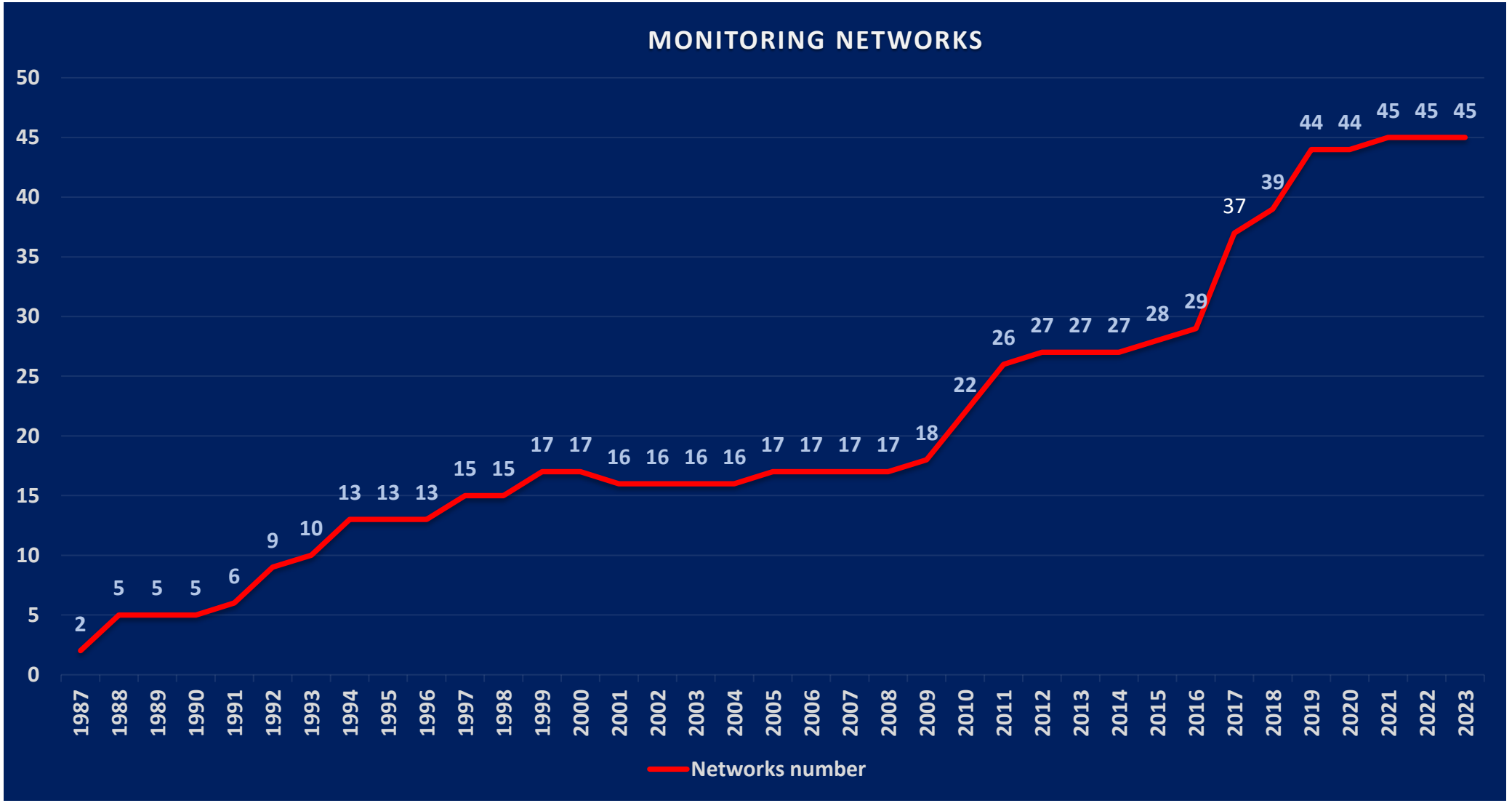
ARPA'S GEOLOGICAL MONITORING NETWORK: THE USE OF GROUND BASED InSAR

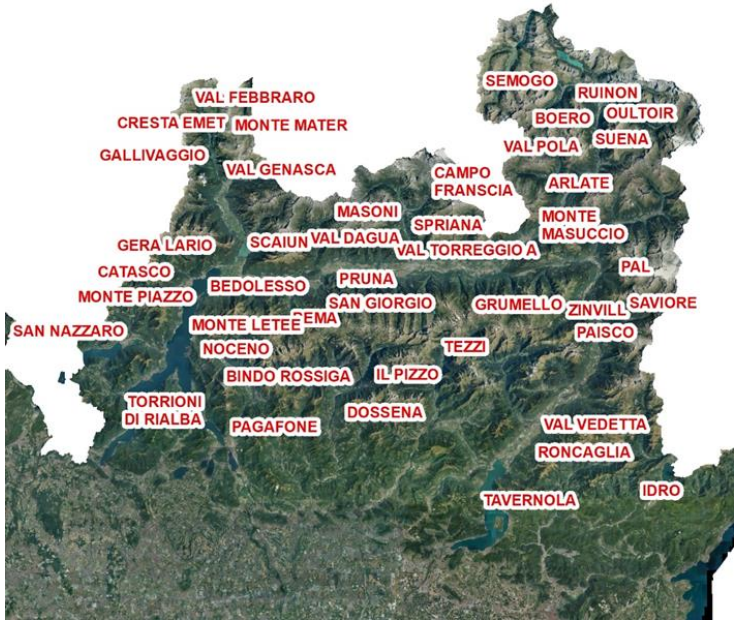
Luca Dei Cas – Centro di Monitoraggio Geologico ARPA Lombardia

VAL POLA 1987


MONITORING NETWORKS
50
45
40
35
30
25
20
15
10
5
0
2 5 5 5 6 9 10 13 13 13 15 15 17 17 16 16 16 16 17 17 17 17 18 22 26 27 27 27 28 29 37 39 44 44 45 45 45
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
Networks number

MONITORED AREAS

- Monitoring Landslide areas: 45
- Early warning monitoring: 29
- Knowledge or control monitoring: 16



DIFFERENT KINDS OF INSTRUMENTATIONS

GEOTECHNICAL

ABOVE SOIL

- Strain gauge
- Fexurimeter
- Distometer
- Inclinometer on wall

ON BOREHOLE

- Inclinometrical probe
- Piezometric probe
- Inclinometrical multiparametric probe DMS
- Wires "TDR"

