

Alessandro Corsini⁽¹⁾, Francesco Ronchetti⁽¹⁾, Francesco Bonacini⁽²⁾,
Alessandro Capra⁽²⁾, Eleonora Bertacchini⁽²⁾, Cristina Castagnetti⁽²⁾, Giovanni
Truffelli⁽³⁾, Giuseppe Caputo⁽³⁾, Gaetano Sartini⁽³⁾, Enrico Leuratti⁽³⁾, Claudio
Corrado Lucente⁽³⁾, Vinicio Manzi⁽⁴⁾, Elena Piantelli⁽⁵⁾

LONG-TERM CONTINUOUS TOPOGRAPHIC LANDSLIDE MONITORING: CASE STUDIES IN THE APENNINES OF EMILIA ROMAGNA REGION

(1) University of Modena and Reggio Emilia - Earth Science Department, Civil and Mechanical Engineering Department.), Modena, Italy, Largo S. Eufemia 19 41121 Modena, +39/059/2058260 alessandro.corsini@unimore.it

(2) University of Modena and Reggio Emilia - Civil and Mechanical Engineering Department

(3) Emilia Romagna Region, Technical Basin Services, Parma, Reggio Emilia, Modena, Rimini (Italy)

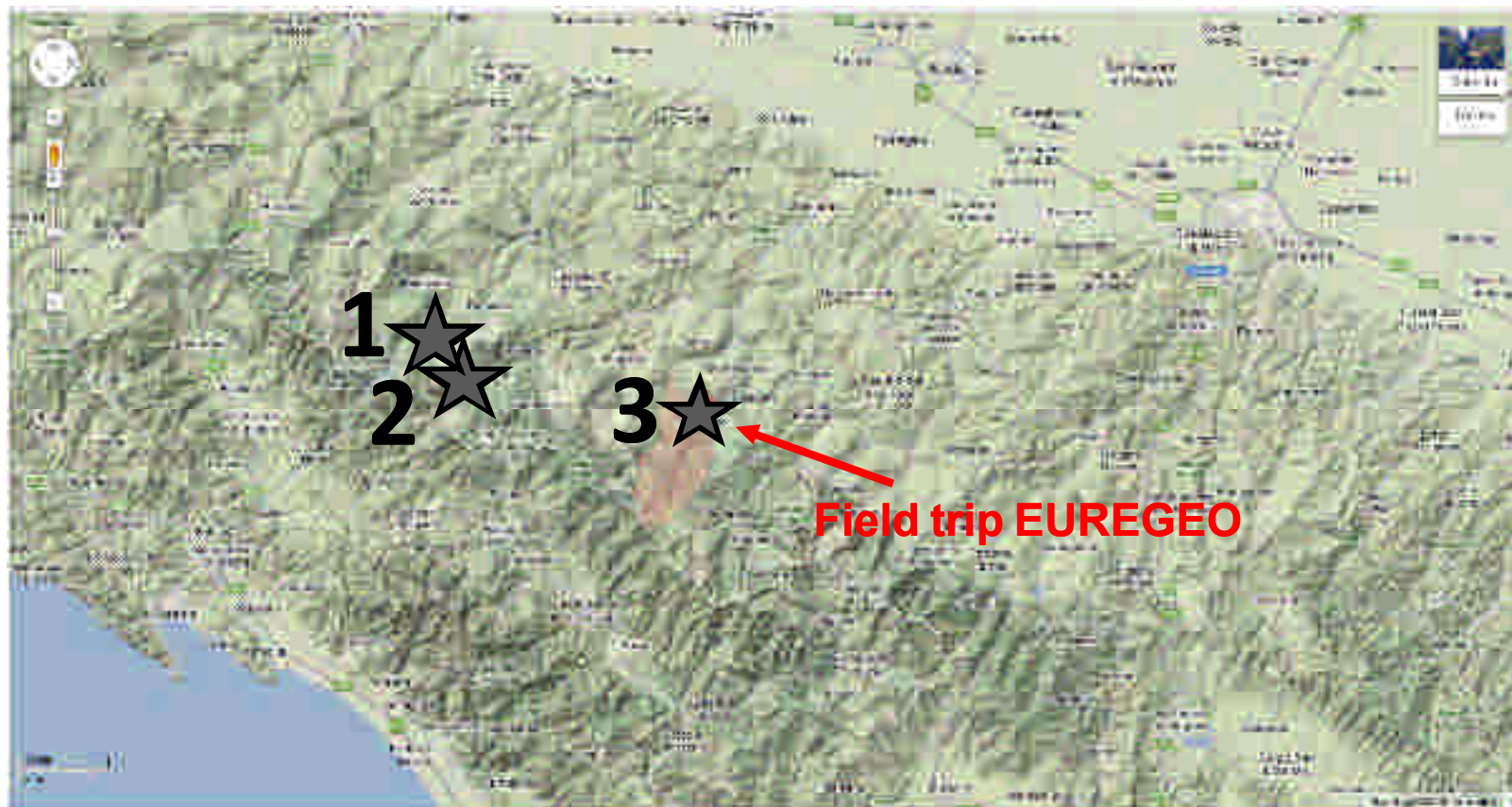
(4) University of Parma - Earth Sciences Department (Italy)

(5) Leica Geosystems, Business Development Engineering & Solutions, Lodi (Italy)



SITES

1. SUCCISO (earth slide)
2. COLLAGNA (rock slide – earth slide)
3. VALORIA (earth slide / flow)





SITES

SUCCISO (cm/year)



Succiso village, road

COLLAGNA (dm/year)



elements at risk

National Road SS63, river

VALORIA (m/year)



Province road, houses, river

RATIONALE & OBJECTIVES

✓ Considered that:

SUCCISO, COLLAGNA and VALORIA cause risk to roads and hamlets

✓ Need for:

- Improve surveillance of surface displacement
- Define spatio-temporal patterns of movements
- Define displacements vs precipitations relationships
- Define structural and/or non structural mitigation strategies

✓ Opted for:

- Topographic monitoring networks based on Automated Total Stations (ATS) since:
 - ATS are precise, reliable and flexible monitoring tools
 - ATS can be controlled from remote.
 - ATS + controlling SW + processing SW can produce semi-continuous near-real time data and processed information.

✓ Agreed that:

- Monitoring for surveillance and attention. NOT for ALARM!



Aims of the presentation

1) To explain the architecture of the monitoring system

2) To show the monitoring network for each of the 3 sites

3) To illustrate the results of the topographic monitoring for each
landslide

4) Explain/Relate the different activity of landslide, the different
distribution or type of movement, according on the different type of
landslide

5) To define the reactivation/acceleration – rainfall relationship



AUTOMATED TOTAL STATIONS (ATS) NETWORK



Regione Emilia-Romagna
 SERVIZIO SCIENTIFICO REGIONALE ED ENTITA' LOCALI



Leica TCA 2003



Leica TM30

**DST-DIMEC
 UNIMORE
 data management
 centre**

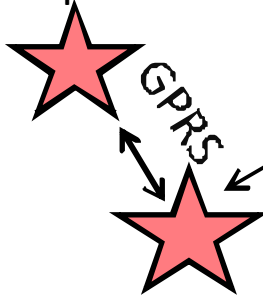
**STB-RER
 Reggio E.**

**STB-RER
 Modena**

**CP & GS - RER
 Bologna**

**SUCCISO
 TCA 2003**

4 duty cycles/day
 about 20 prisms



**COLLAGNA
 TM30 + MASTER**

4 duty cycles/day
 about 40 prisms

**VALORIA
 TCA2003 + MASTER [+ GPS]**

3 to 4 duty cycles/day; about 40 prisms

GPRS

GPRS

automated data transfer
 every duty cycle

ftp & remote
 desktop

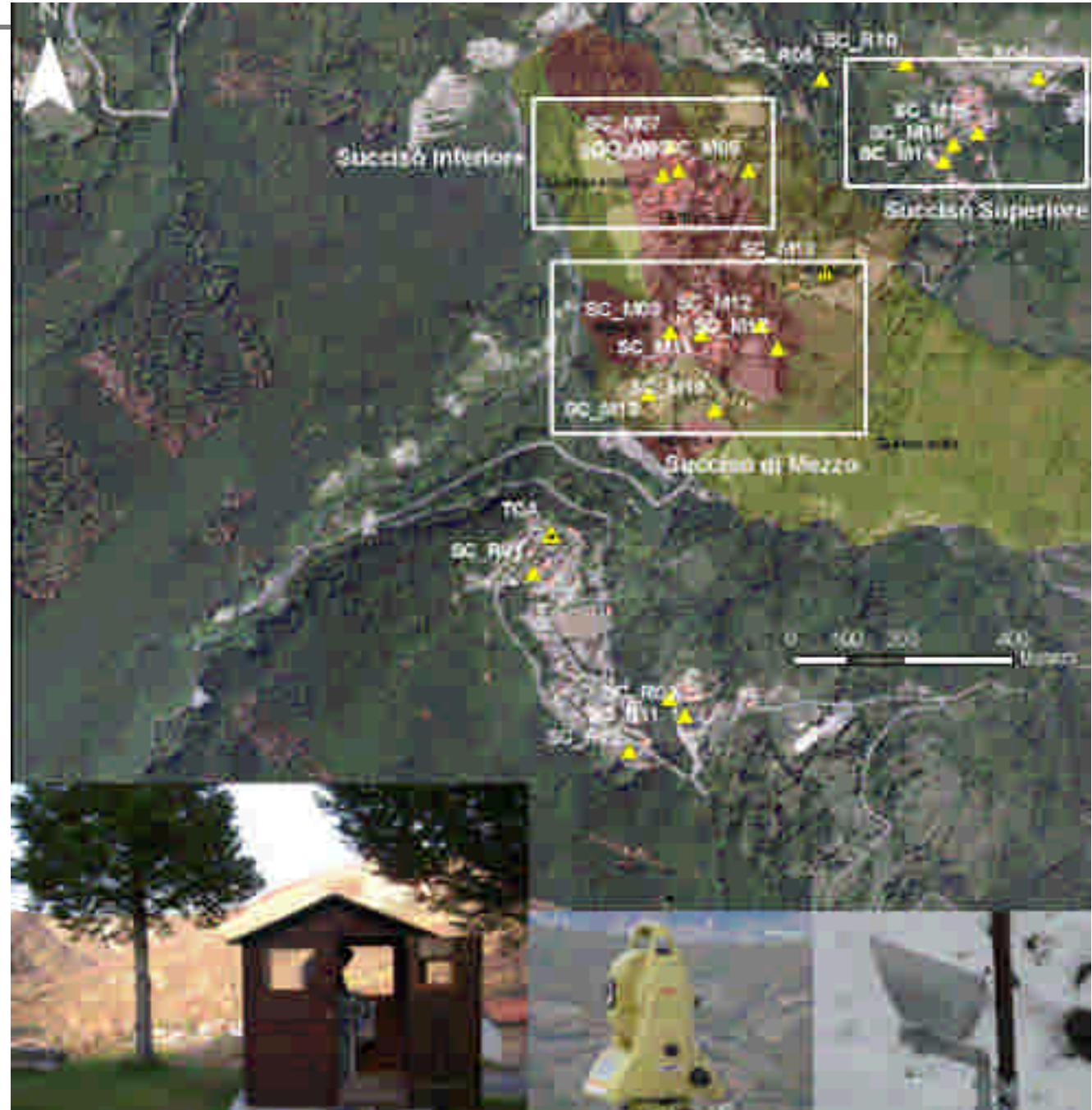
ftp & remote desktop



SUCCISO (earth slide)

