Results and future of Wi-GIM

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UNIVERSITÀ DEGLI STUDI FIRENZE

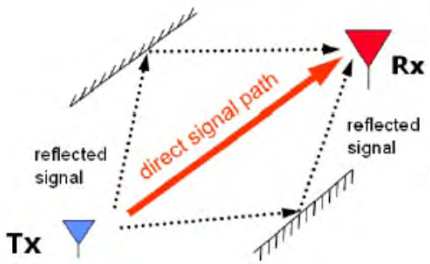
DST DIPARTIMENTO DI SCIENZE DELLA TERRA
CENTRO DI COMPETENZA DEL SERVIZIO NAZIONALE DELLA PROTEZIONE CIVILE

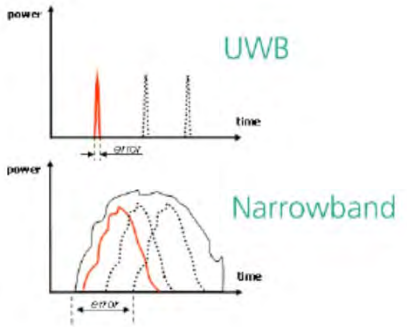
Design criteria

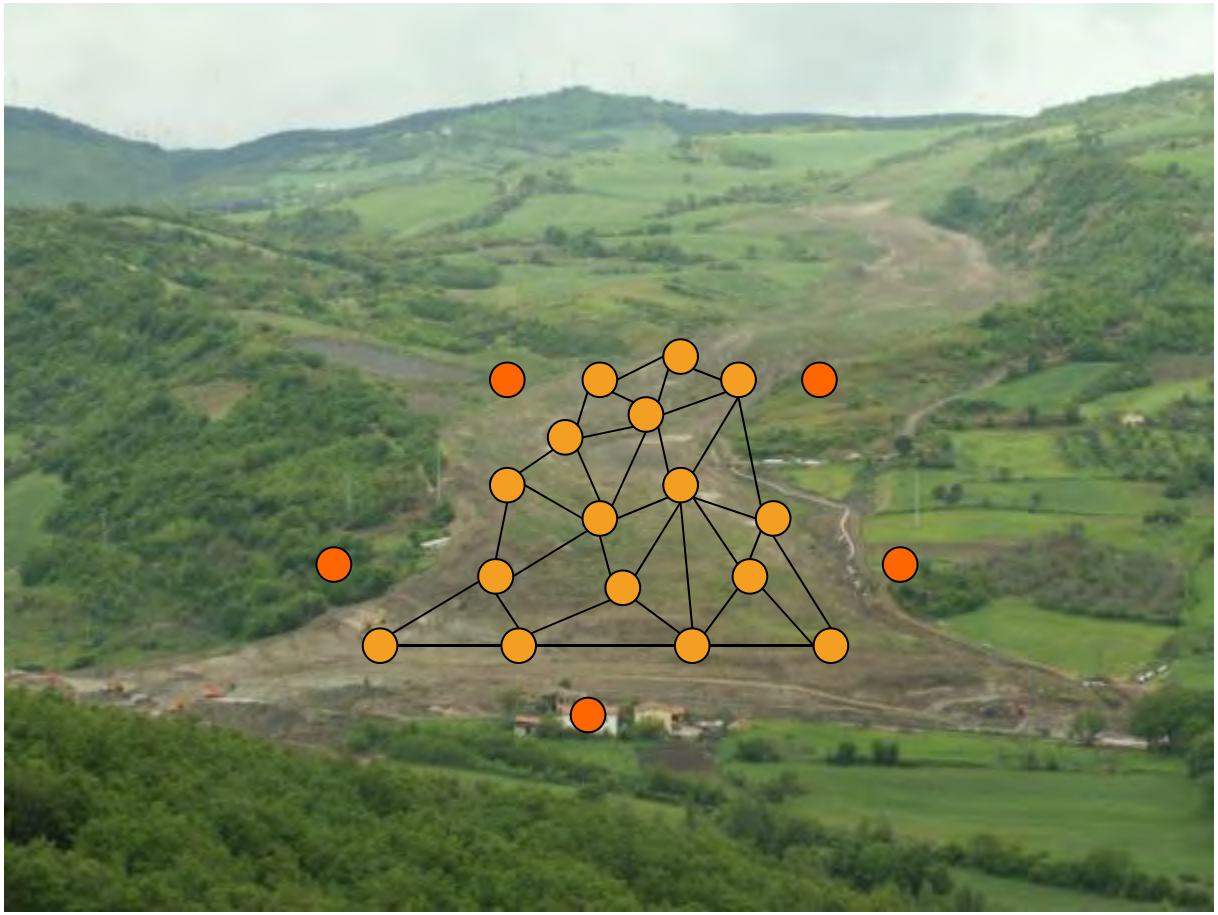
- Emergency monitoring
- Low cost
- Fast installation