RADAR INTERFEROMETRY

- Satellite radar

- Ground Sar radar

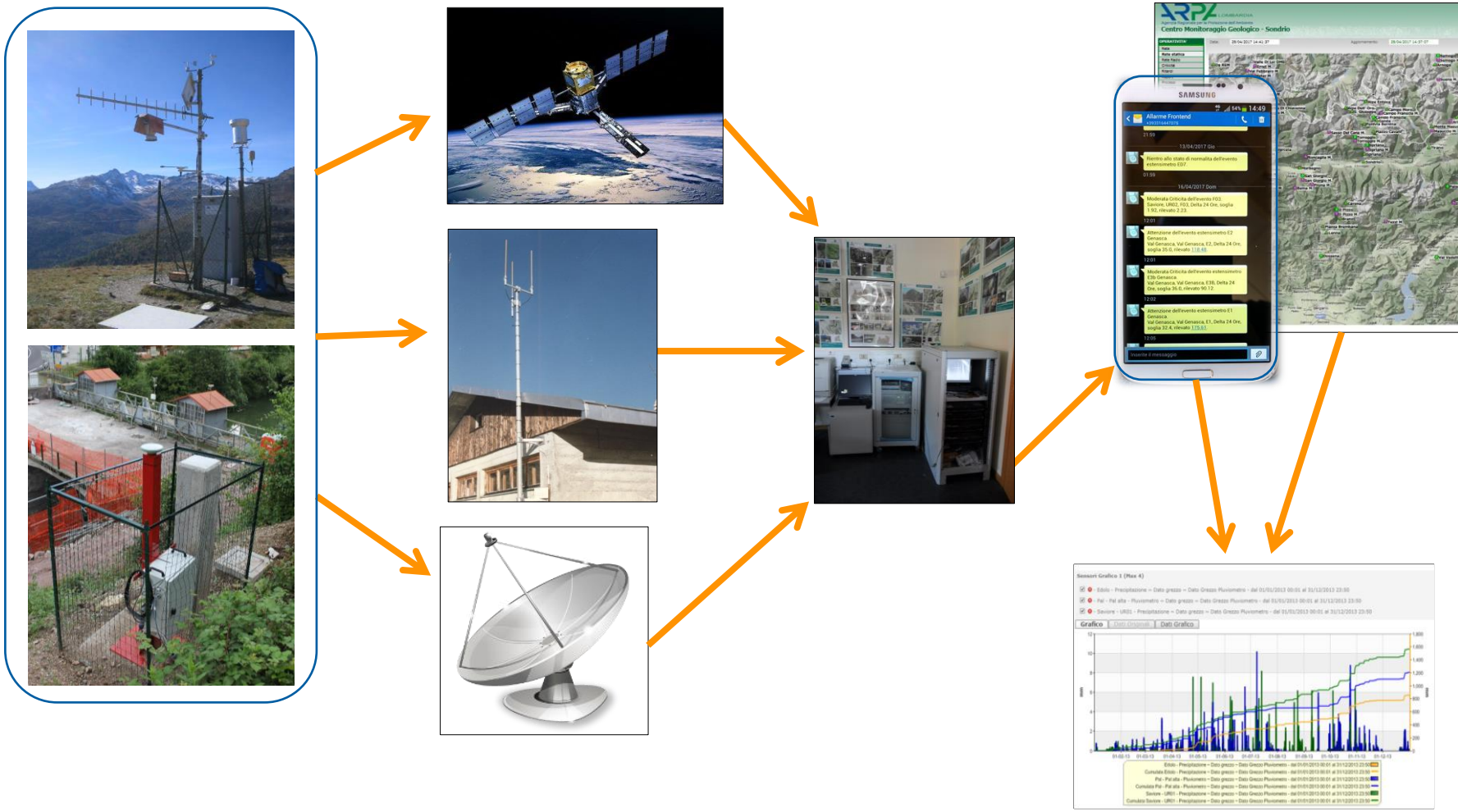
TOPOGRAPHIC

- Total station
- GPS

METEOROLOGICAL INSTRUMENTS

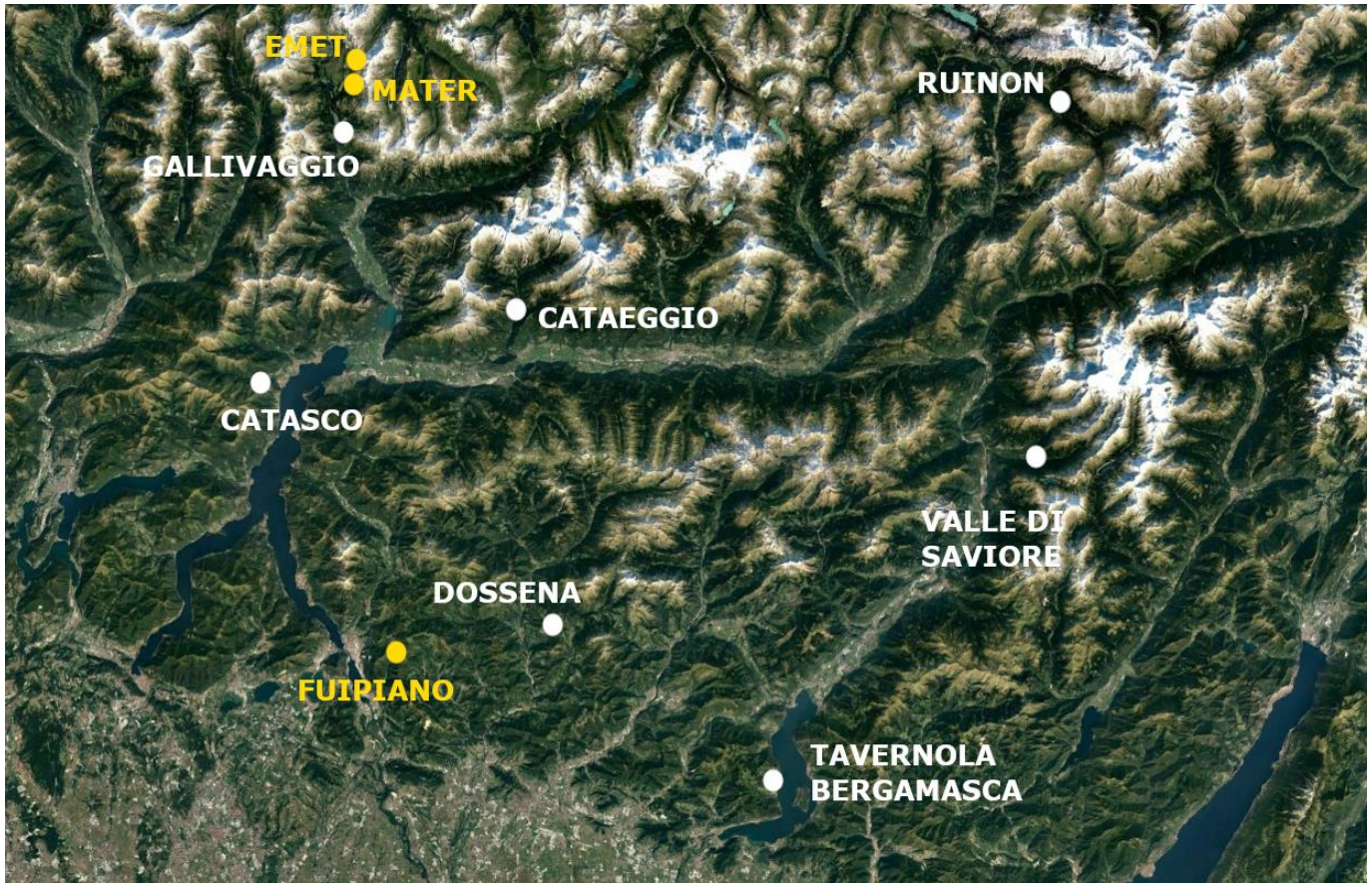
- Rain gauge
- Snow gauge
- Thermometer
- Barometer