about 20 prisms

MONITORING NETWORK



MONITORING NETWORK

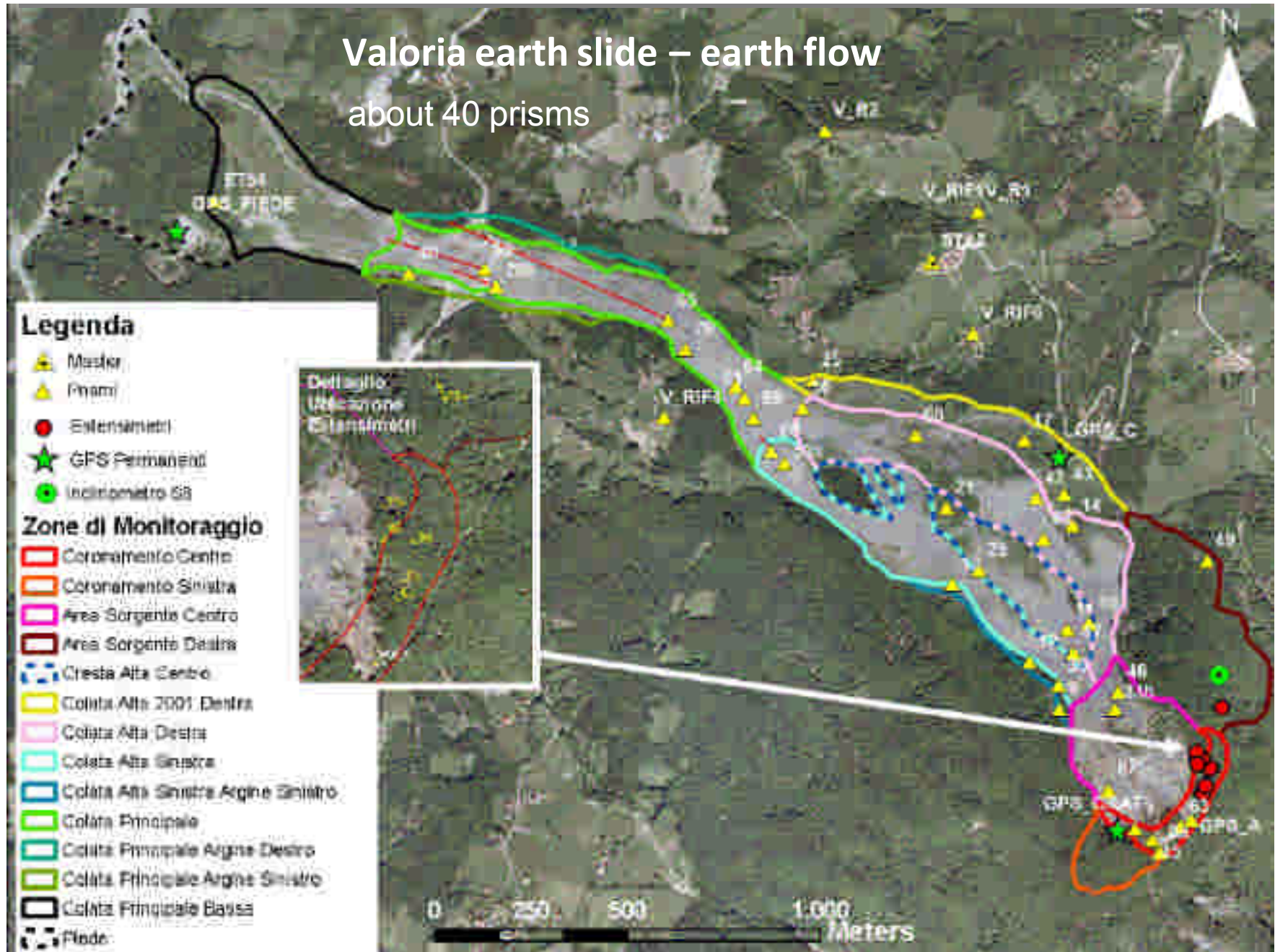
Field trip EUREGEO

Valoria earth slide – earth flow
about 40 prisms



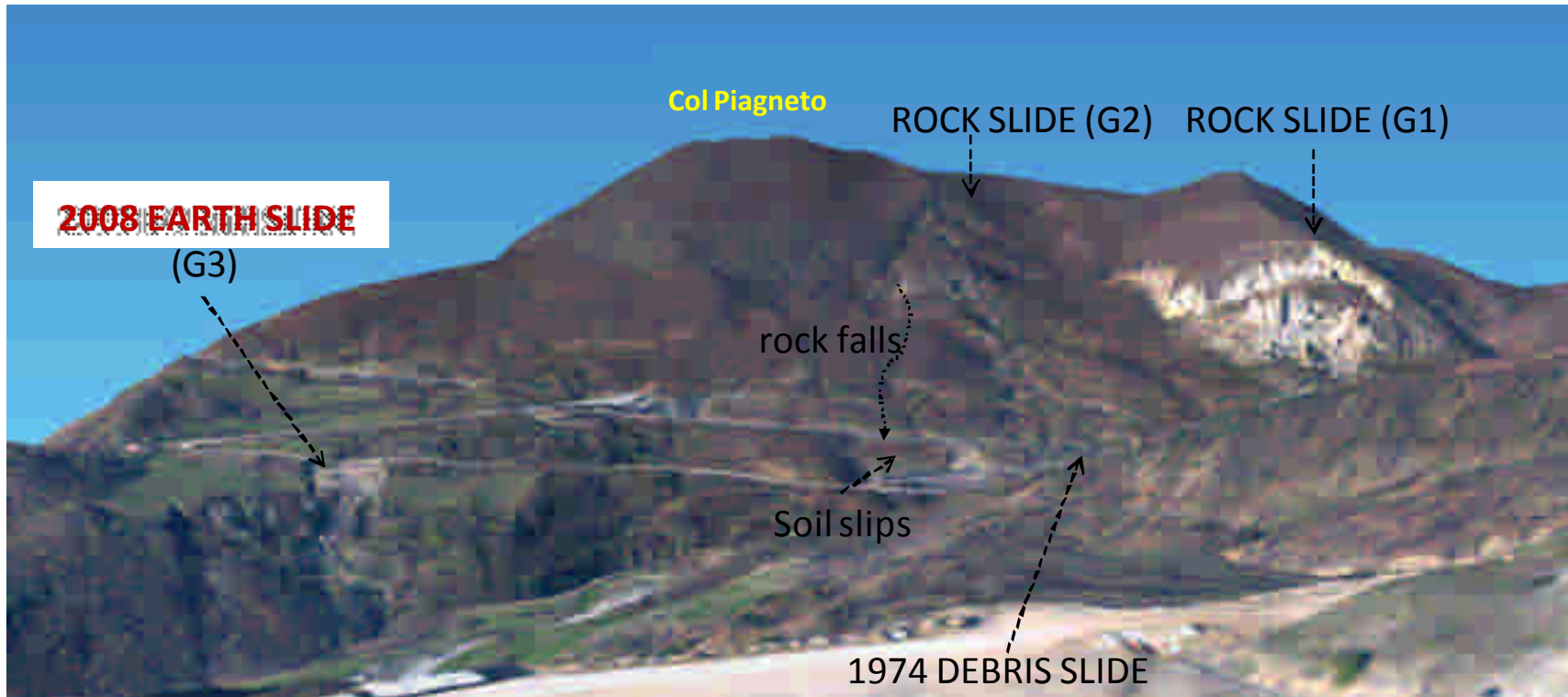
Regione Emilia-Romagna
SERVIZIO REGIONALE REGIONALE DEL TERRITORIO

WWW.UNIMORE.IT



MONITORING NETWORK

COLLAGNA (rock slide – earth slide)



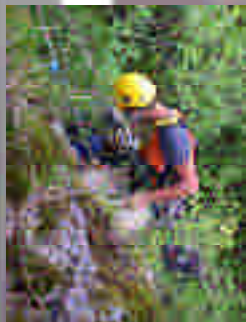
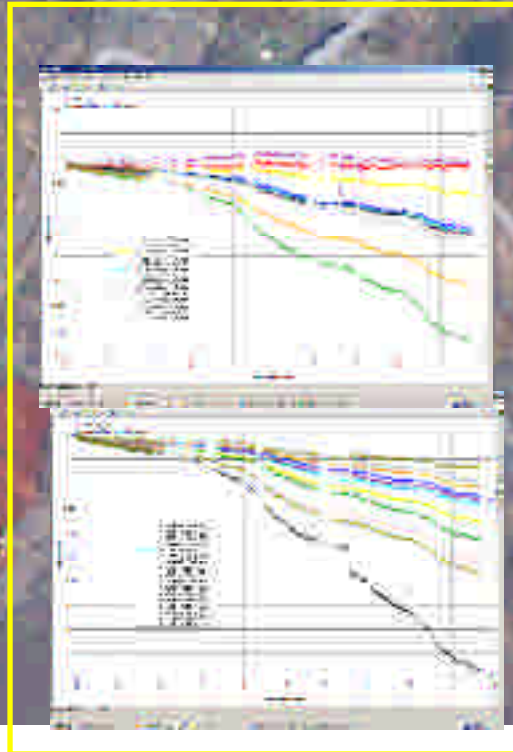
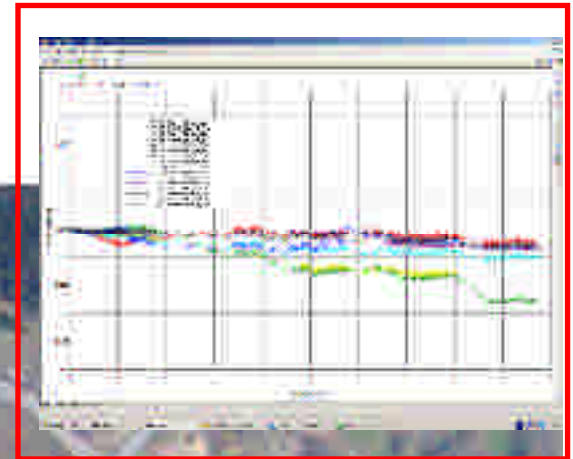
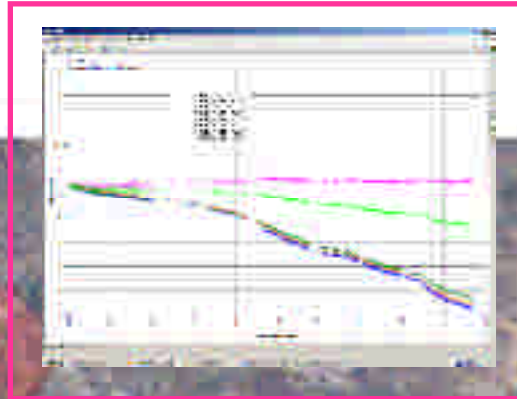
MONITORING NETWORK



Regione Emilia-Romagna
SERVIZIO REGIONALE PROTEZIONE CIVILE

COLLAGNA (rock slide – earth slide)

34 prisms
6 reference points

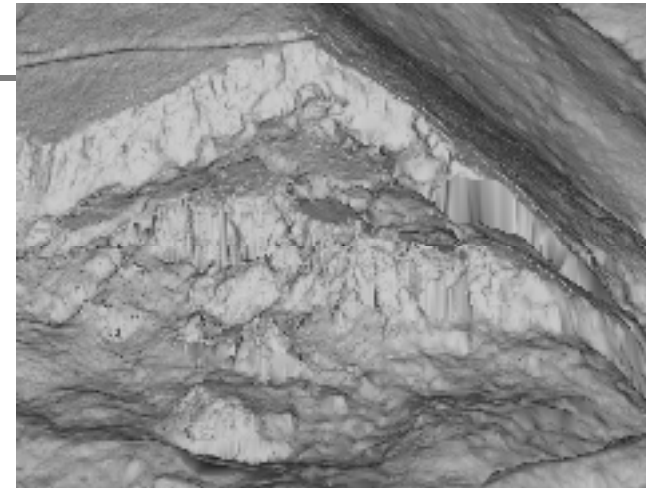


WWW.DPC

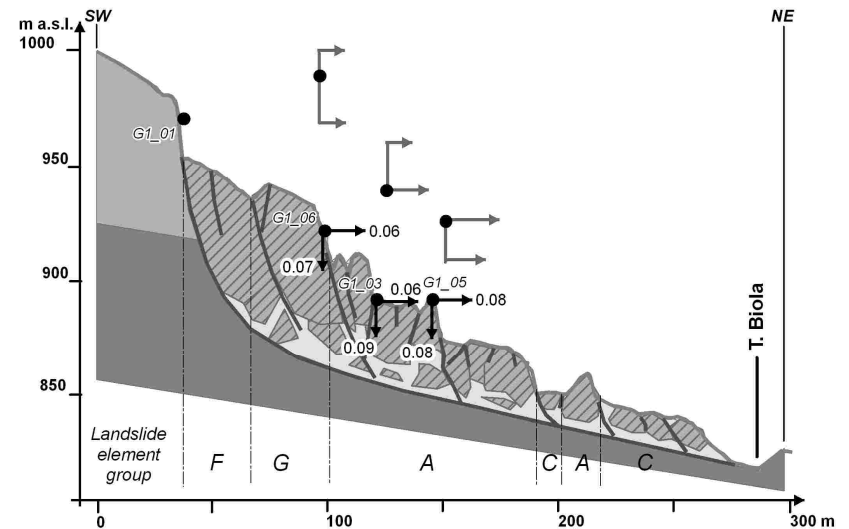


RESULT: COLLAGNA ROCK SLIDE

Monitoring from Oct 2009 – Jun 2012



Limestone blocks, separated by large open fractures, sliding on clayey-shale

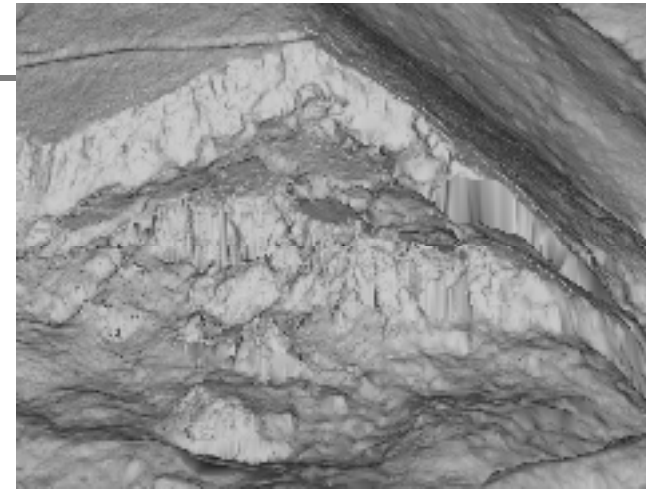


| | |
|-------------------------|--------------|
| Length [m] | 450 |
| Max. depth [m] | 50-60 |
| Travel Angle [°] | 30 |

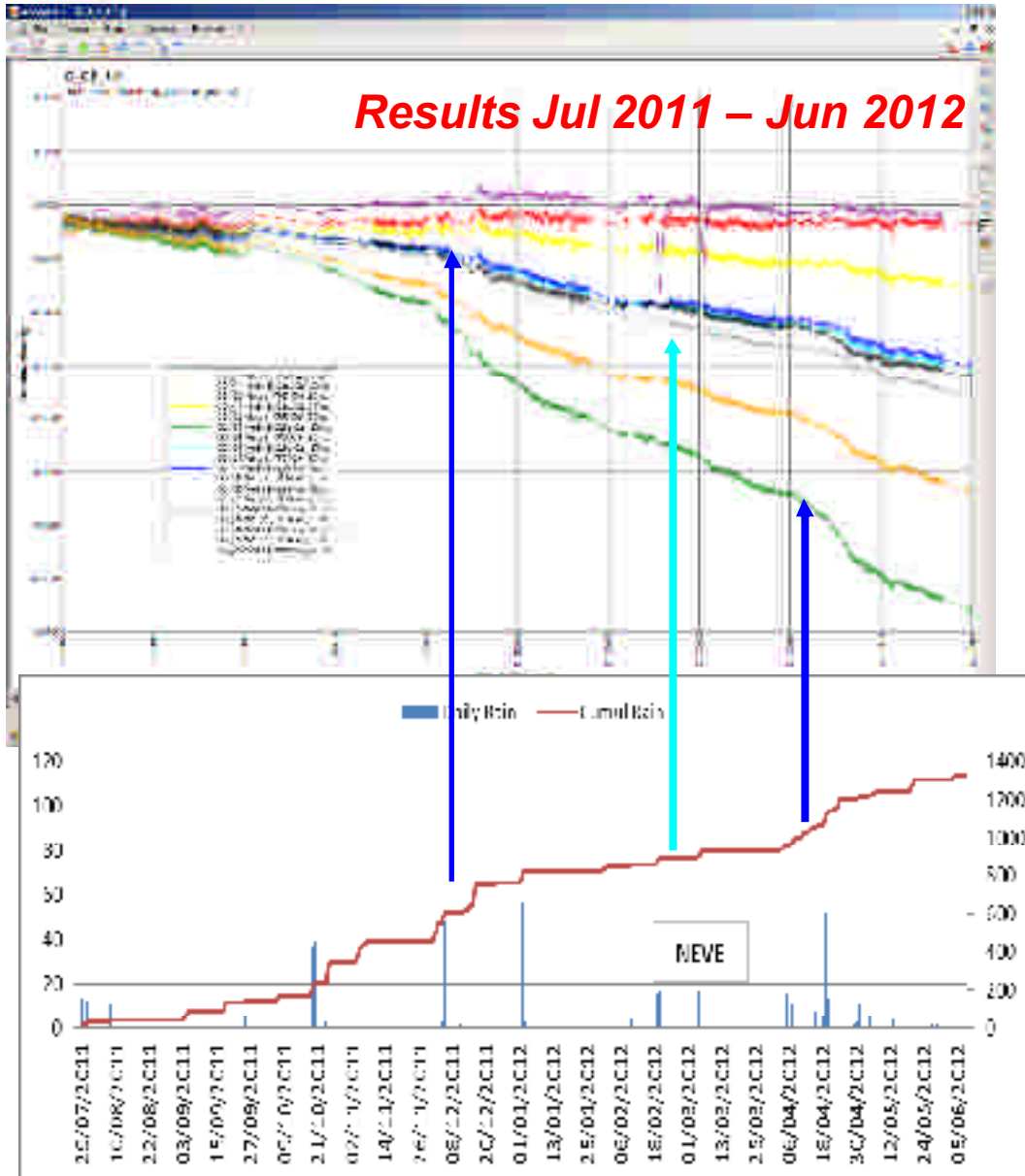


RESULT: COLLAGNA ROCK SLIDE

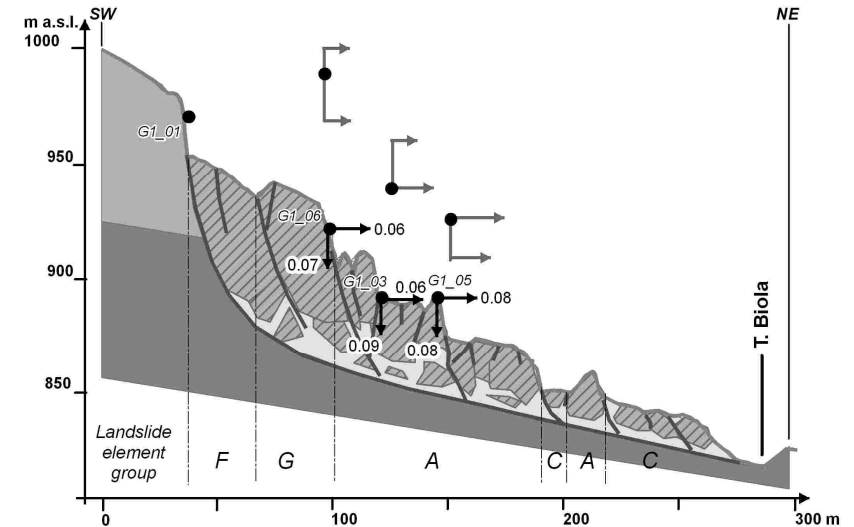
Monitoring from Oct 2009 – Jun 2012



Results Jul 2011 – Jun 2012



Limestone blocks, separated by large open fractures, sliding on clayey-shale



| | |
|-------------------------|--------------|
| Length [m] | 450 |
| Max. depth [m] | 50-60 |
| Travel Angle [°] | 30 |

