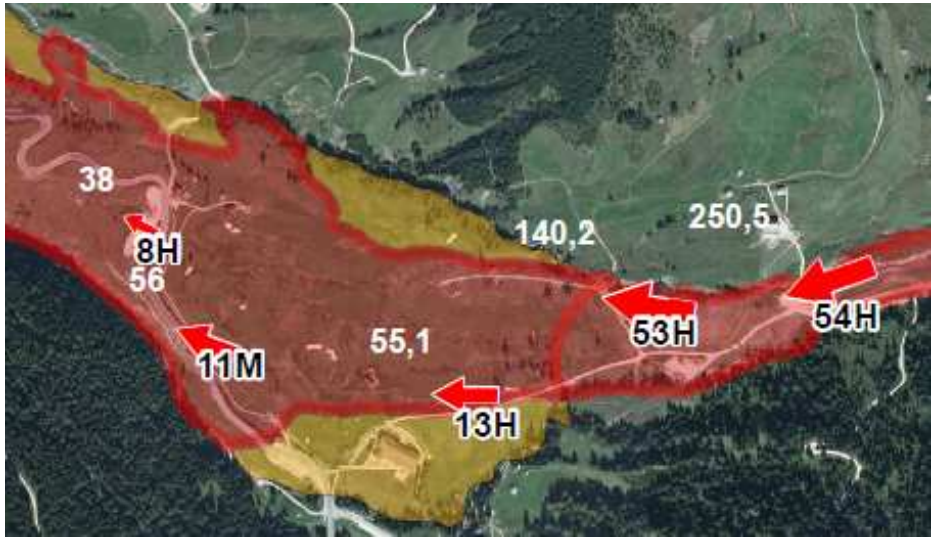
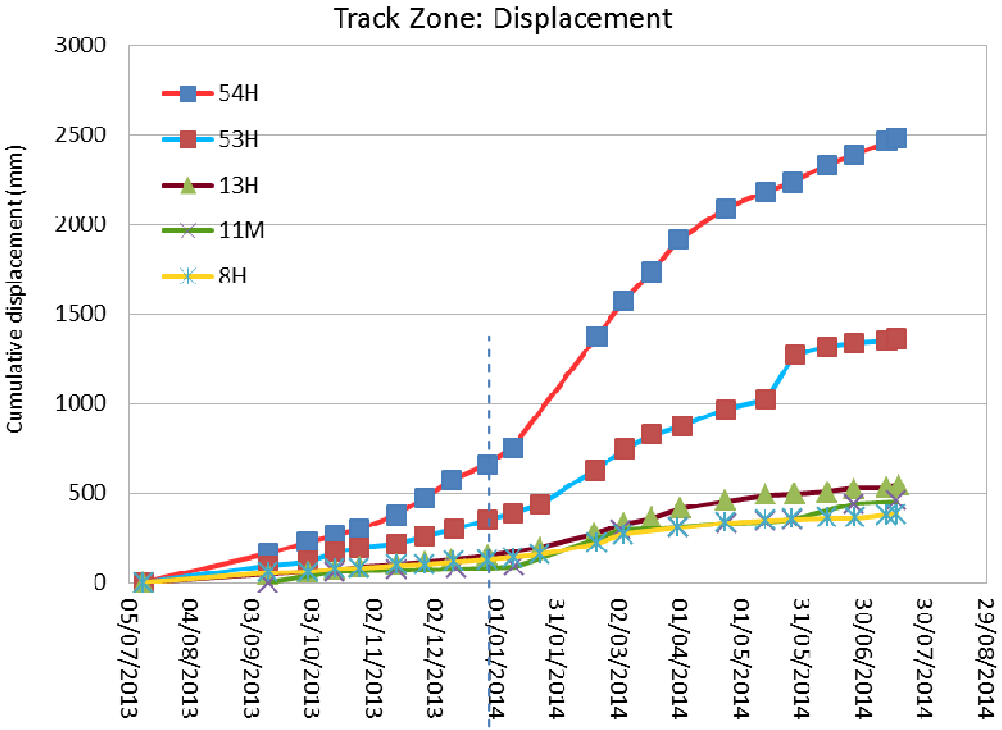
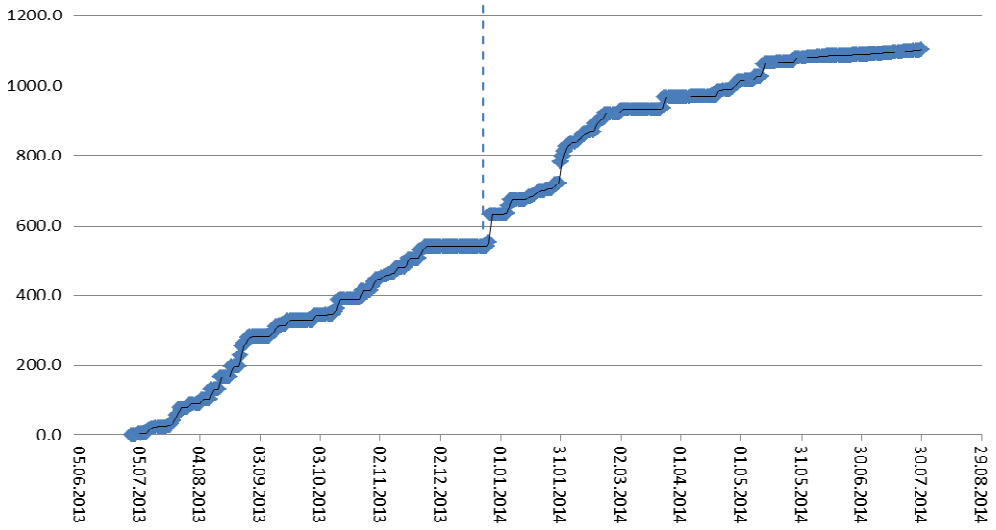
Periodic GPS







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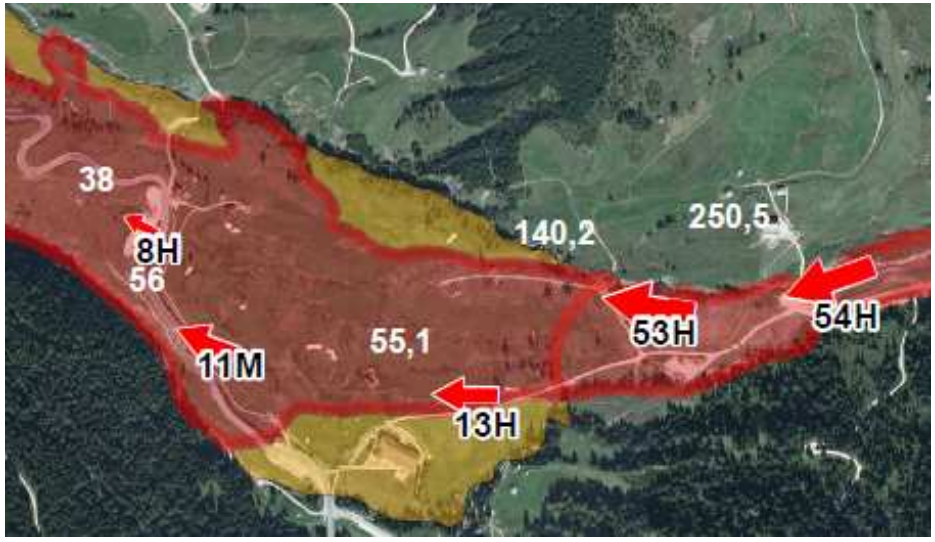