DOUBLE (REDUNTANT) TRASMISSION .....

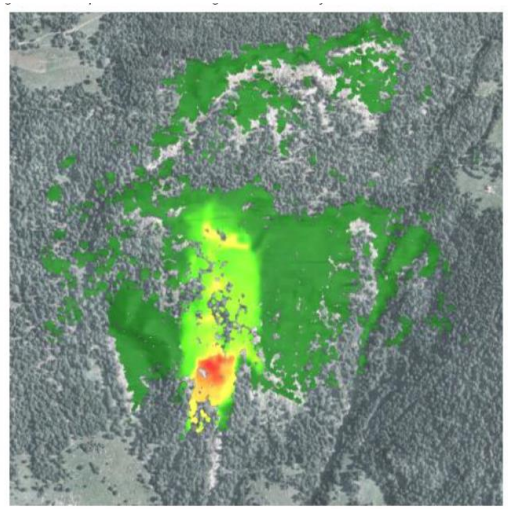


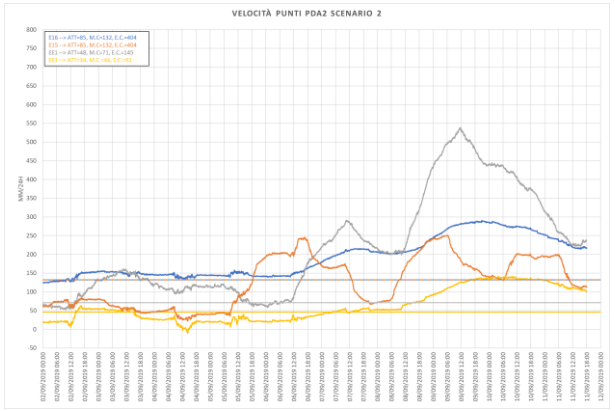
To guarantee the transmission of data values from landslides even in critical situations, it's important to have a transmission redundant system

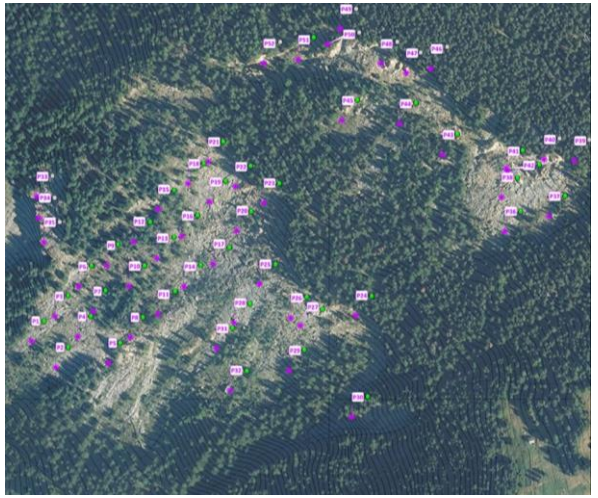
AREAS BEEN MONITORED BY GROUND SAR RADAR