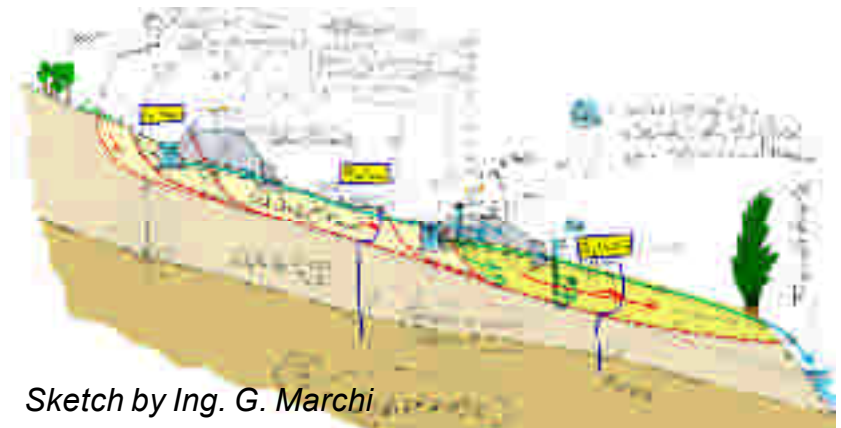


RESULT: COLLAGNA EARTH SLIDE - FLOW

Monitoring from Oct 2009 – Jun 2012



Landslide material: silt-clay matrix

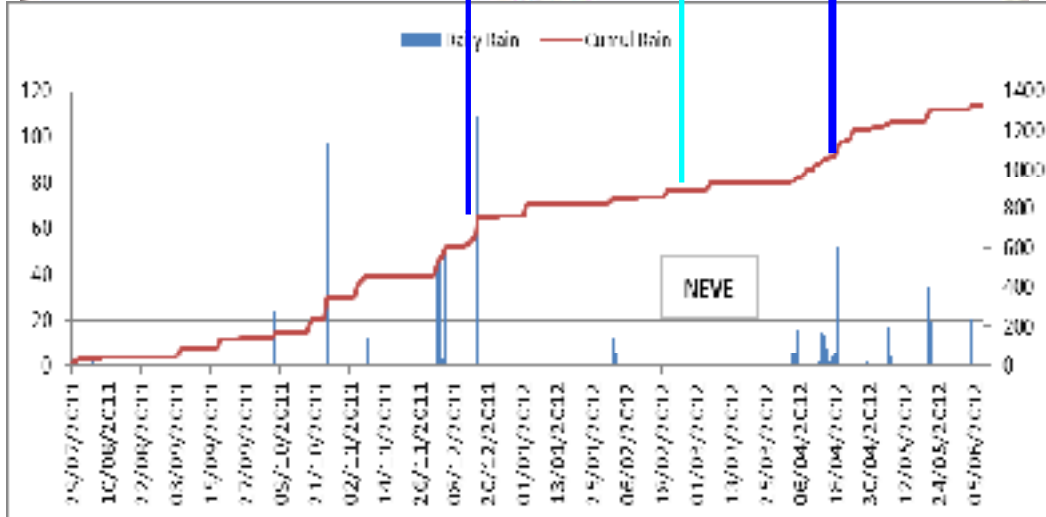


| | |
|-------------------------|------------|
| Length [m] | 350 |
| Max. depth [m] | 15 |
| Travel Angle [°] | 12 |

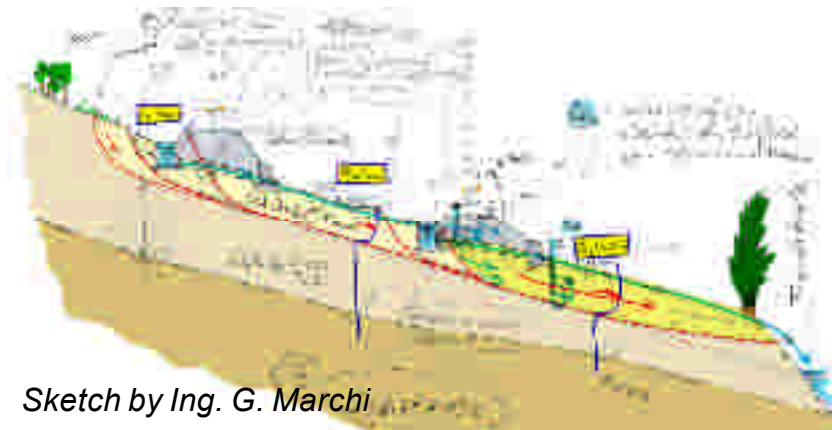


RESULT: COLLAGNA EARTH SLIDE - FLOW

Monitoring from Oct 2009 – Jun 2012



Landslide material: silt-clay matrix



| | |
|-------------------------|------------|
| Length [m] | 350 |
| Max. depth [m] | 15 |
| Travel Angle [°] | 12 |

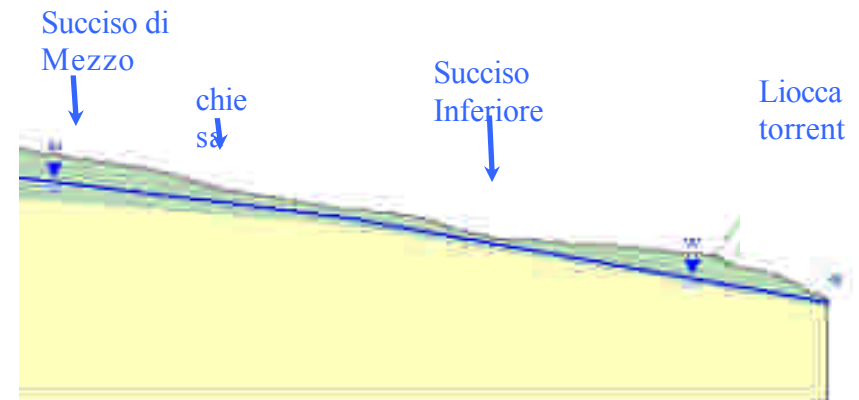


RESULTS: SUCCISO (earth slide)

Monitoring from Oct 2009 – Jun 2012



**Landslide material: moraine deposit
with high clay content**



| | |
|-------------------------|-------------|
| Length [m] | 1300 |
| Max. depth [m] | 30 |
| Travel Angle [°] | 9 |

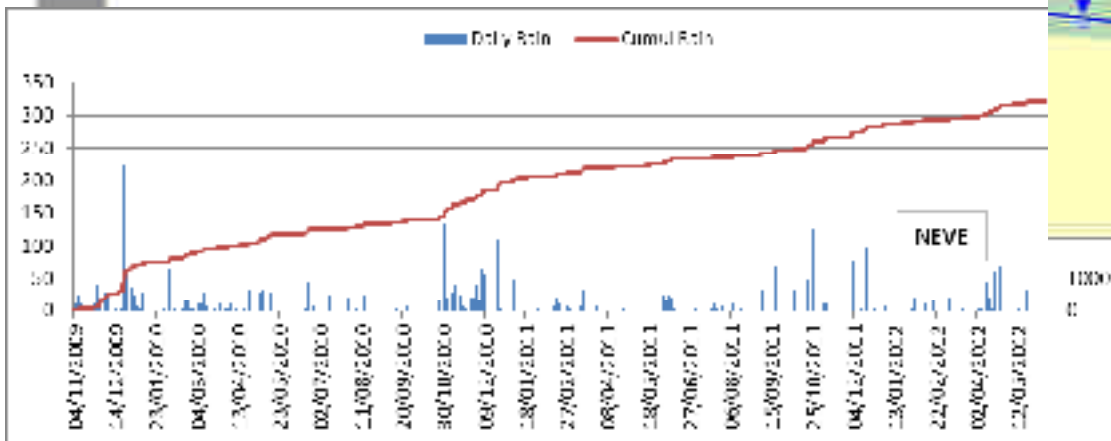
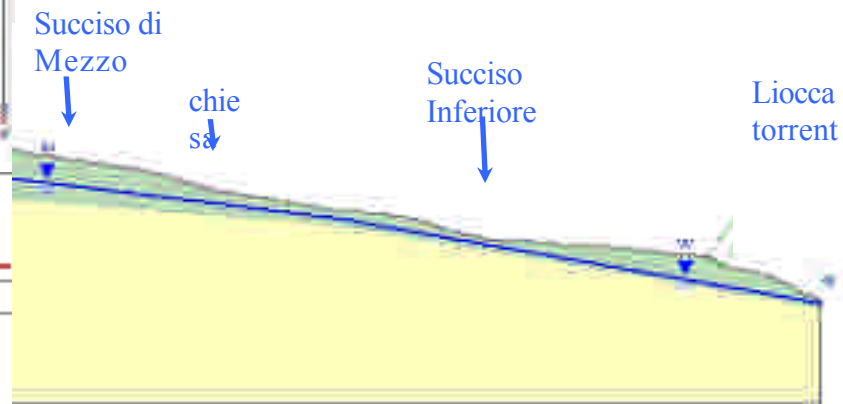
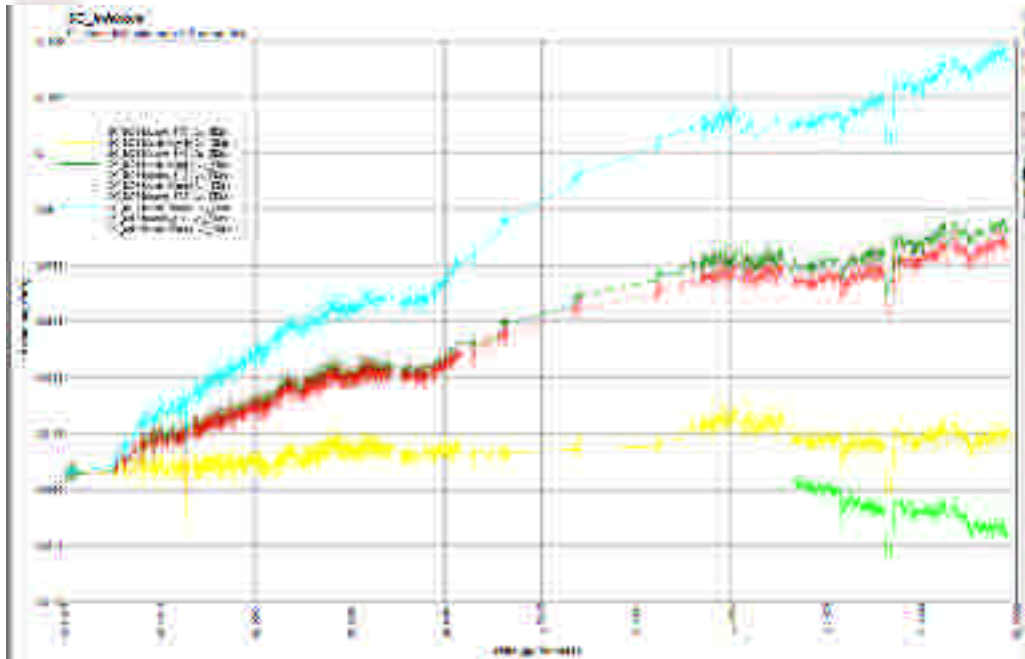


RESULTS: SUCCISO (earth slide)

Monitoring from Oct 2009 – Jun 2012



Landslide material: moraine deposit with high clay content



| | |
|-------------------------|-------------|
| Length [m] | 1300 |
| Max. depth [m] | 30 |
| Travel Angle [°] | 9 |

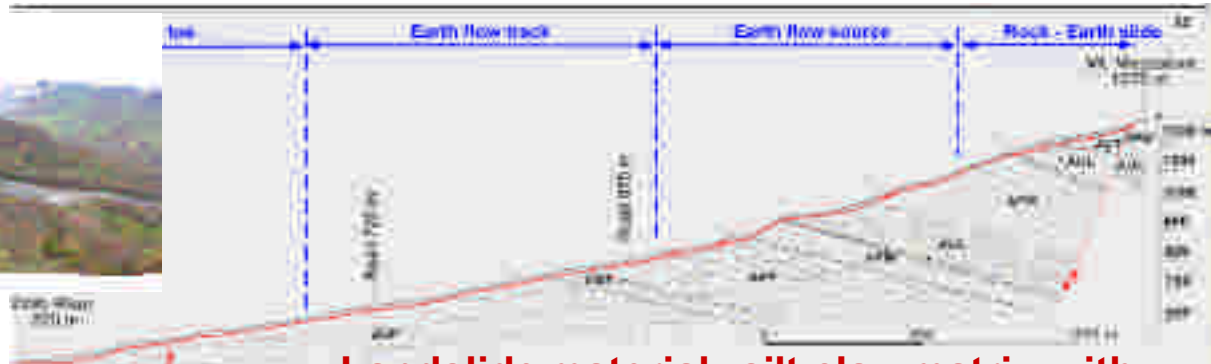


RESULTS: VALORIA EARTH SLIDE - FLOW

Monitoring from Mar 2008 – Jun 2012



| | |
|------------------|------|
| Length [m] | 3500 |
| Max. depth [m] | 30 |
| Travel Angle [°] | 14 |