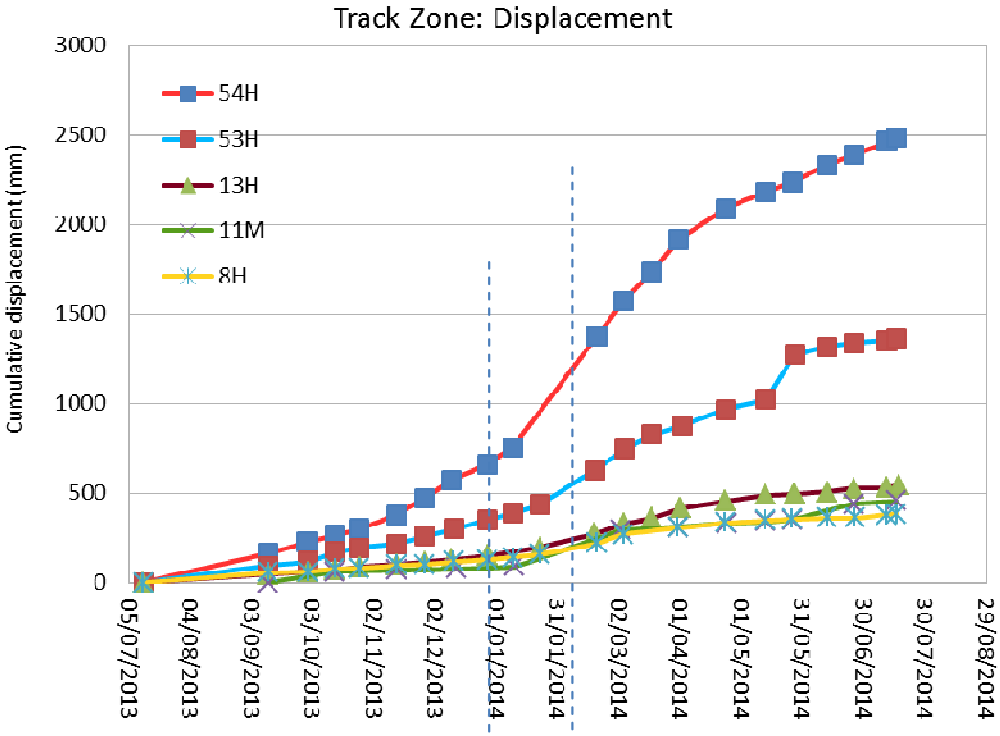
Periodic GPS





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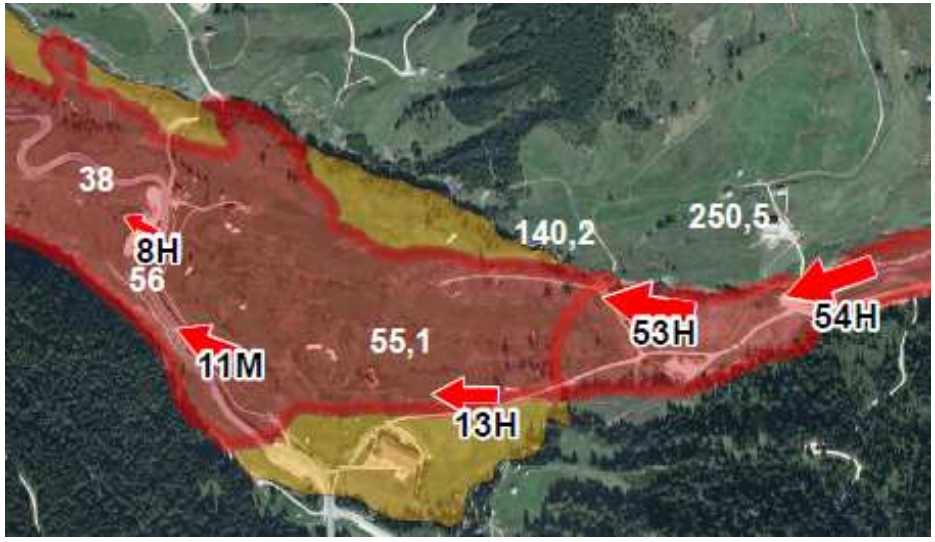
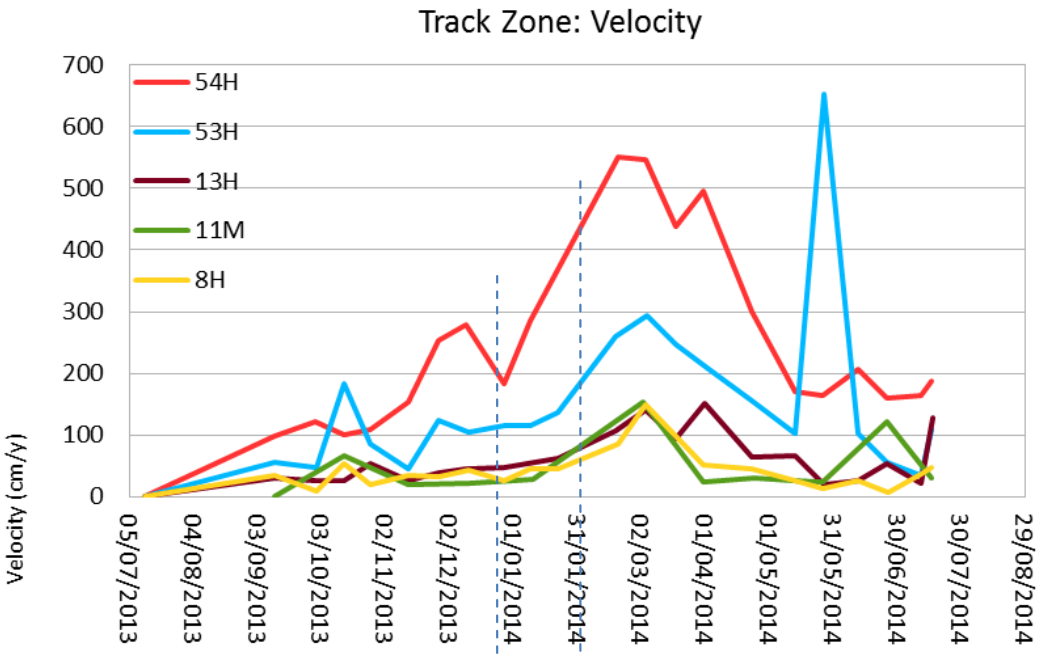
Periodic GPS





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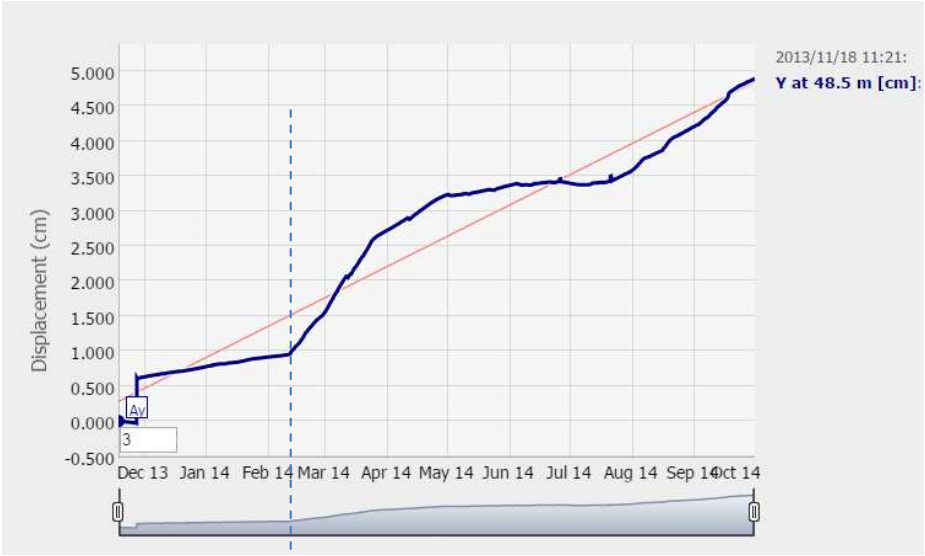