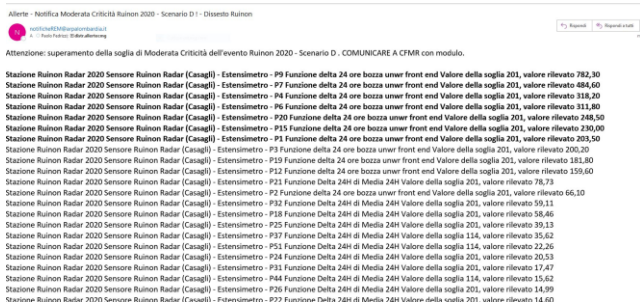


THE 7 AREAS MONITORED, BY GROUND SAR RADAR, FOR EARLY WARNING





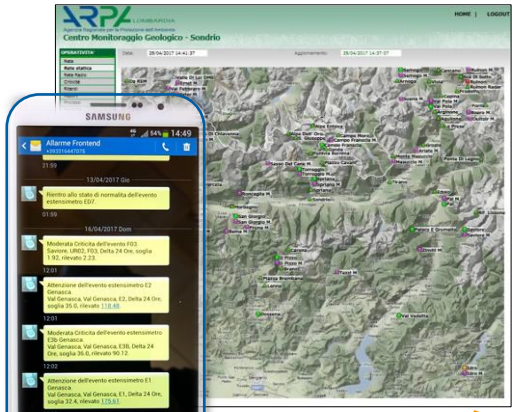


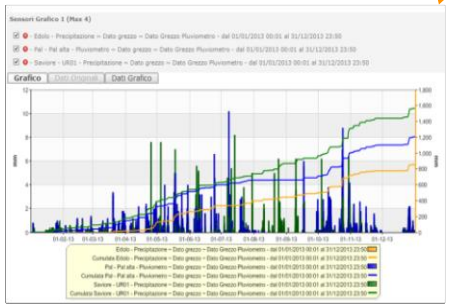


GROUND SAR RADAR: REDUNTANT TRASMISSION

GPRS

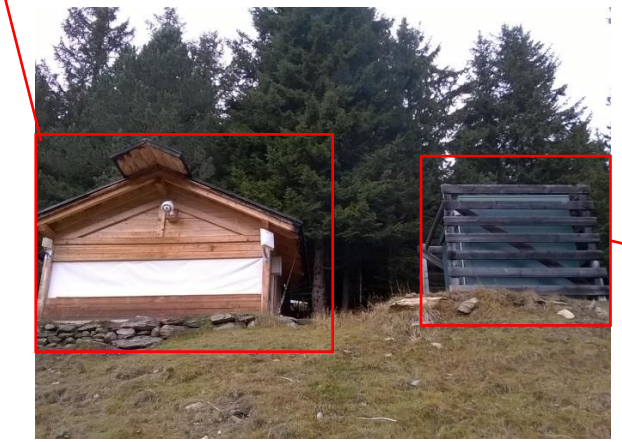
STARLINK

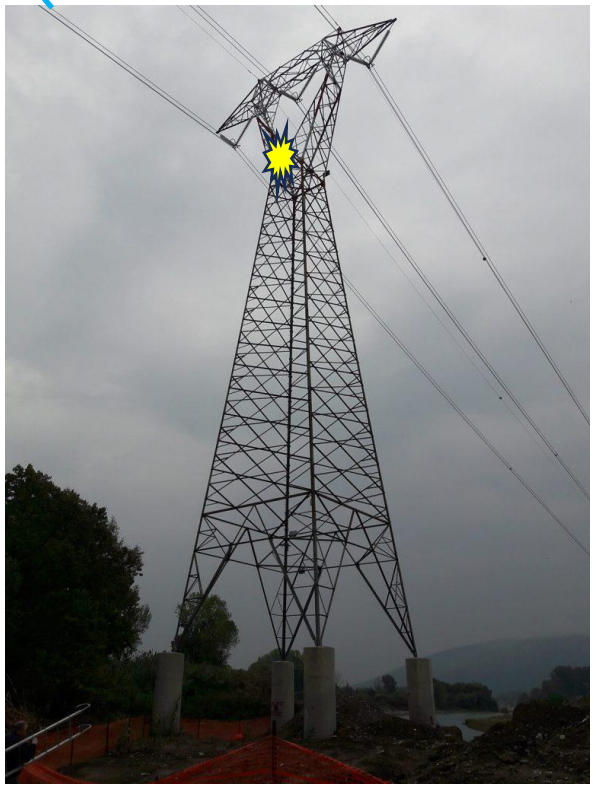




AREAS MONITORED BY GROUND SAR RADAR FOR EARLY WARNING : REDUNTANT ENERGY POWER

Power line connection





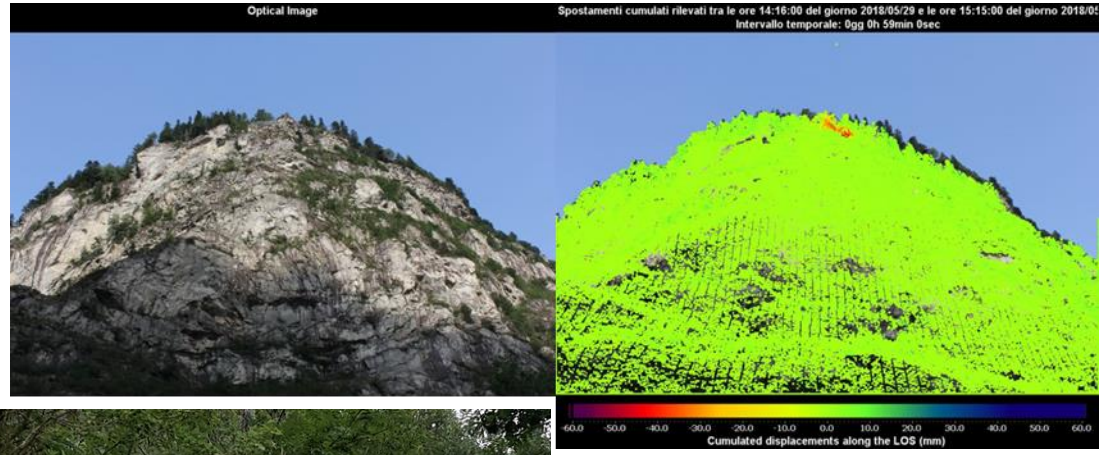
Gallivaggio landslide: Area location

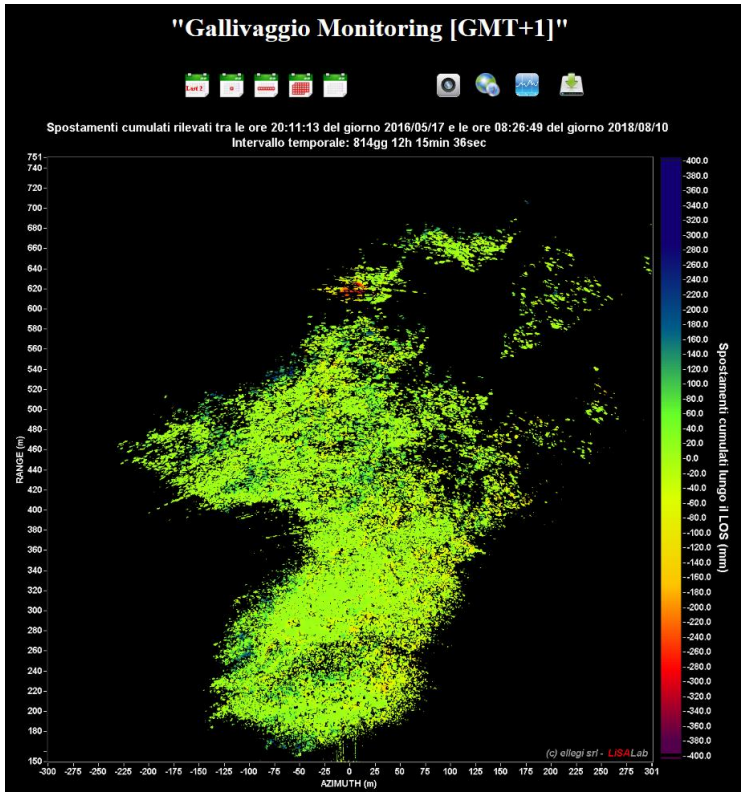
What was the situation during the years before the collapse ?