Landslide material: silt-clay matrix with rock fragments

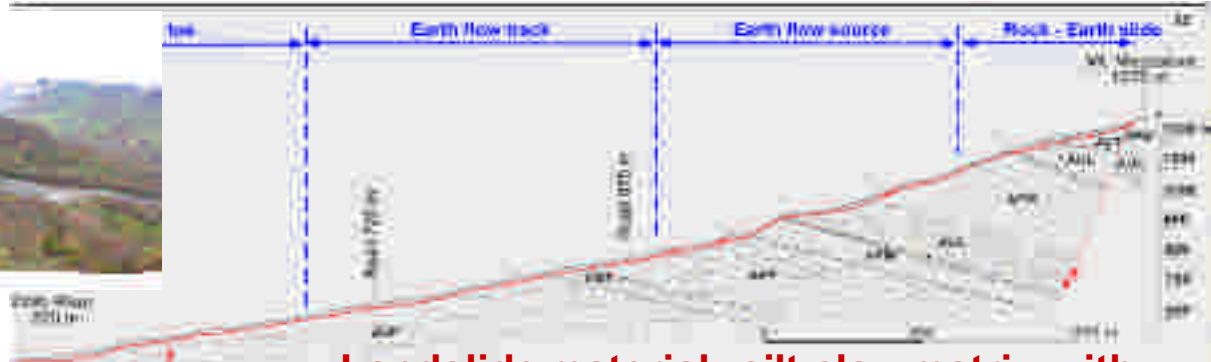


RESULTS: VALORIA EARTH SLIDE - FLOW

Monitoring from Mar 2008 – Jun 2012



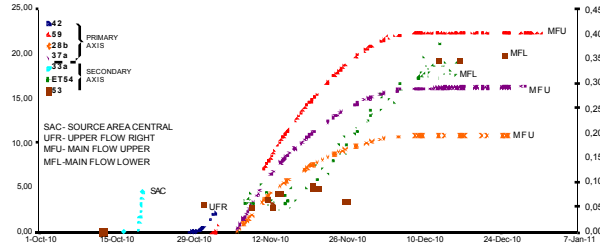
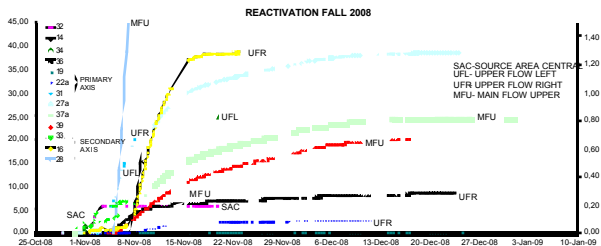
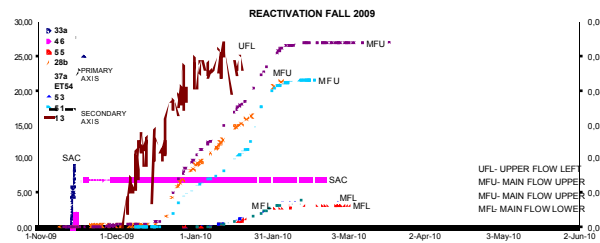
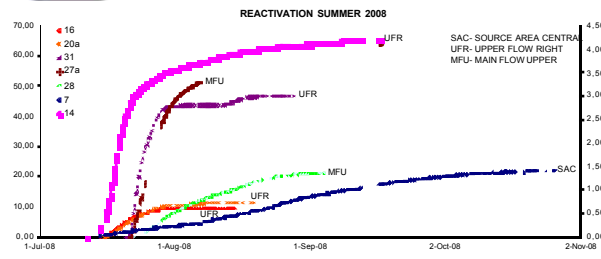
| | |
|----------------|------|
| Length [m] | 3500 |
| Max. depth [m] | 30 |
| Angle [°] | 14 |