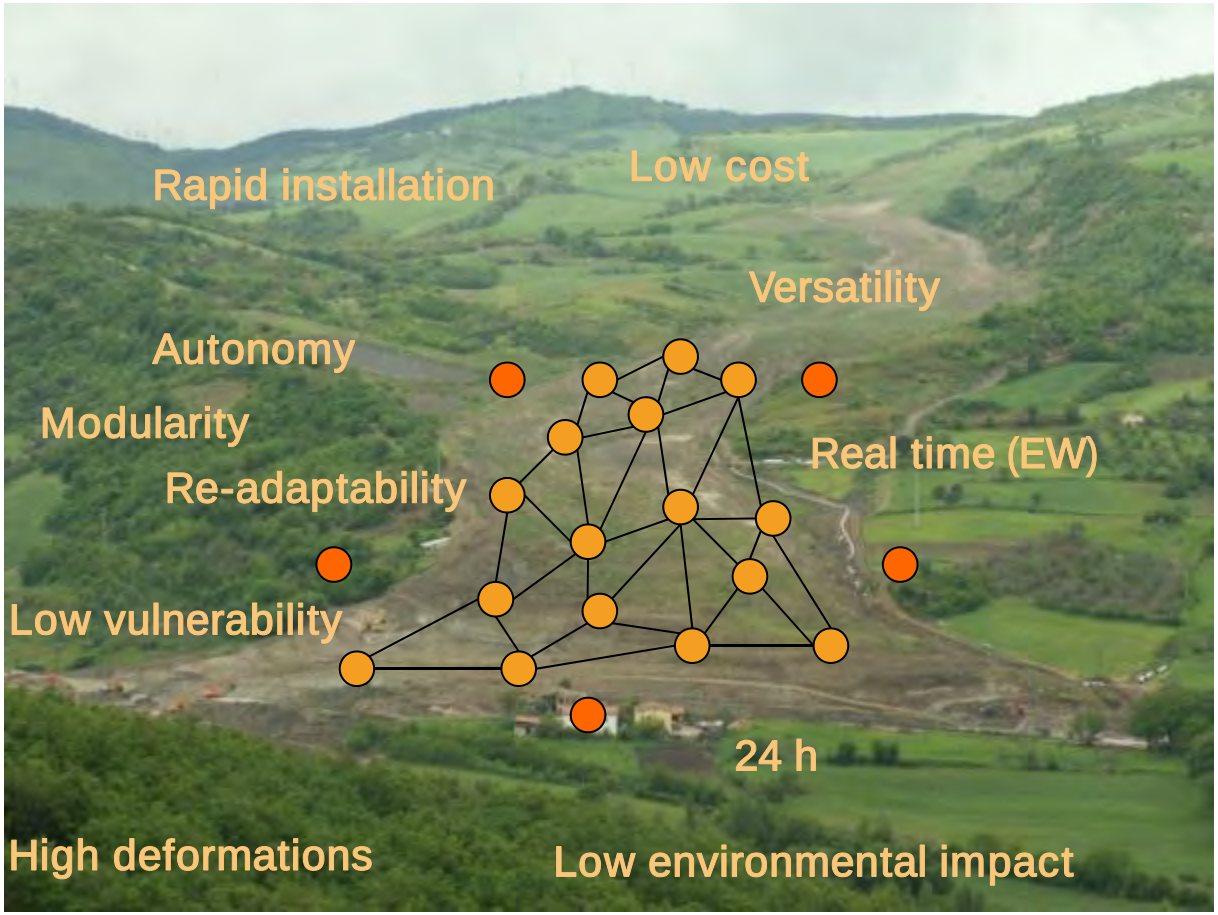
Wireless Sensor Network

Ranging

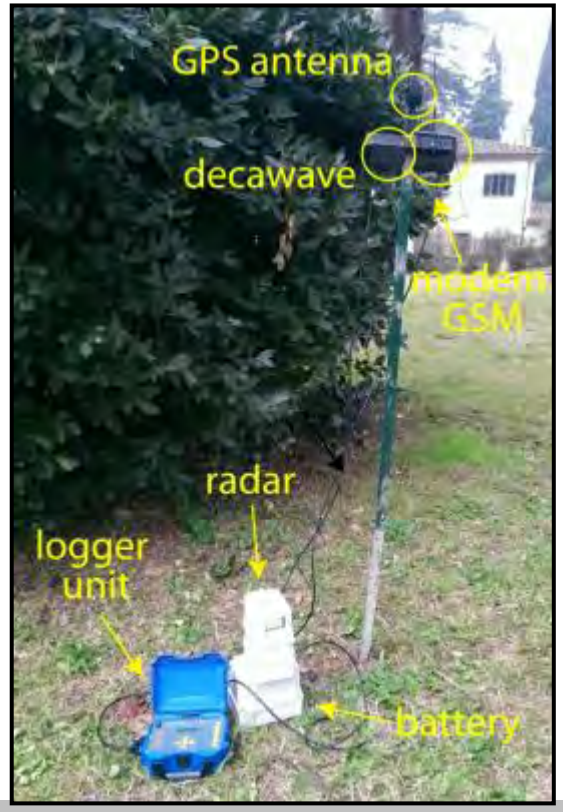