2008: rockfall embankment and flexible barriers

PROTECTION AGAINST LANDSLIDE

2011/2012: geological monitoring network



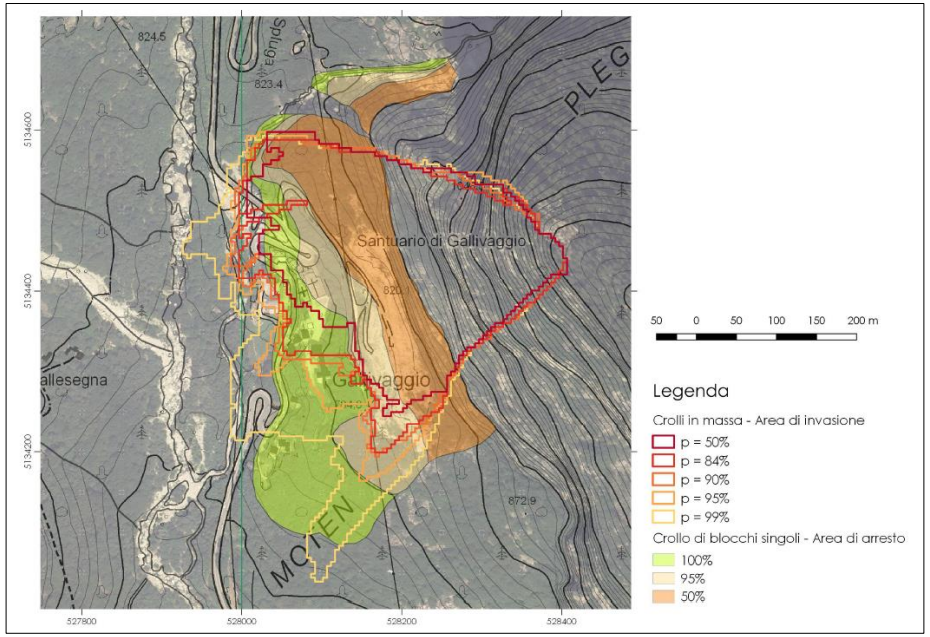


2017: Geotechnical model

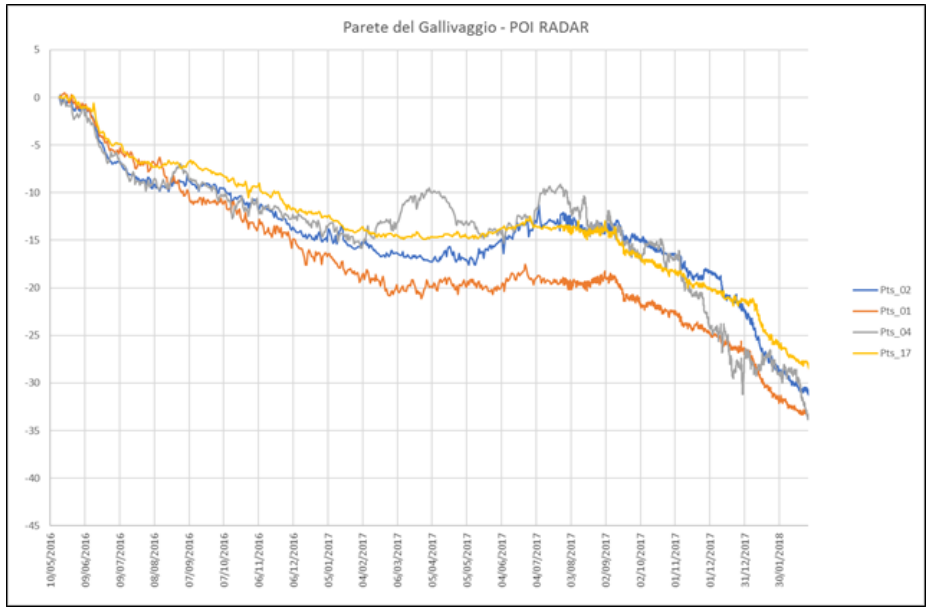
In 2017, a study called "**Geotechnical model and discern thresholds of trigger for the Gallivaggio landslide**" showed us different manifestations of rock mass failure.

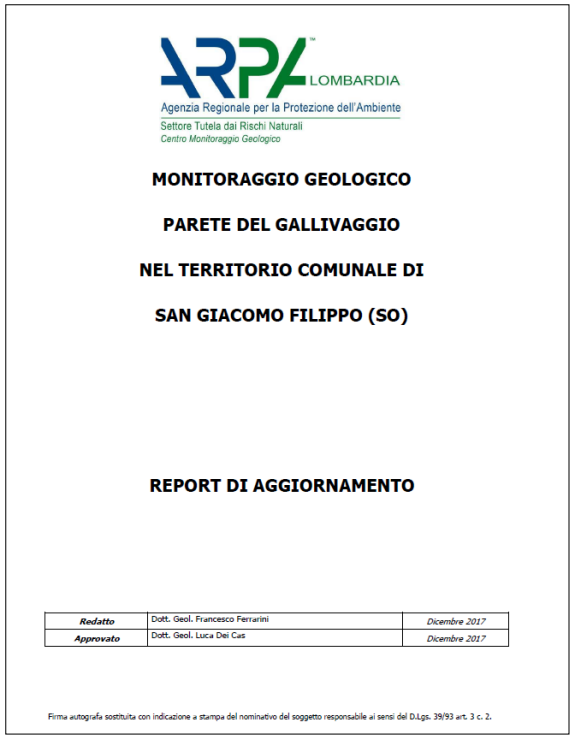
The different colour lines represent the **area boundary where the landslide could arrive** with changeable probability (function of historical events printed on bibliography).

Most of the analysis showed that the infrastructure and cultural heritage (road and Sanctuary) are threatened (the rock mass failure could impact them)



During the Autumn 2017 the data analysis values acquired, enabled us to notify the Lombardy Region Civil Protection of a **dangerous acceleration** of movement in about 460 m^2 of the rock area (5-6000 mc).





ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente
Settore Tutela dai Rischi Naturali
Centro Monitoraggio Geologico

MONITORAGGIO GEOLOGICO

PARETE DEL GALLIVAGGIO

NEL TERRITORIO COMUNALE DI

SAN GIACOMO FILIPPO (SO)

REPORT DI AGGIORNAMENTO

Redatto	Dott. Geol. Francesco Ferrarini	*Dicembre 2017*
Approvato	Dott. Geol. Luca Dei Cas	*Dicembre 2017*

Firma autografa sostituita con indicazione a stampa del nominativo del soggetto responsabile ai sensi del D.Lgs. 39/93 art. 3 c. 2.

In February 2018, we sent another notification in which we informed the Civil Protection about the acceleration showed a doubling of the values compare to the previous ones in Autumn.