Landslide material: silt-clay matrix with rock fragments

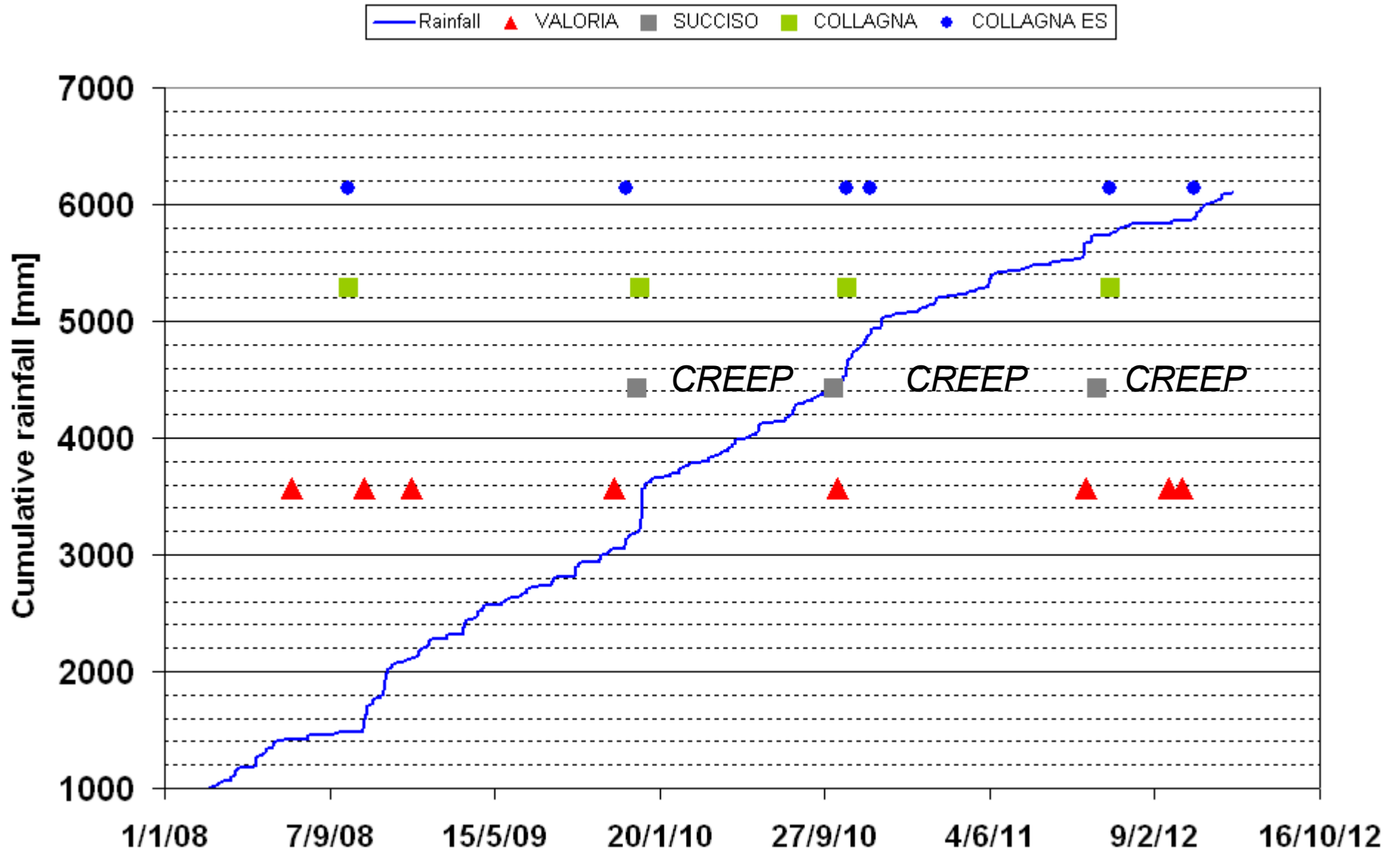
Results Mar 2008 – Jul 2011

Results Jul 2011 – Jun 2012





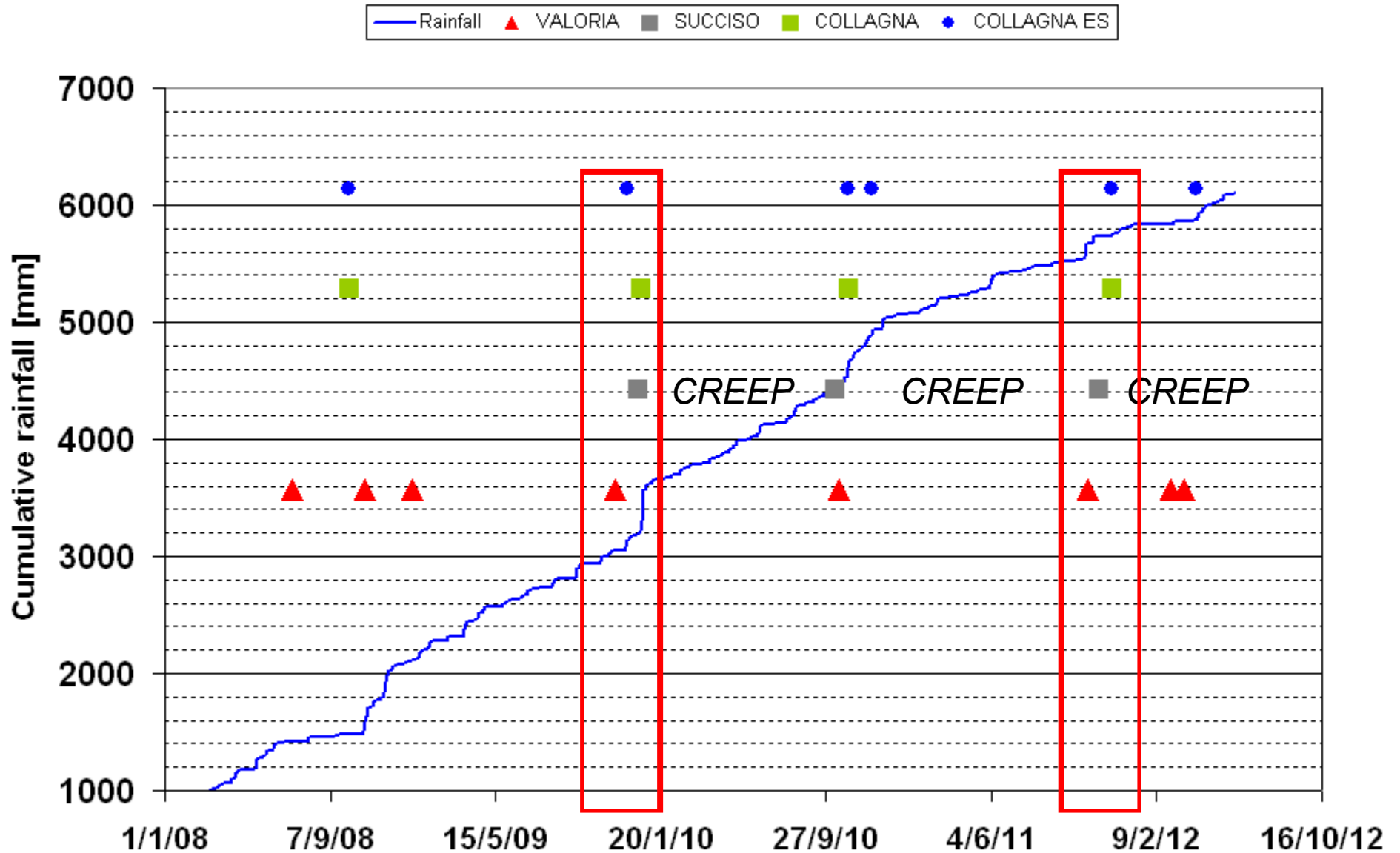
MONITORING RESULTS





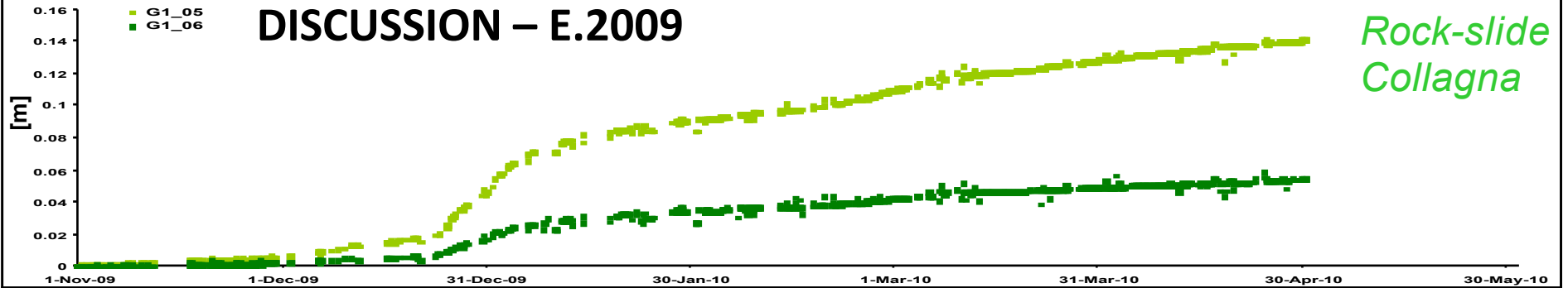
DISCUSSION

ACTIVITY State and Distribution

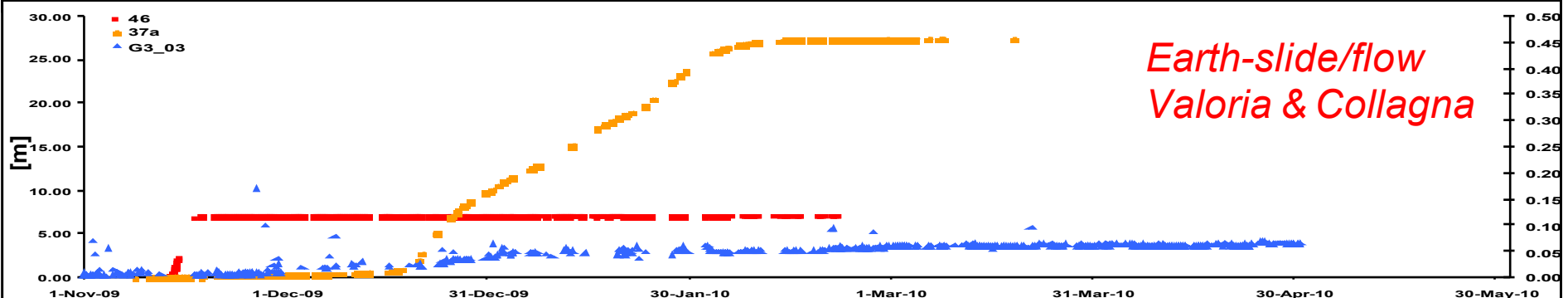


DISCUSSION – E.2009

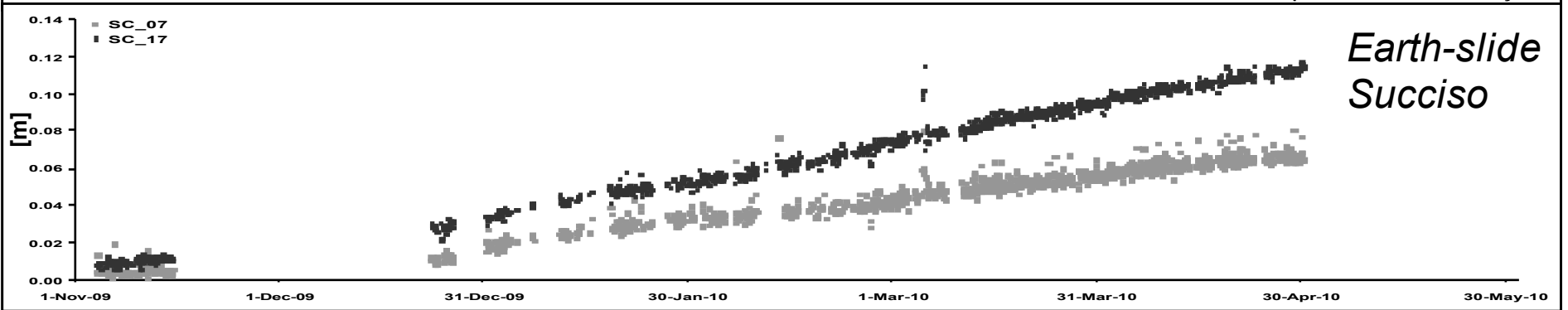
*Rock-slide
Collagna*



*Earth-slide/flow
Valoria & Collagna*



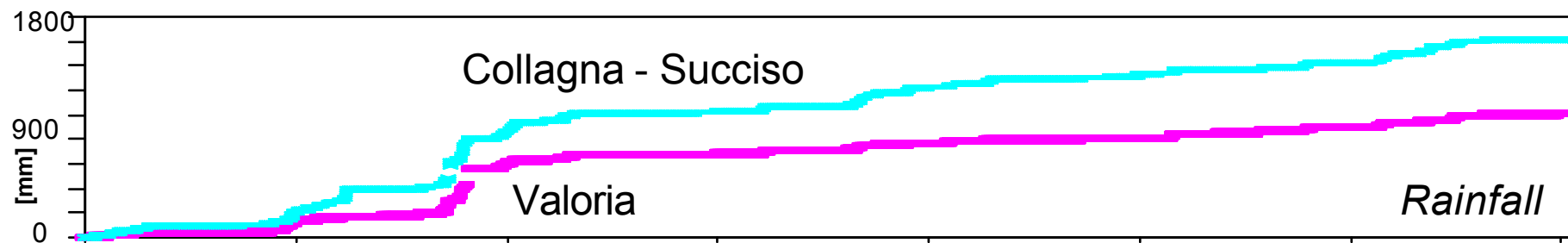
*Earth-slide
Succiso*

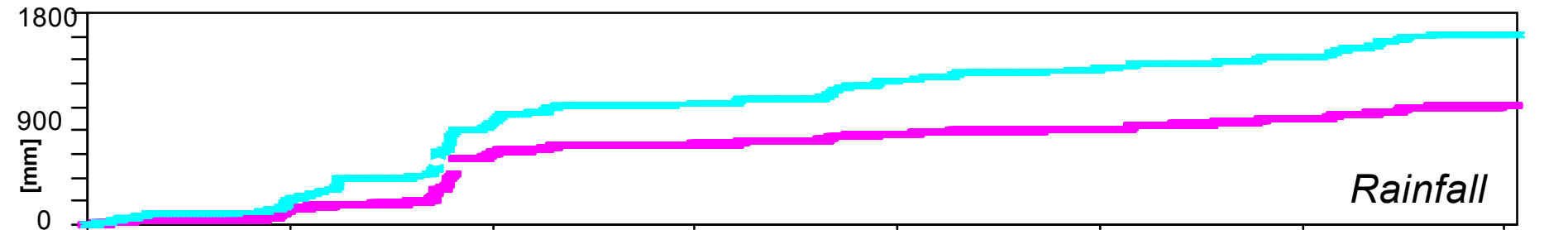
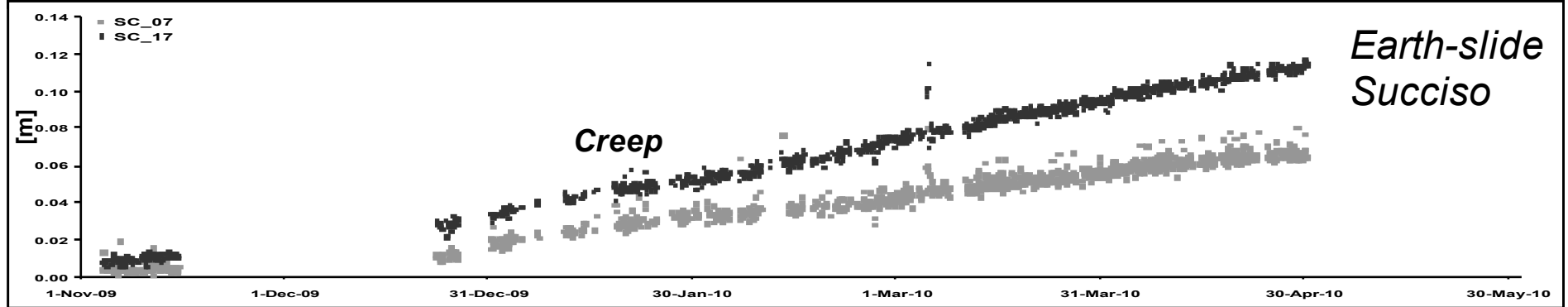
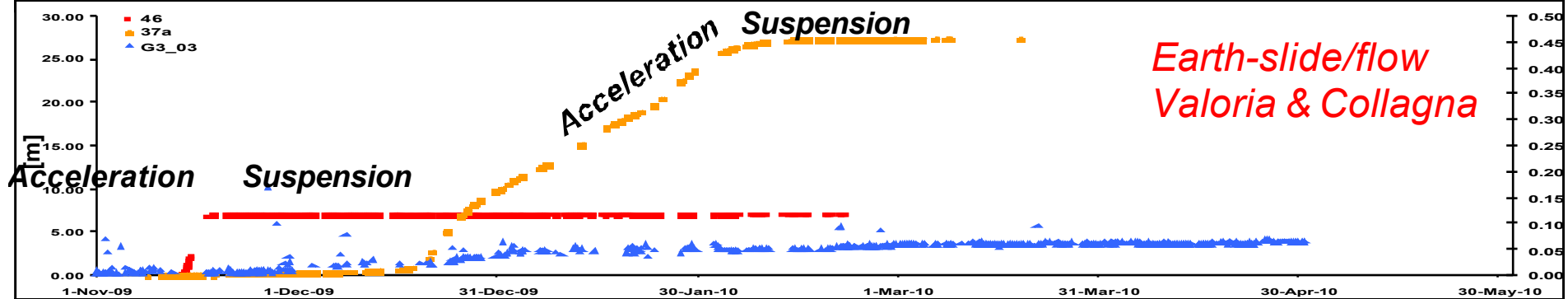
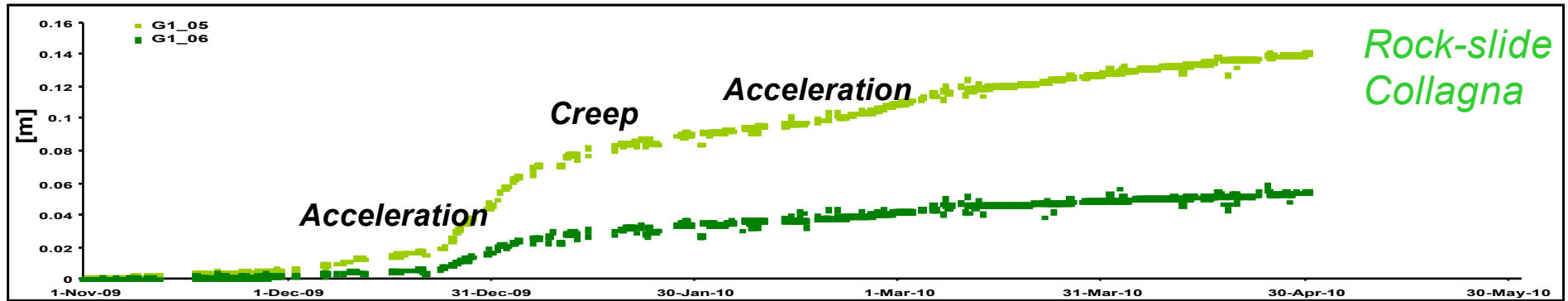


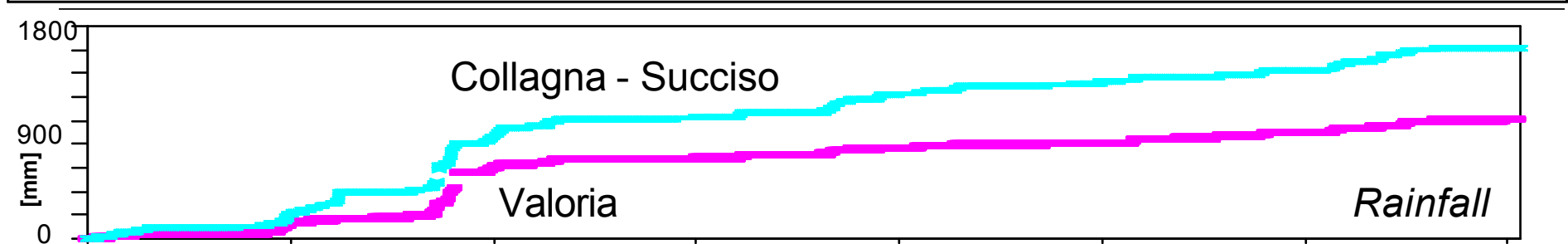
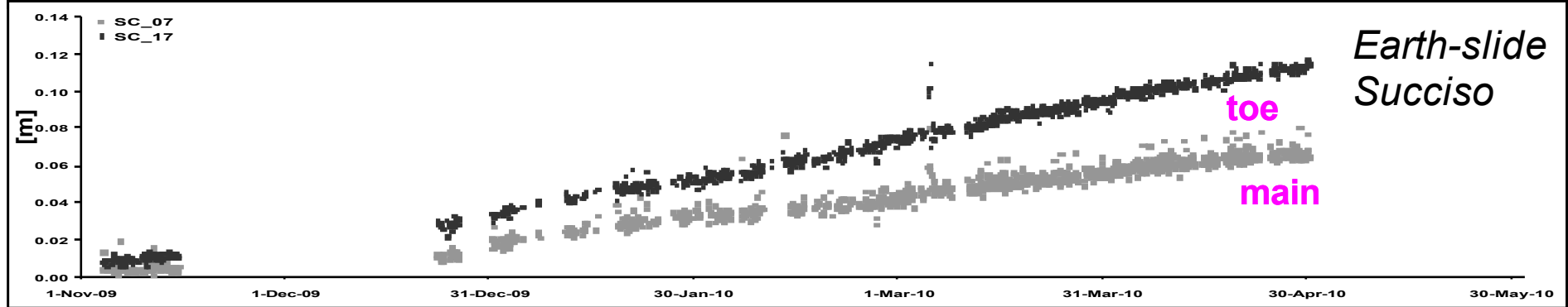
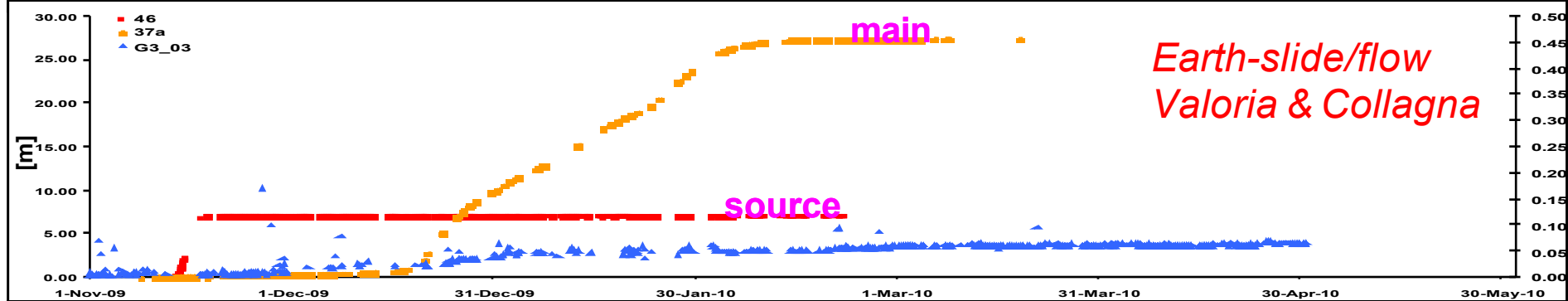
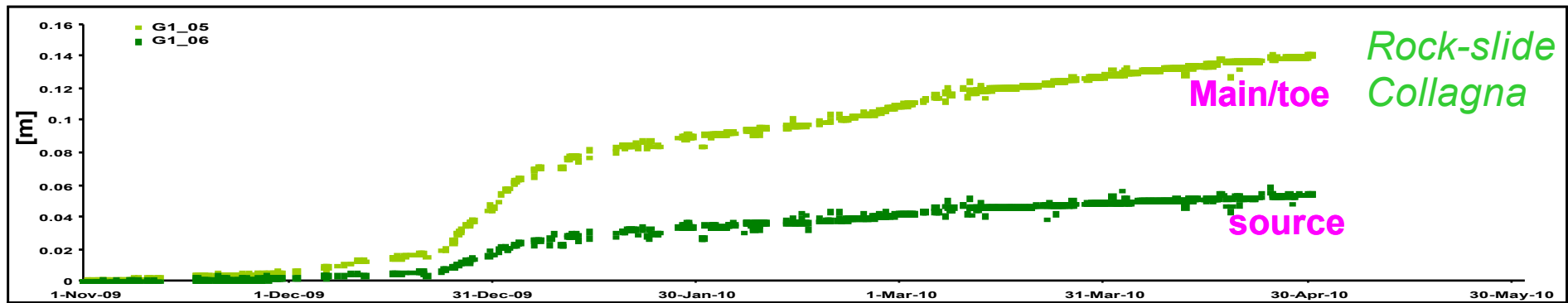
Collagna - Succiso