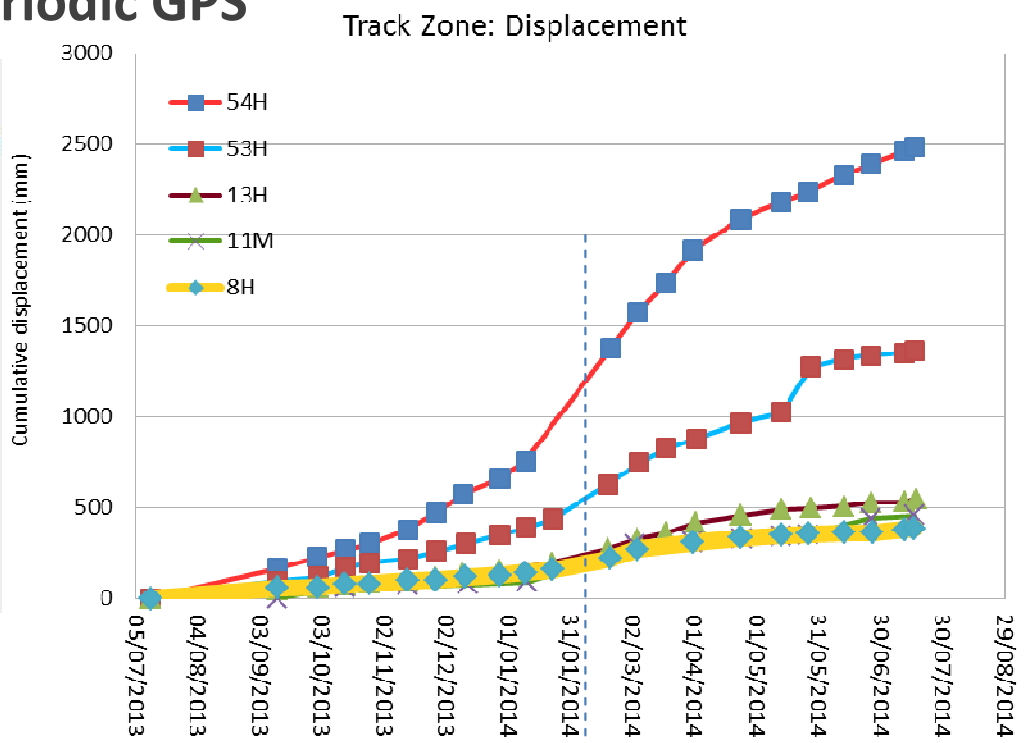
In-place inclinometers



Periodic GPS



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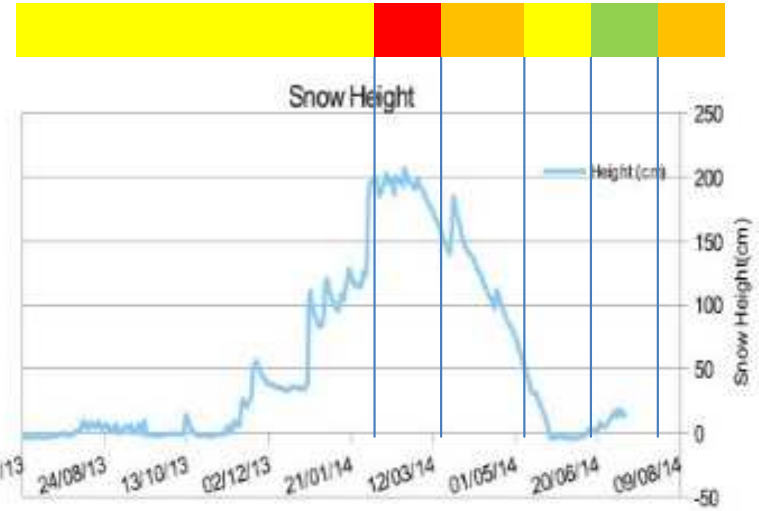
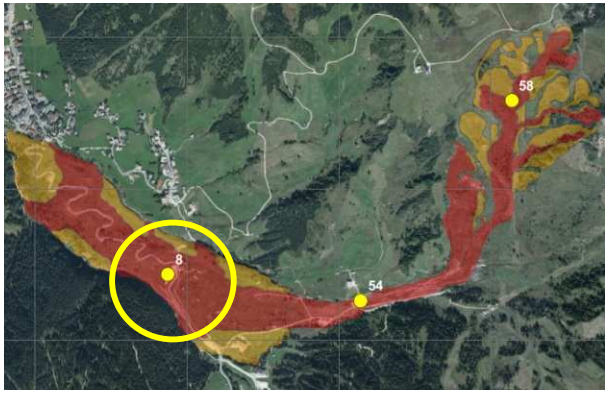