Rock block failure: April 13th 2018

MAY 11TH 2018: PROTECTION OF CULTURAL HERITAGE

24TH MAY 2018

Notice of TRIGGER THRESHOLD EXCEEDED 3mm/24h 24/05/2018 ore 08:01 → **Notice of TRIGGER THRESHOLD EXCEEDED 4mm/24h 24/05/2018 ore 20:42** → **Route «SS 36» closed H24**

29TH MAY 2018

Last Report sent from ARPA LOMBARDIA at hour 16:00

REPORT

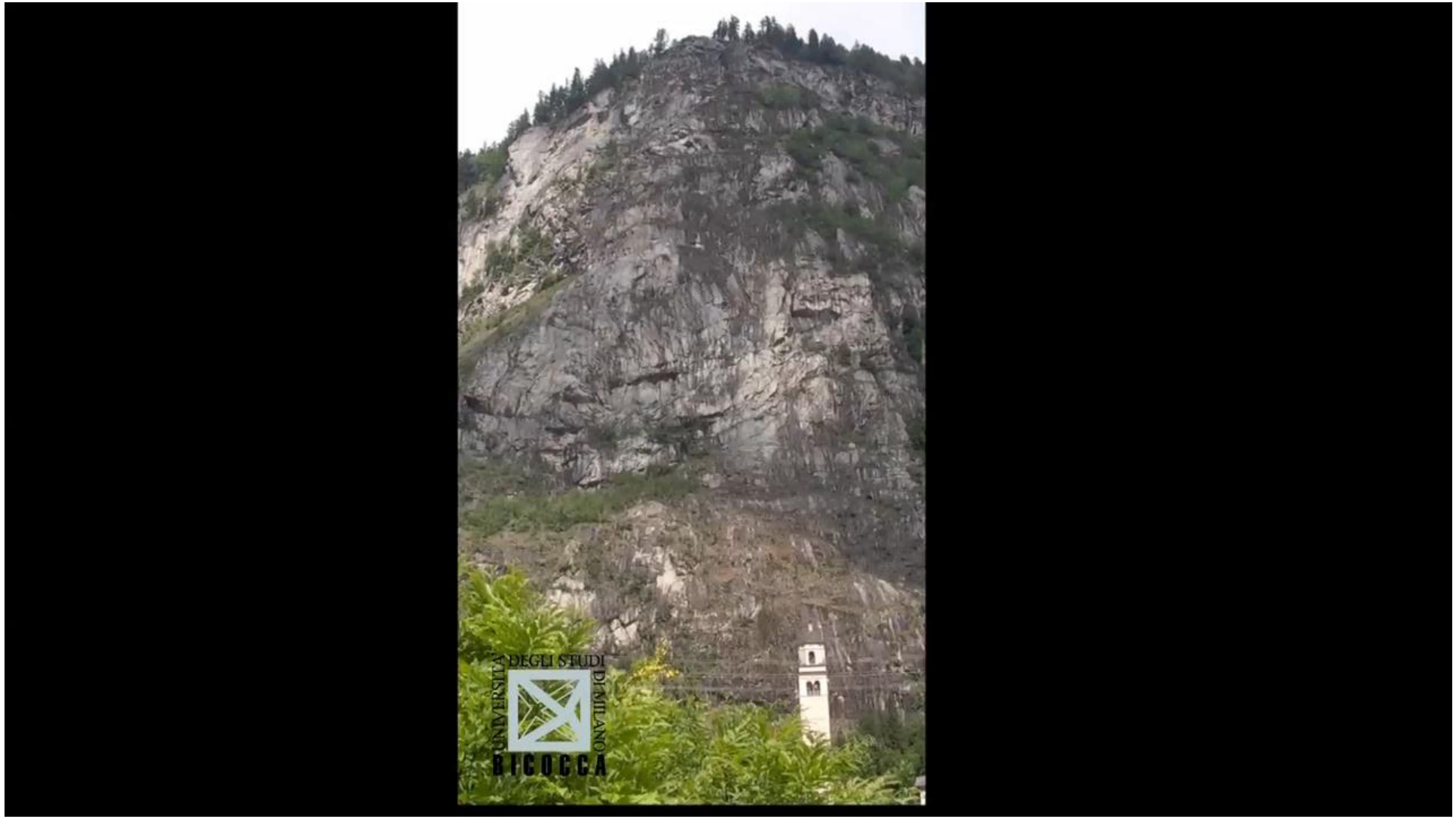
ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

*EMESSO **MARTEDÌ 29 MAGGIO 2018** ALLE **ORE 16.00***

A: REGIONE LOMBARDIA - UNITA' ORGANIZZATIVA PROTEZIONE CIVILE

Situazione del dissesto

Facendo seguito a quanto precedentemente comunicato si osservano nelle ultime 24 ore velocità dei punti monitorati in ulteriore aumento, con valori che hanno raggiunto un massimo di 107.2 mm/24h, con velocita orarie fra le 15 e le 16 di oggi di circa 2 cm/h. Valori così elevati non erano finora stati osservati sull'ammasso. ed il trend di continua accelerazione indica una situazione di estrema pericolosità ormai prossima al collasso.