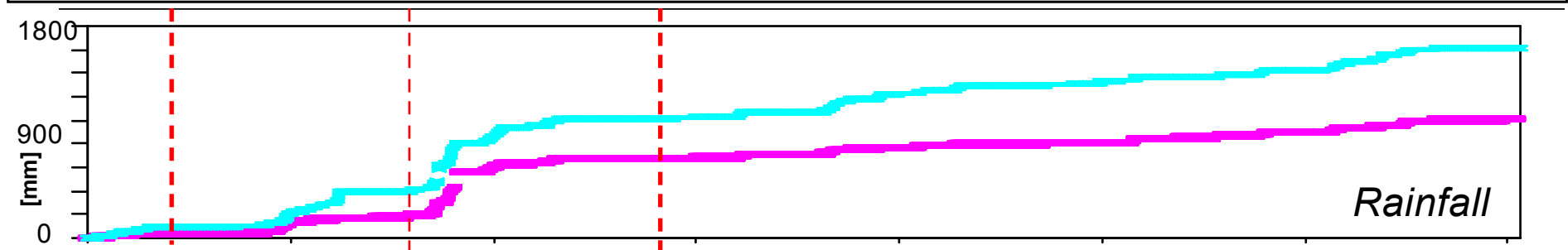
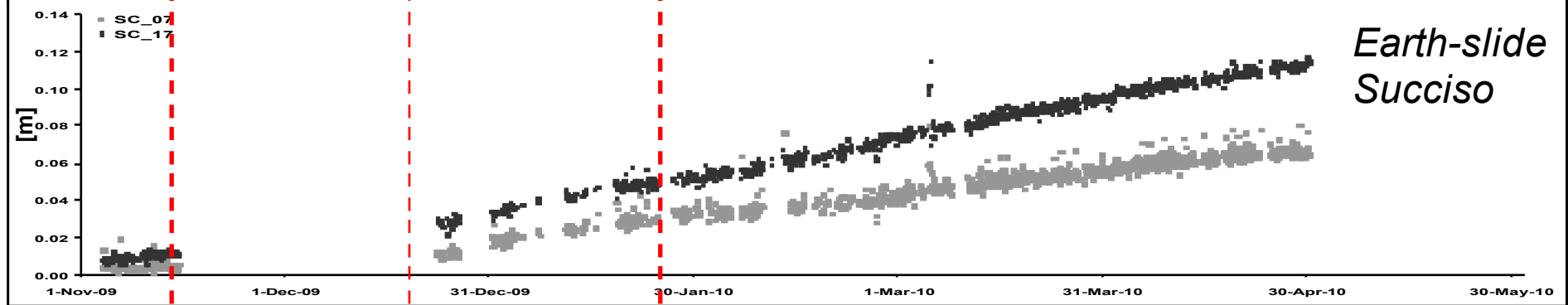
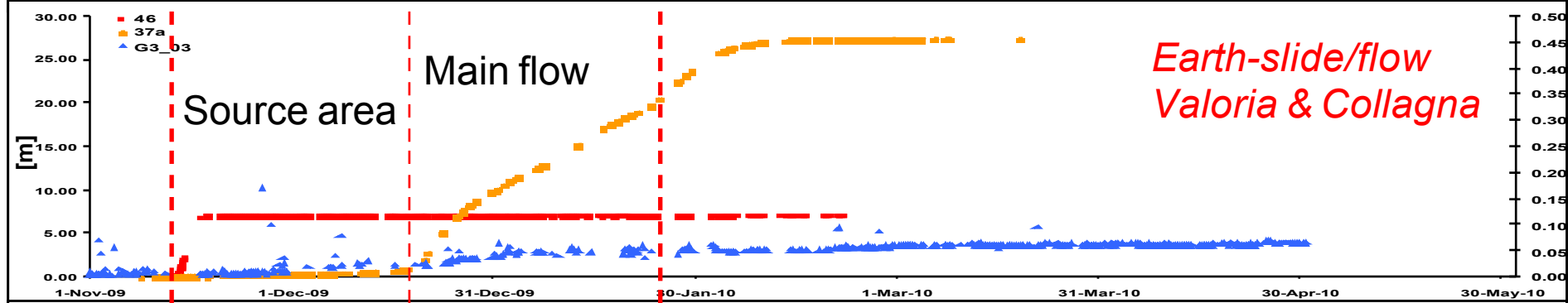
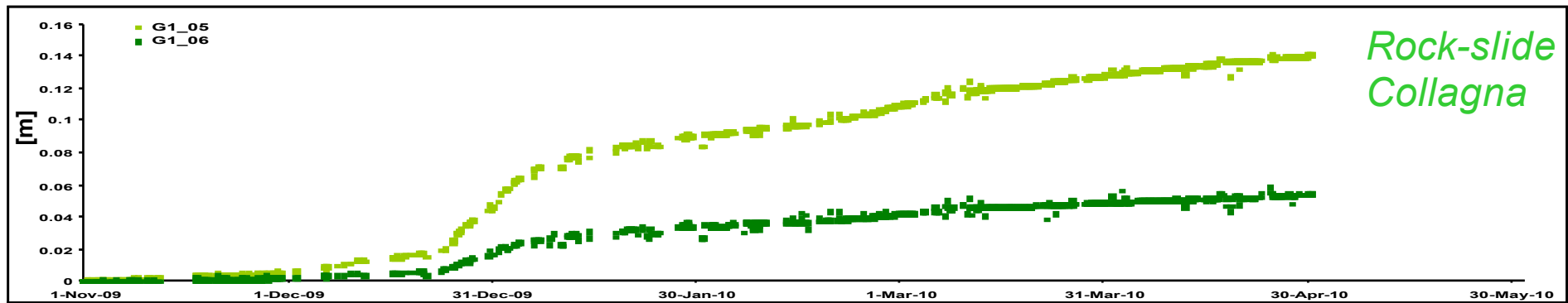
Valoria

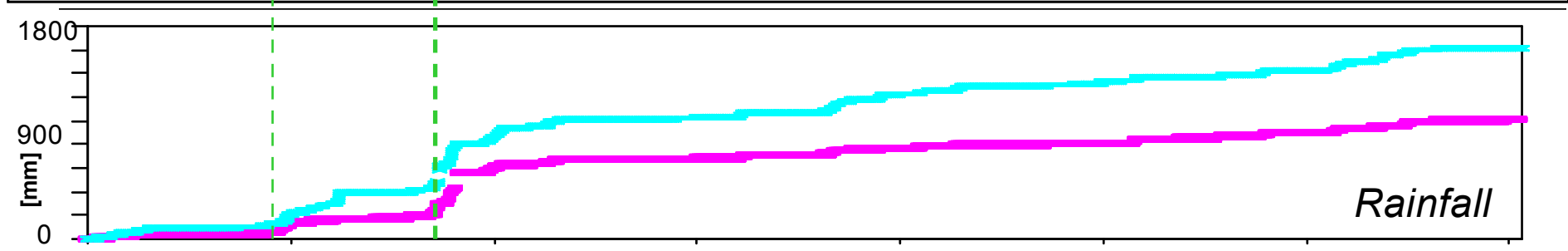
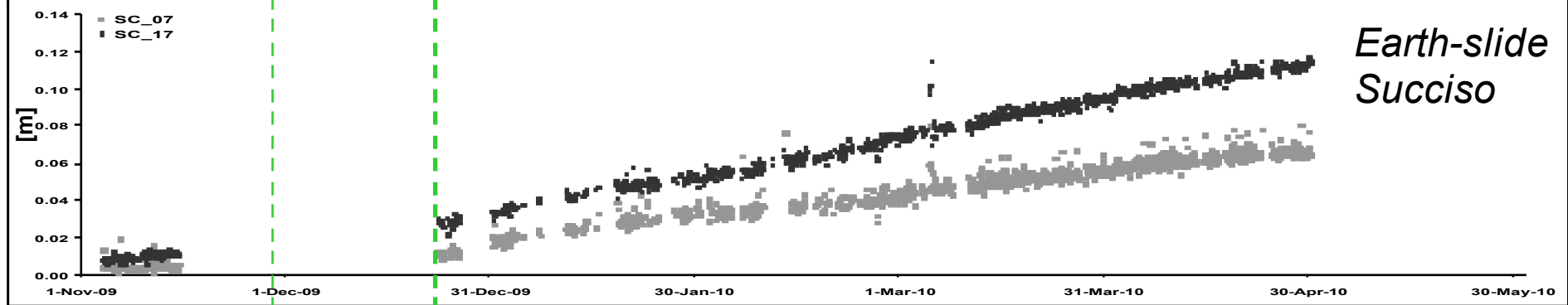
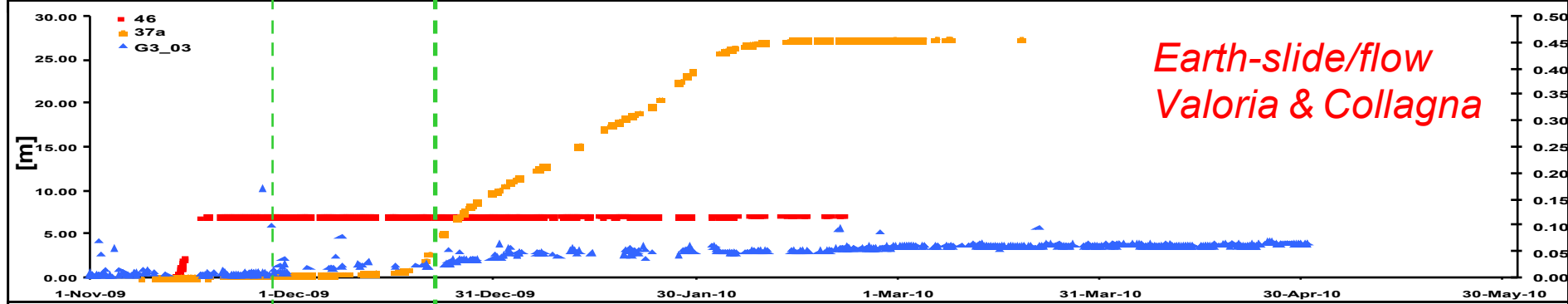
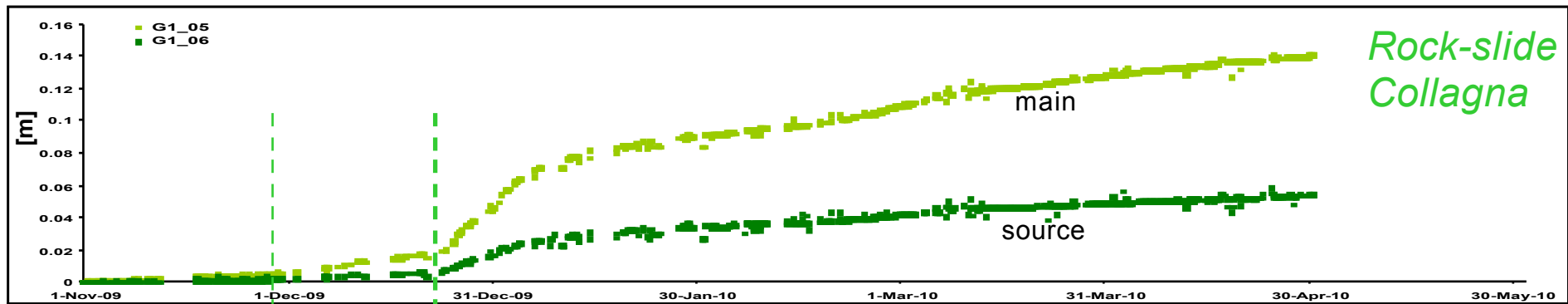
Rainfall



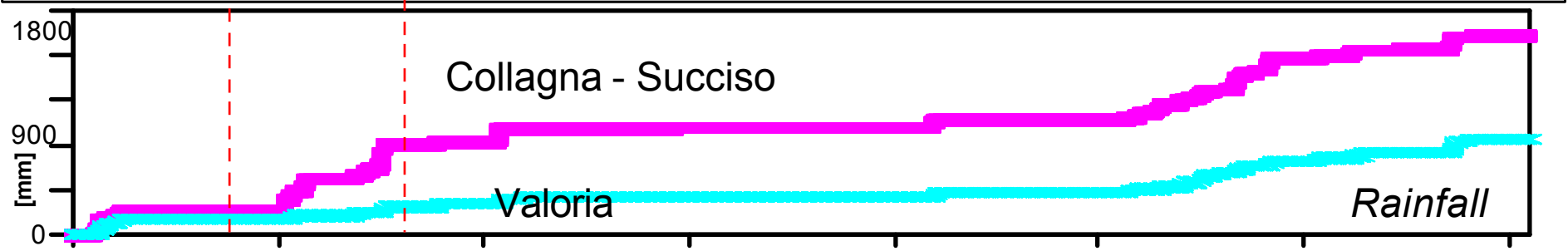
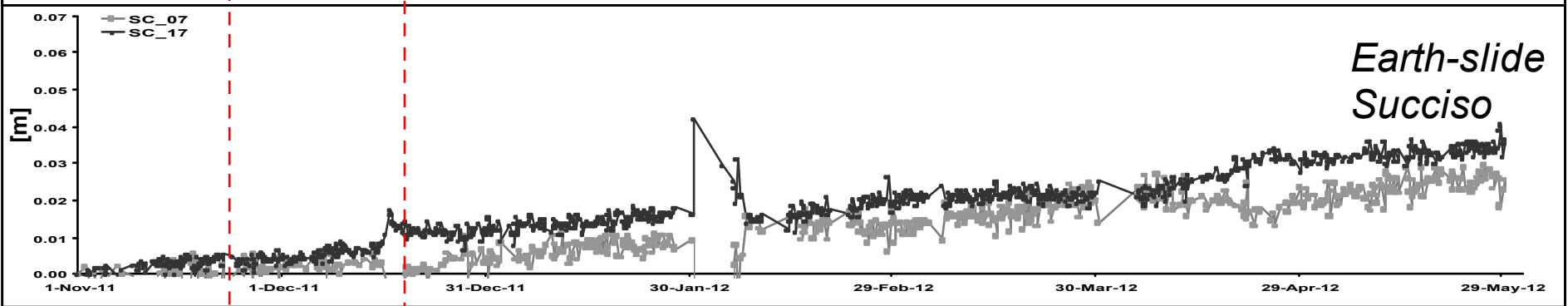
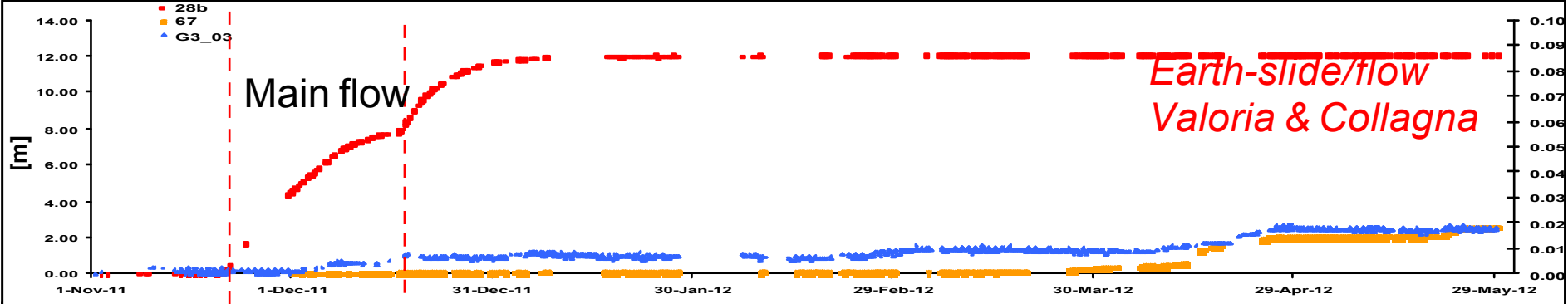
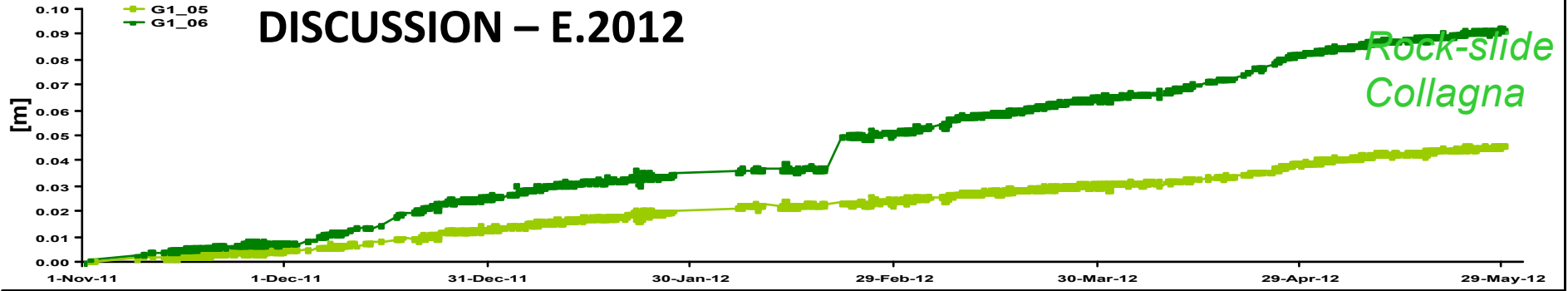