Snow accumulation





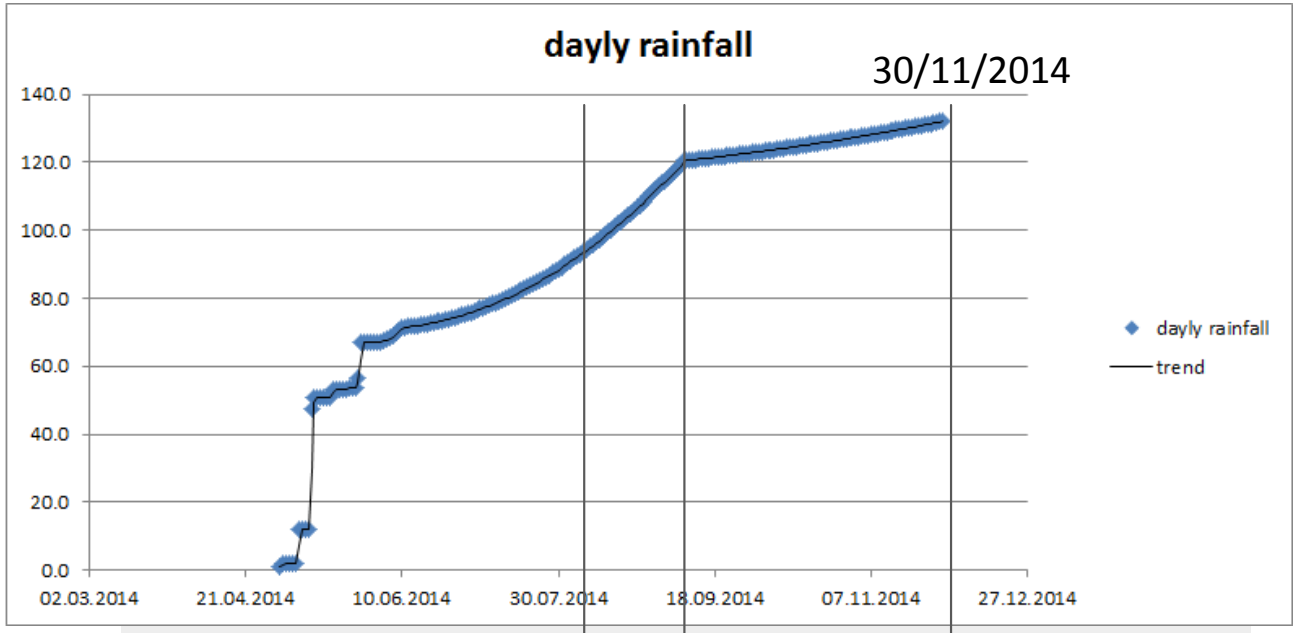
Continuous In-place inclinometers

(Dec. 2013 to Nov. 2014)

- ✓ Fase 1: da novembre 2013 all'8÷10 febbraio 2014.
  (Vel_media asse Y: prof. 47 m = 0.2 mm/d; prof. 48.5 m = 0.05 mm/d)