UNIVERSITÀ DEGLI STUDI DI MILANO
BICOCCA

The infrastructures and cultural heritage after the collapse

Bell tower

The infrastructures and cultural heritage after the collapse

The church

The infrastructures and cultural heritage after the collapse

Sanctuary Square

The infrastructures and cultural heritage after the collapse

Behind the Sanctuary

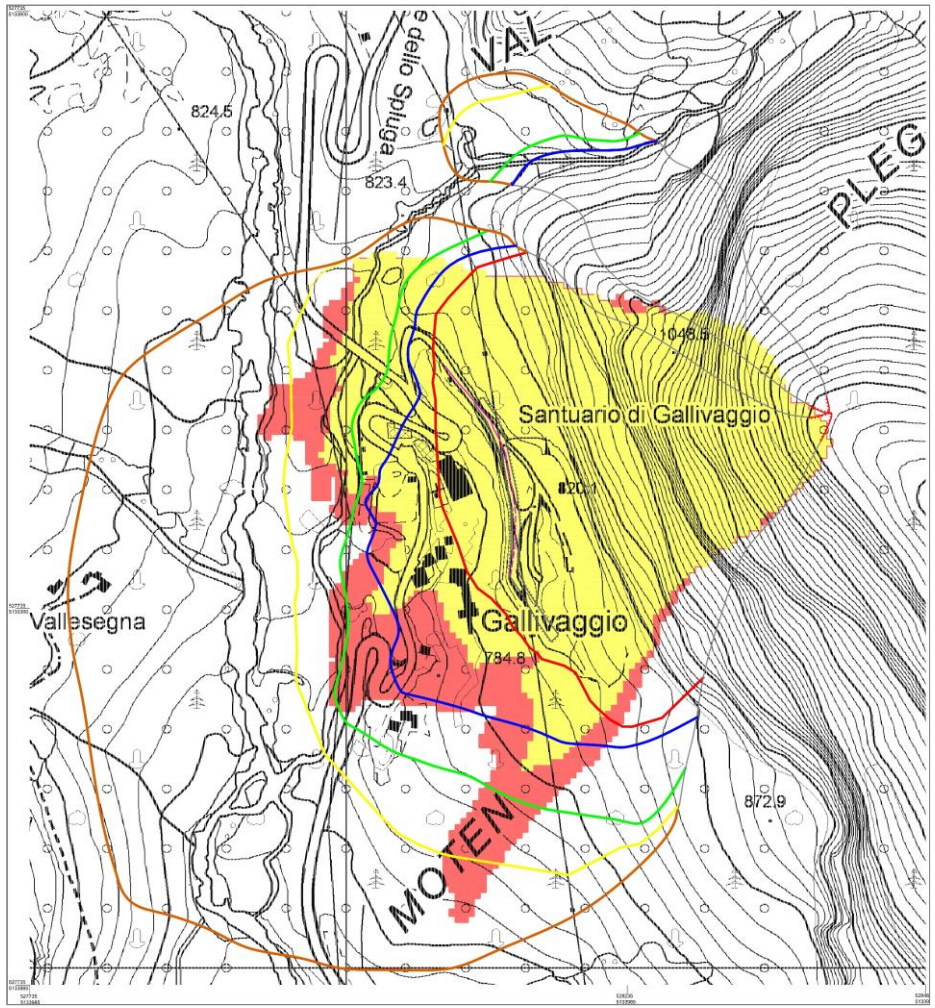
The infrastructures and cultural heritage after the collapse