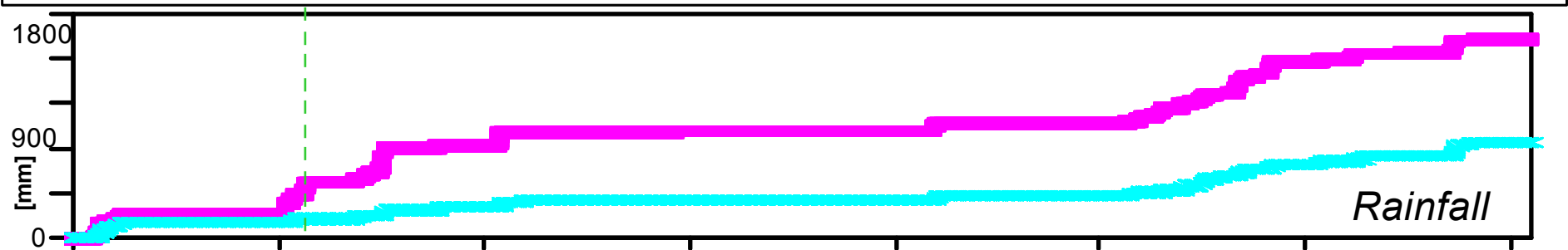
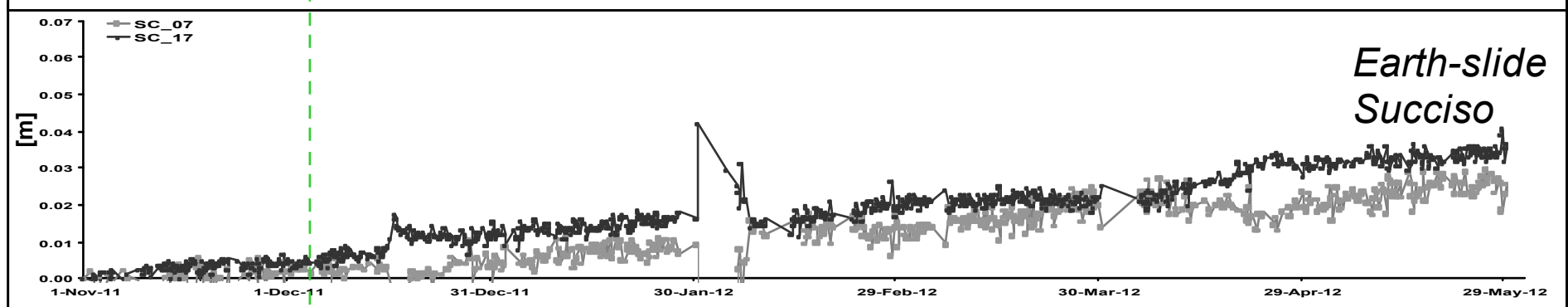
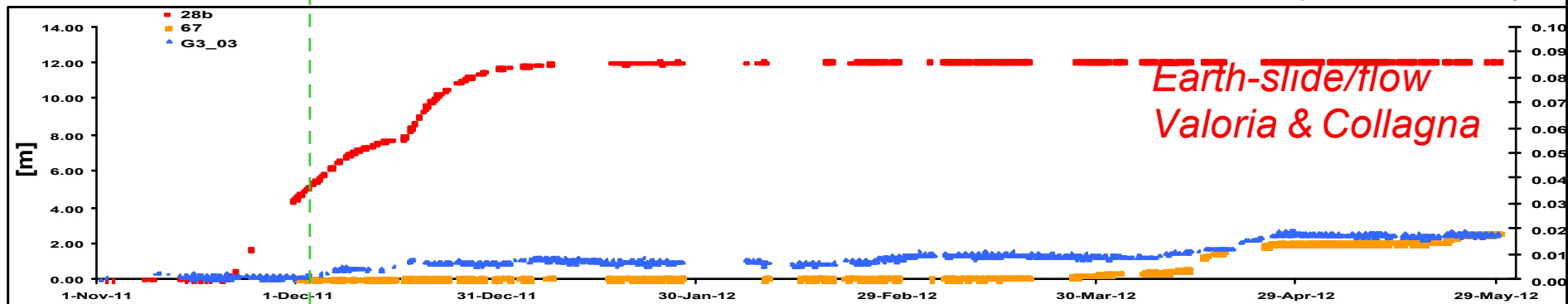
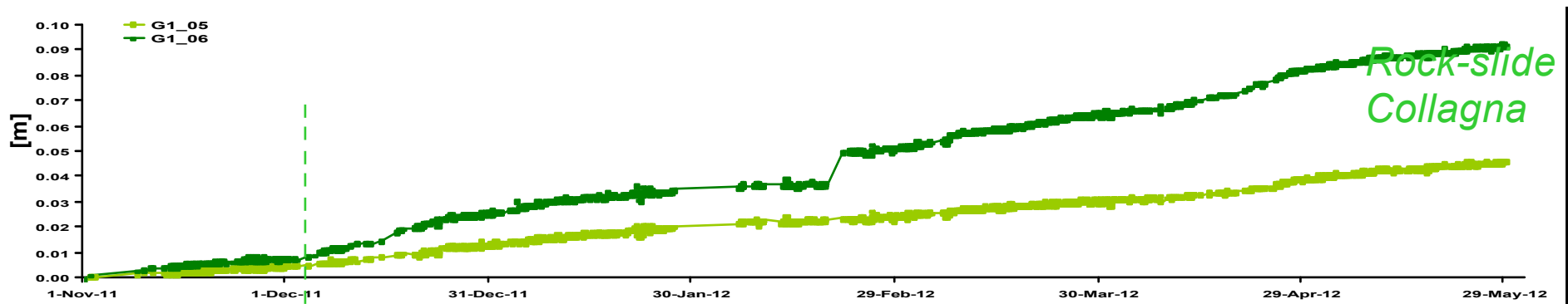


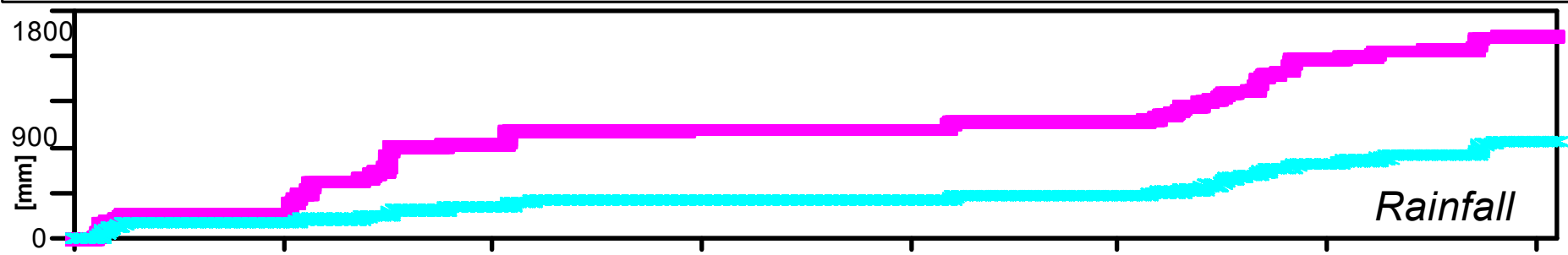
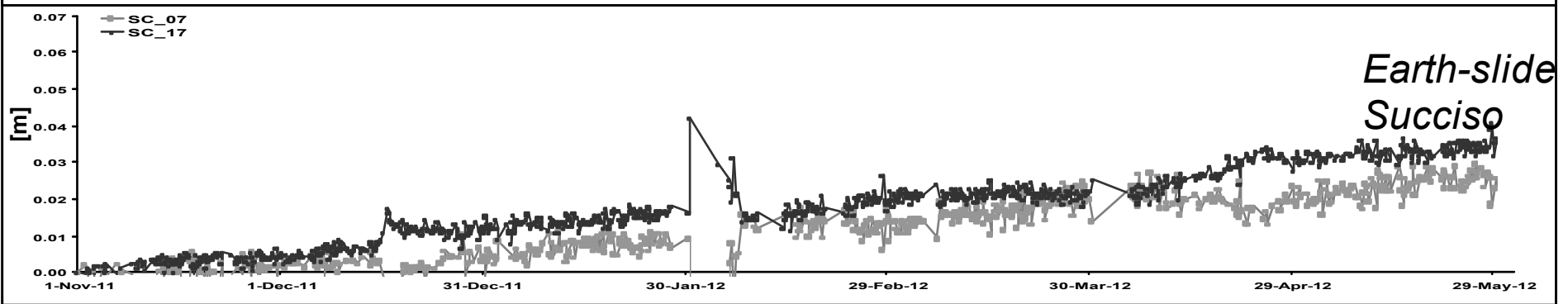
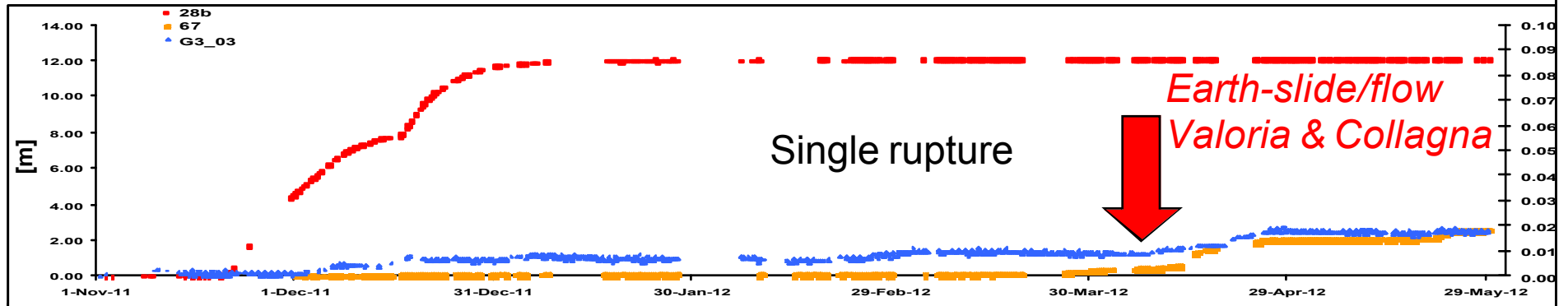
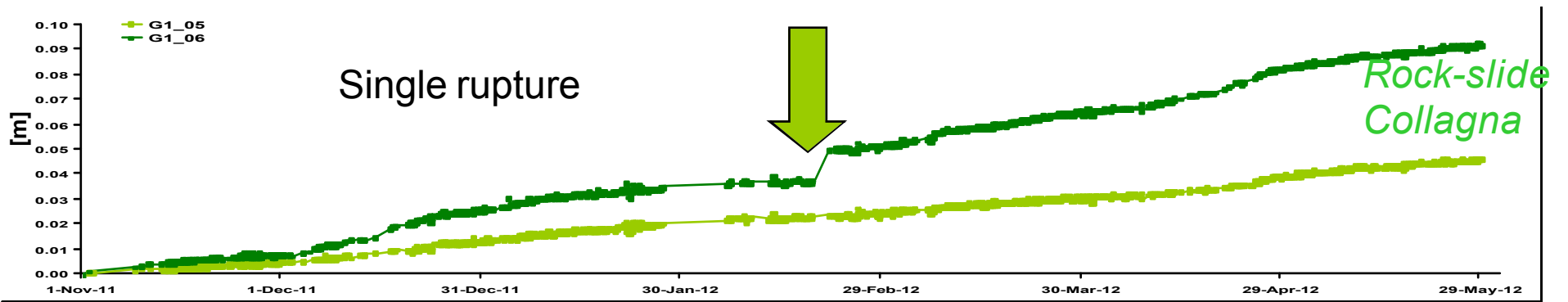




DISCUSSION – E.2012



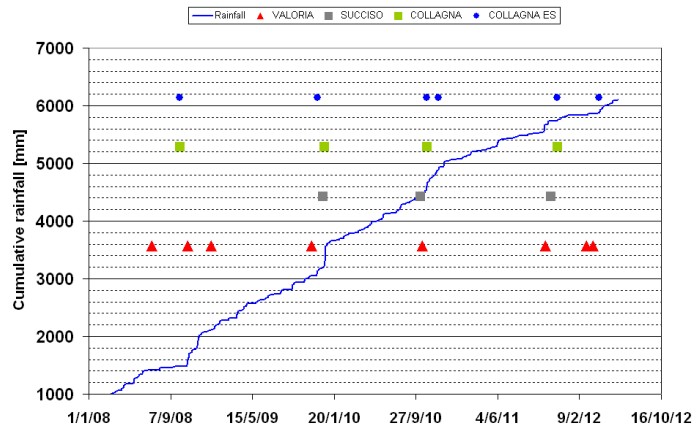






DISCUSSION

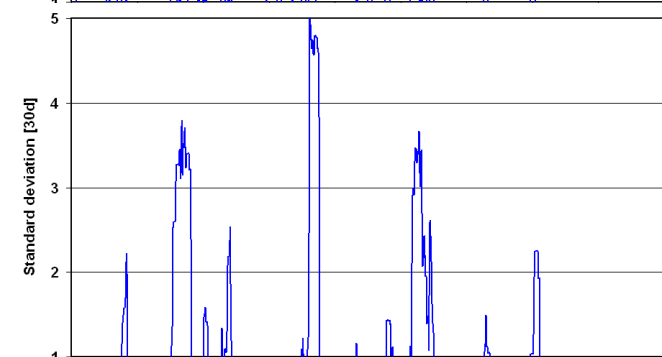
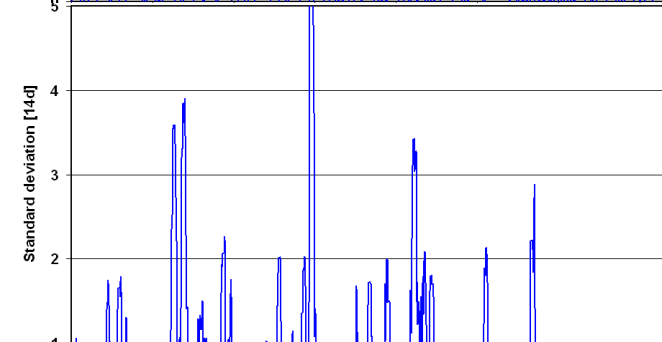
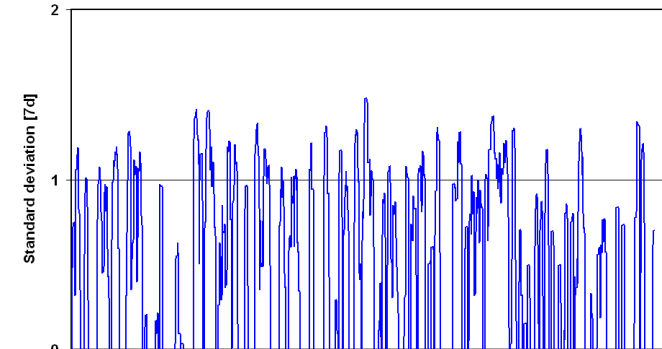
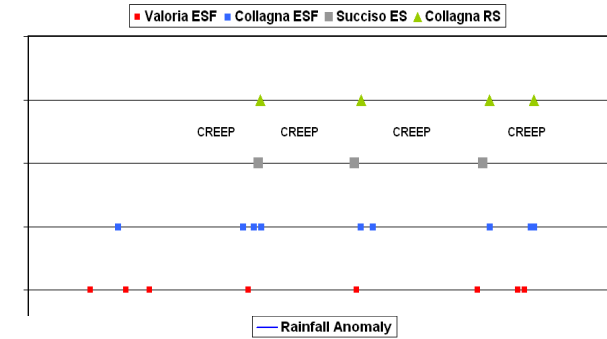
LANSLIDE EVENT (acceleration) VS RAINFALL PATTERN