- ✓ Fase 2: dall' 8÷10 febbraio 2014 al 25÷27 marzo 2014
  (Vel_media asse Y: prof. 47 m = 1.5 mm/d; prof. 48.5 m = 0.4 mm/d)
- ✓ Fase 3: dal 25÷27 marzo 2014 al 02÷03 maggio 2014
  (Vel_media asse Y: prof. 47 m = N.D; prof. 48.5 m = 0.17 mm/d)
- ✓ Fase 4: dal 02÷03 maggio 2014 al 27÷28 giugno 2014
  (Vel_media asse Y: prof. 47 m = N.D; prof. 48.5 m = 0.04 mm/d)
- ✓ Fase 5: dal 27÷28 giugno 2014 al 20÷21 luglio 2014
  (Vel_media asse Y: prof. 47 m = N.D; prof. 48.5 m = 0.001 mm/d)
- ✓ Fase 6: dal 20÷21 luglio 2014 al 20 novembre 2014
  (Vel_media asse Y: prof. 47 m = N.D; prof. 48.5 m = 0.2 mm/d)

Continuous In-place inclinometers

(Dec. 2013 to Nov. 2014)



more than just rainfall

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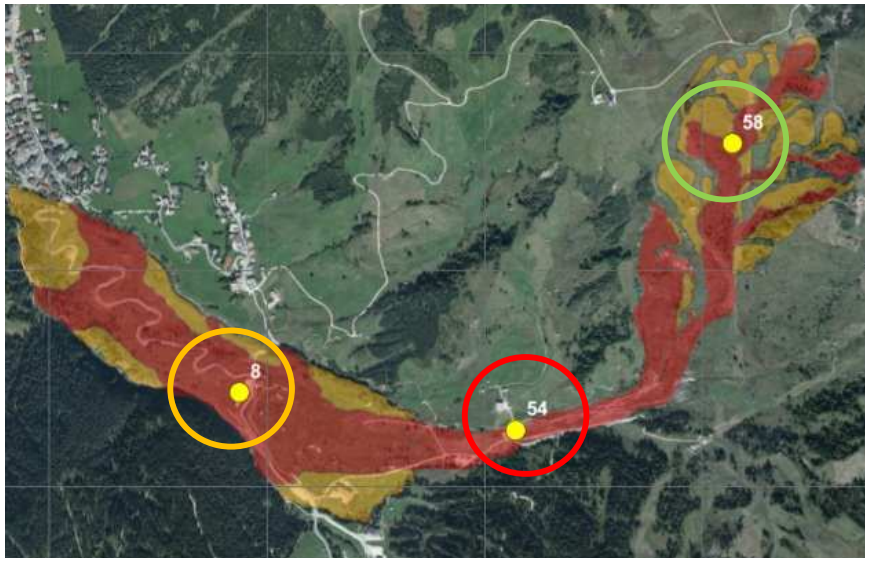