Rokfall embankment and plants

The infrastructures and cultural heritage after the collapse

Road

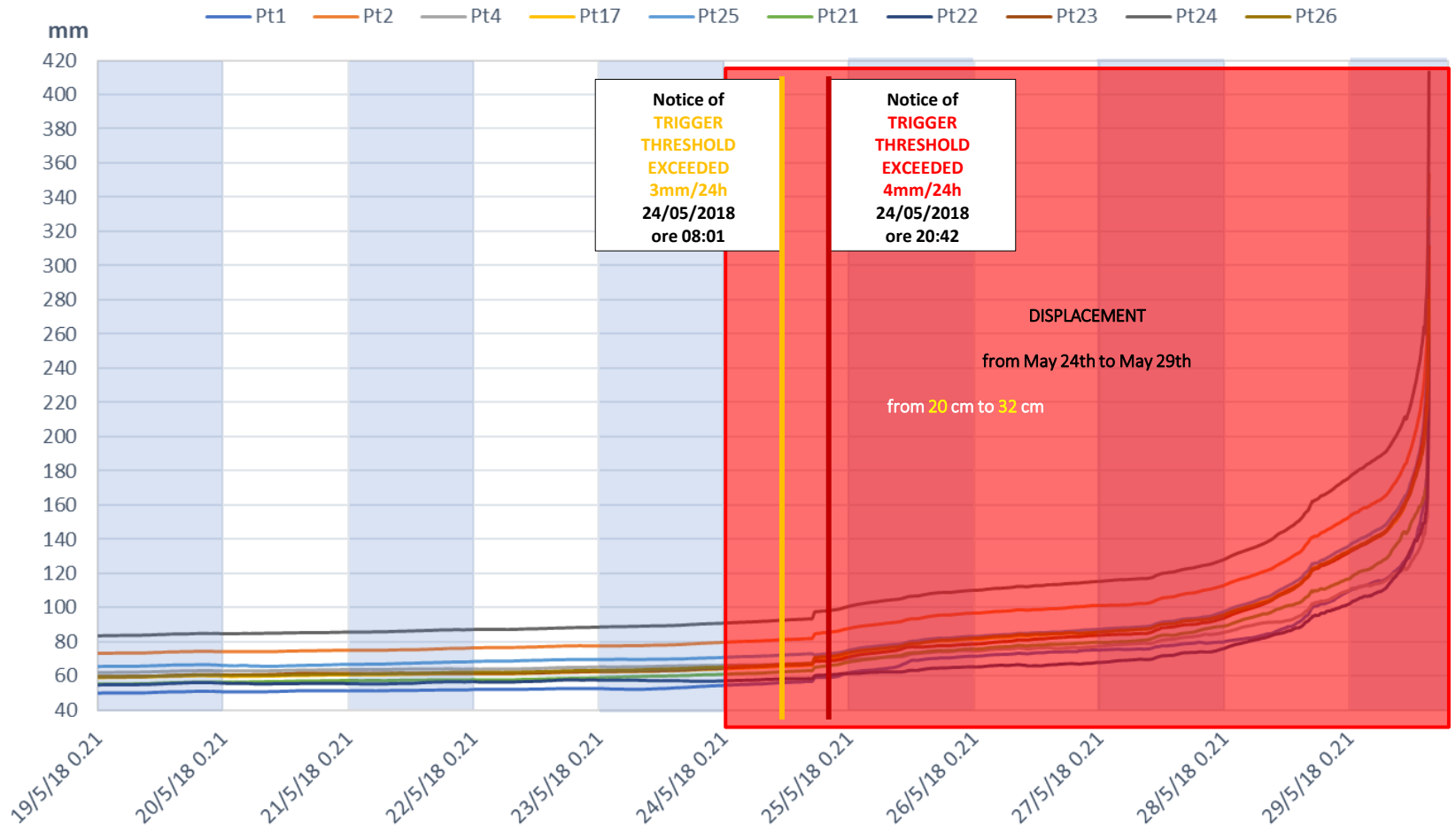
Rock mass failure

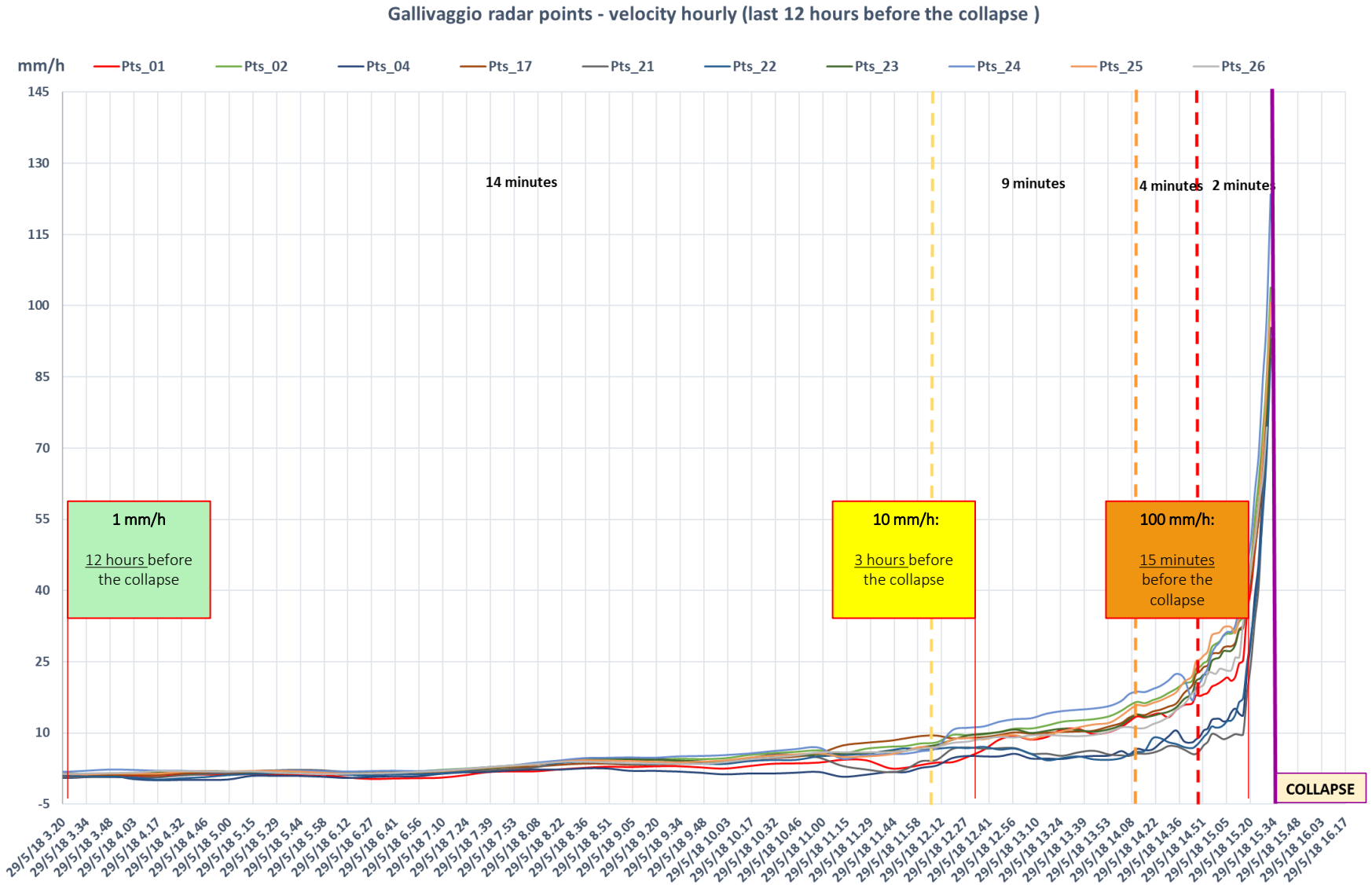


LEGEND (areal distribution of the deposit)

- Landslide crown
- Boundary line rock blocks fallen (b>0,5 m^3)
- Boundary line r. blocks fallen (0,5 m^3 >b>0,05 m^3)
- Boundary line r. b. fallen (0,05 m^3 >b>0,005 m^3)
- Boundary line r. blocks fallen (b<0,005 m^3)
- Boundary line fine grain debris
- Boundary line of lateral debris fallen
- Flexible barriers razed
- Flexible barriers not razed
- Embankment
- Rock mass failure: covered area 95% probability (Cancelli engineering study 2017)
- Rock mass failure: covered area 99% probability (Cancelli engineering study 2017)

Gallivaggio Radar points
Displacements from May 19th to May 29th




Gallivaggio radar points - velocity hourly (last 12 hours before the collapse)
mm/h
Pts_01
Pts_02
Pts_04
Pts_17
Pts_21
Pts_22
Pts_23
Pts_24
Pts_25
Pts_26
145
130
115
100
85
70
55
40
25
10
-5
14 minutes
9 minutes
4 minutes
2 minutes
1 mm/h
12 hours before the collapse
10 mm/h:
3 hours before the collapse
100 mm/h:
15 minutes before the collapse
COLLAPSE

Conclusion

Efficacy of the monitoring network: the performance of the network gives us data values to identify vast movement areas and permit us to see gradual movement (0,03 mm/d) and then to monitoring movement close to any failure. It isn't effective for single rock block falls.

The collection of GBInSAR data values: the collection of data values, from the start of acceleration to the time of rock mass failure, permitted us to have all acceleration data values (0,1 mm/h 6 day from failure, 1 mm/h 40 hour from failure, 10 mm/h 3 hour from failure, 100 mm/h 15 minutes before failure).

In May 2018, monitoring was the only activity to guarantee human safety and protection of cultural heritage: with evacuation, the SS 36 route closed, removal of sacred paintings and gold sacred cups before the failure.

THANK YOU FOR YOUR ATTENTION !!

Gallivaggio landslide Bibliography

- «**Gallivaggio landslide: the geological monitoring, of a rock cliff, for early warning system**" Italian Journal of Geology and Enviroment. n.2(2018) pg.41-55; Aut: L. Dei Cas et al. DOI 10.4408/IJEGE.2018-02.O-03

-"**Geological monitoring networks for risk management close to large rock cliffs: the case history of Gallivaggio and Cataeggio in the italian Alps**" Geogr. Helv., 76, 85–101, 2021 Aut.: Luca Dei Cas, Maria Luisa Pastore, Andrea Pavan, and Nicola Petrella DOI.org/10.5194/gh-76-85-2021

-"**Rockfall forecasting and risk management along a major transportation corridor in the Alps through ground-based radar interferometry**" Landslides, April 2019 . Aut: T. Carlà, T. Nolesini, L Solari, C. Rivolta, L. Dei Cas, N Casagli DOI 10.1007/S10346-019-01190-y

-«**Previsione e gestione del rischio da caduta massi e progettazione degli interventi di mitigazione. Il caso della parete rocciosa di Gallivaggio**" ATTI DEL XXVII CONVEGNO NAZIONALE DI GEOTECNICA (pg. 573-580) Reggio Calabria 13-15 luglio 2022: Aut: G. Bragonzi, P. Cancelli, F. Cattaneo, L. Dei Cas, L. Tedeschi, ISBN 978-88-97517-14-6

- "**Reliability and Uncertainties of the Analysis of an Unstable Rock Slope Performed on RPAS Digital Outcrop Models: the Case of the Gallivaggio Landslide (Western Alps, Italy)**» Remote Sensing May 2020 Aut: T. Menegoni D. Giordan