EARTH SLIDE
seasonal recharge

ROCK SLIDE
single event in Autumn

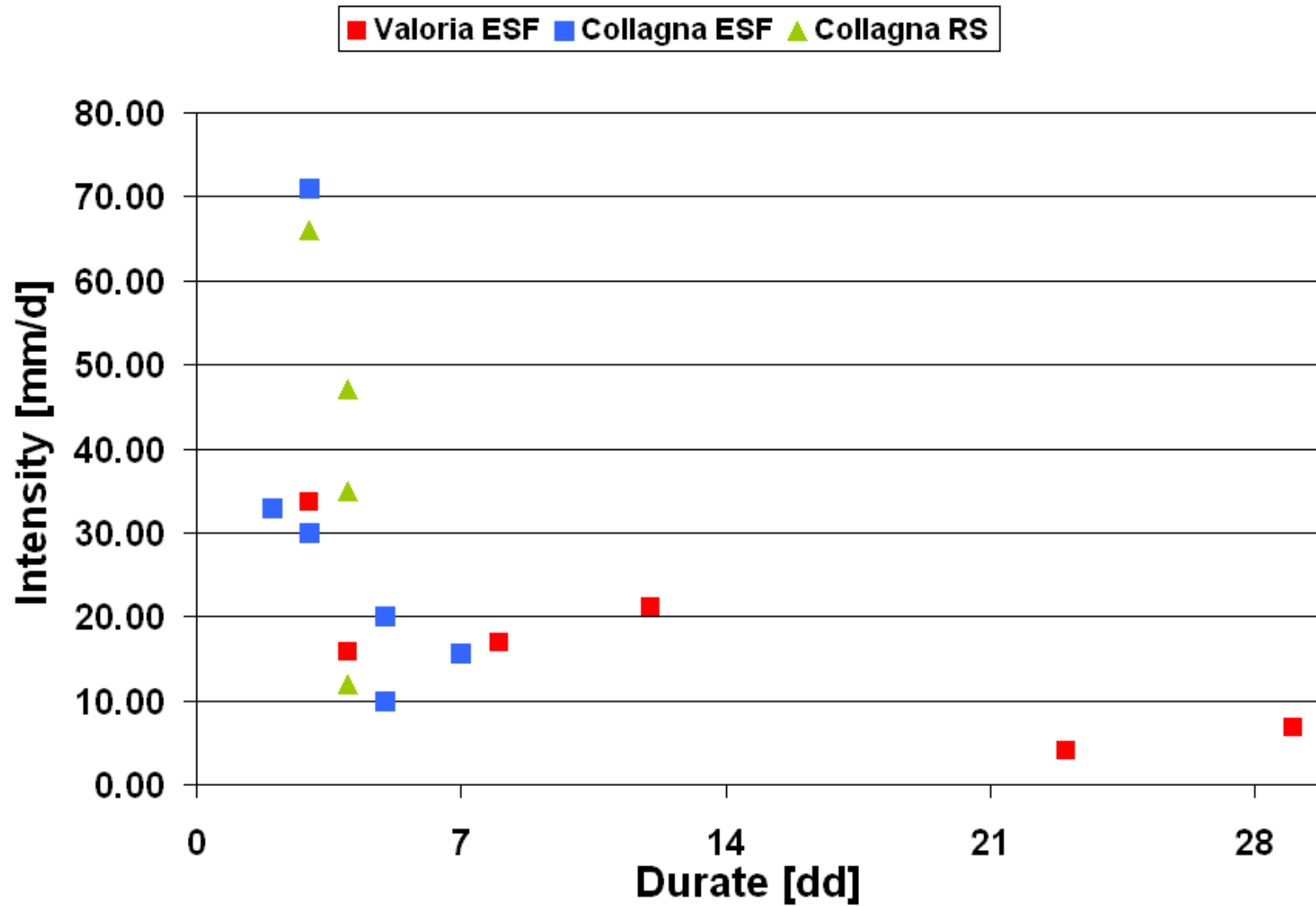
EARTH SLIDE/FLOW
single and scattered event in the year
but in the wet seasons



1/1/08 19/7/08 4/2/09 23/8/09 11/3/10 27/9/10 15/4/11 1/1/11 19/5/12 5/12/12

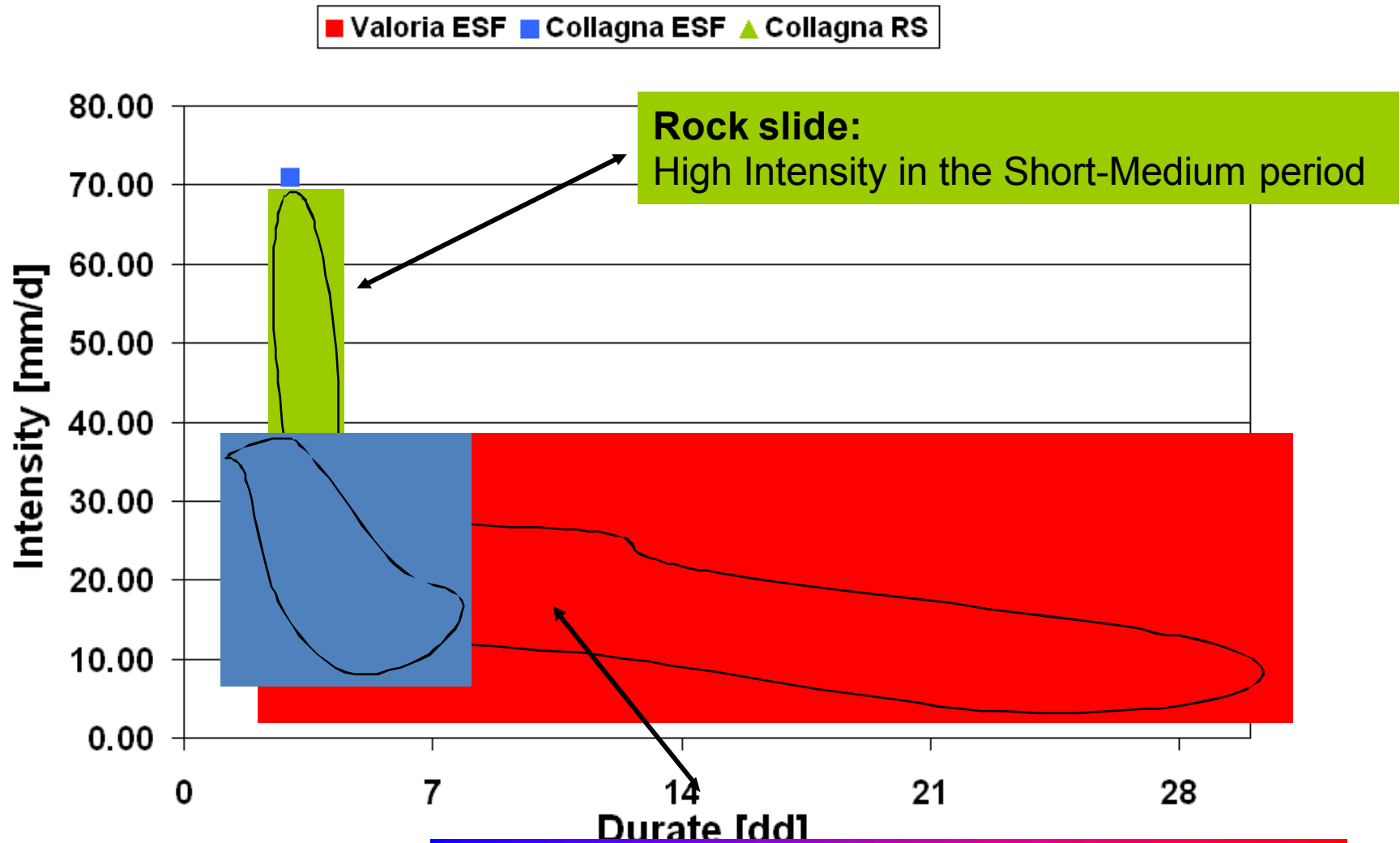
DISCUSSION

LANSLIDE EVENT (acceleration) VS "RAINFALL TYPE"



DISCUSSION

TRIGGERING RAINFALL



Earth slide – flow:
Rain with Low Intensity in the Medium-Long period





CONCLUSION

From 2008...

Earth slide



Moraine deposit with high clay content
Activity state

Continuous creep

Distribution of the activity:

Advancing

Pattern and type of the activity:

Slide in "block"

8 landslide event

Earth slide/flow



Silt-clay matrix with rock fragments

Suspension alternated by acceleration events

Retrogressive

Landslide sequence
source area > main flow > toe
(...also isolated slides)

4 landslide event

Rock slide



Limestone blocks in a silt-clay matrix

Creep alternated by acceleration

Advancing

Movements in same time but
Large displacements in the
middle-lower slope
(...also isolated slide/falls)

CONCLUSION

Earth slide



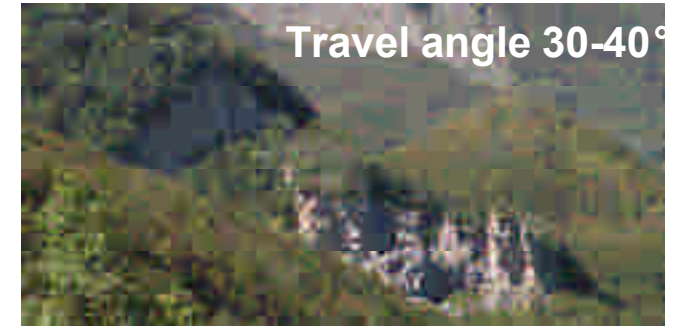
Moraine deposit with high clay content

Earth slide/flow



Silt-clay matrix with rock fragments

Rock slide



Limestone blocks in a silt-clay matrix

Triggering rainfall thresholds:

Seasonal effect

Single and prolonged rainfall event, in the wet season

Single and intense rainfall event, in autumn seasons

Max displacement in same landslide event (2009):

2 cm

> 20 m

20 cm

Daily velocity in same landslide event (2009):

1 mm/g

1-5 m/g

0.1-1 cm/g



ACKNOWLEDGEMENTS

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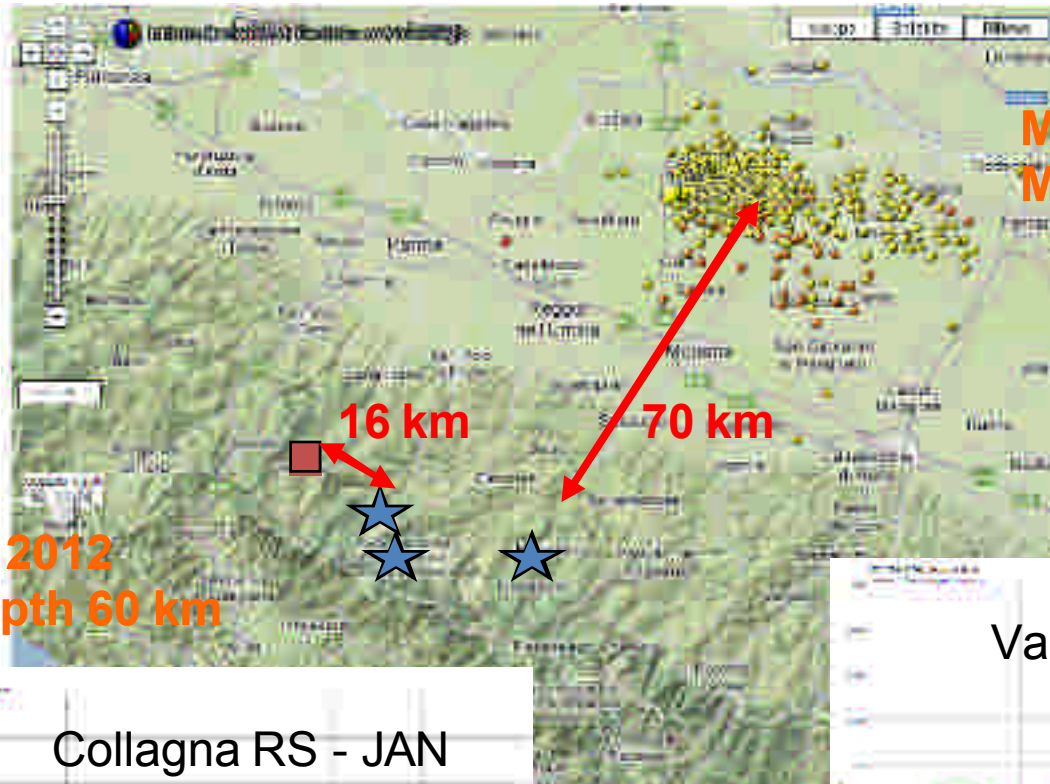
It is presently carried out in the frame of the collaborative project between Agency of Civil Protection of Emilia Romagna Region and University di Modena e Reggio Emilia “ASPER-RER: *Special activities on support to the forecast and emergency planning of Civil Protection with respect to hydrogeological risk*”.

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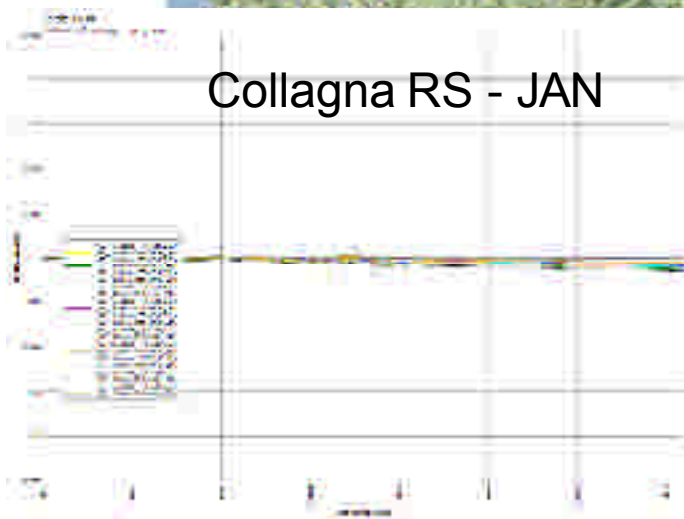
What happen in our Ls during 2012 Emilia Romagna Region Earthquakes???



May-June 2012
Mg max 5.9 depth 6 km

January 2012
Mg 5.4 depth 60 km

Collagna RS - JAN



Valoria ESF - MAY JUNE