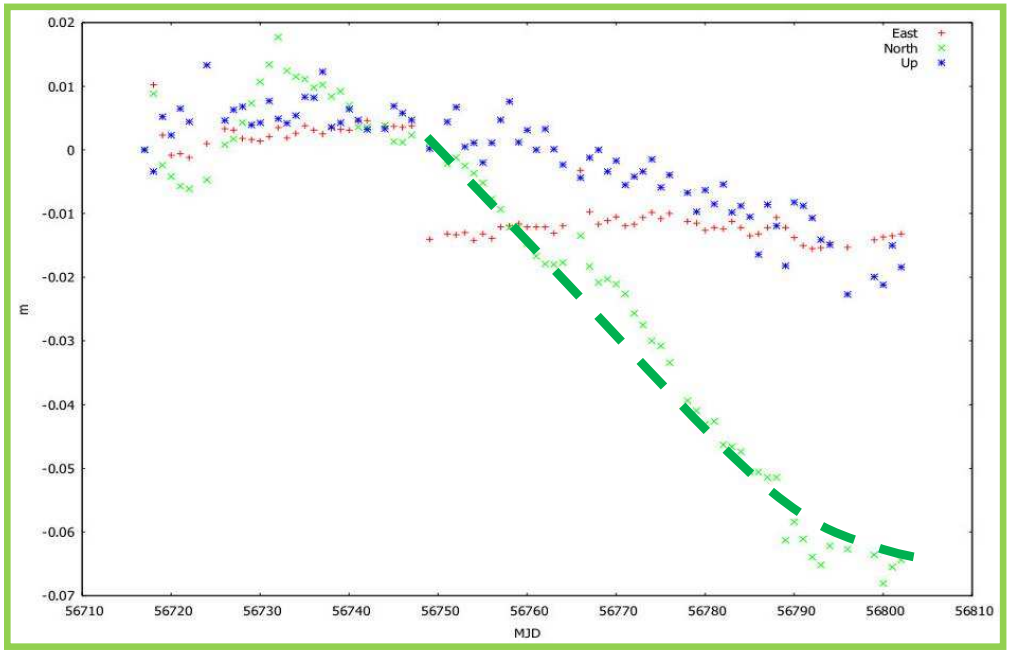
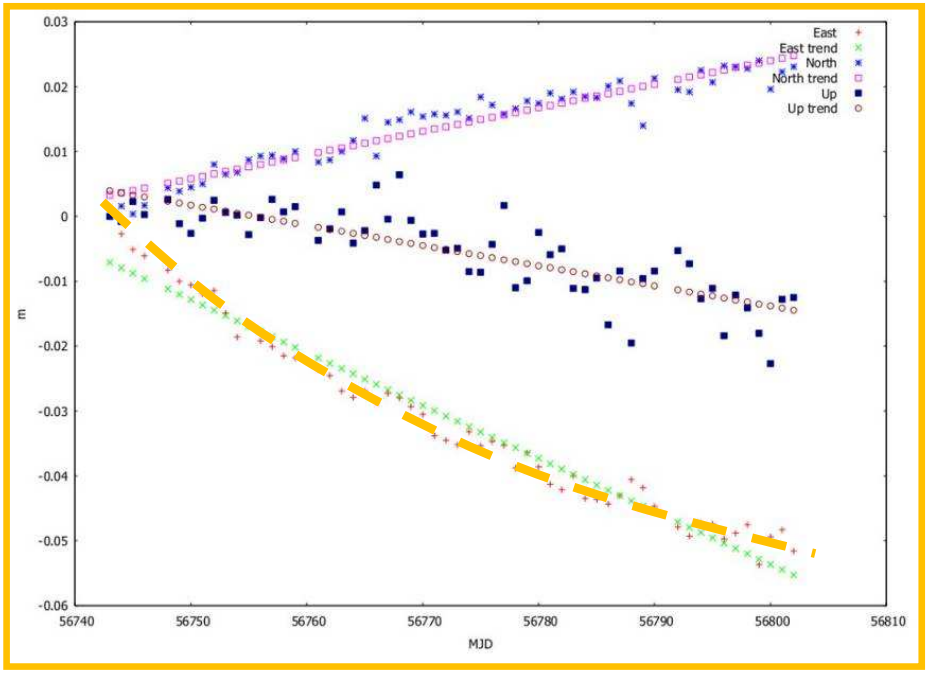
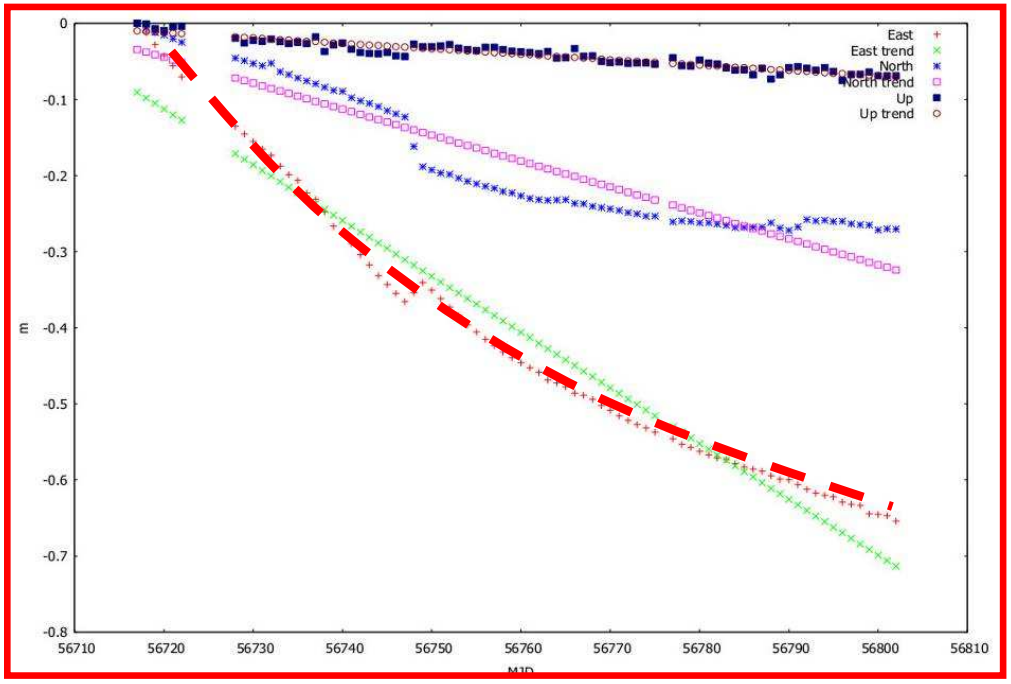
Continuous GPS (from Feb 2014..)

(data from Feb 2014. to May 2014)









Thanks for your attention