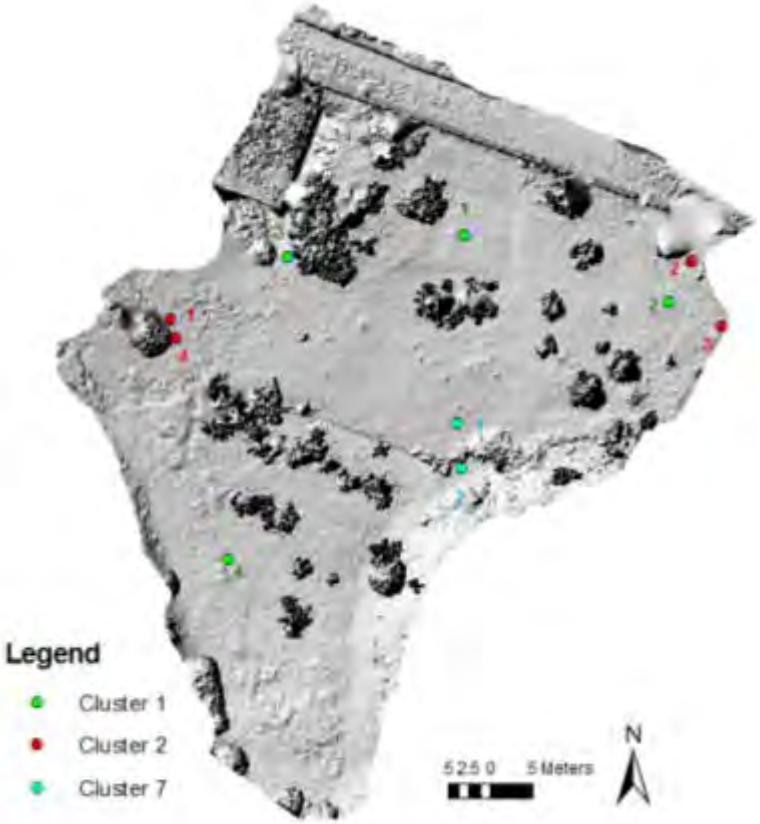


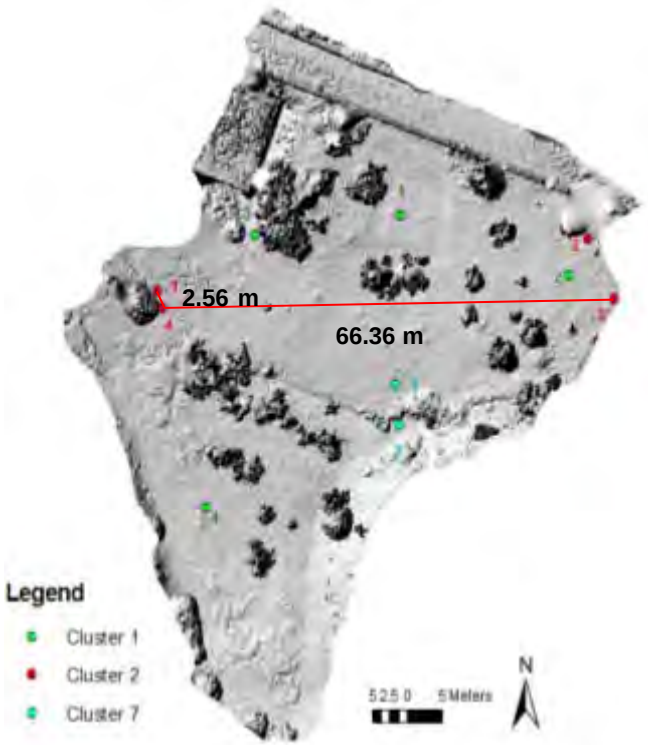


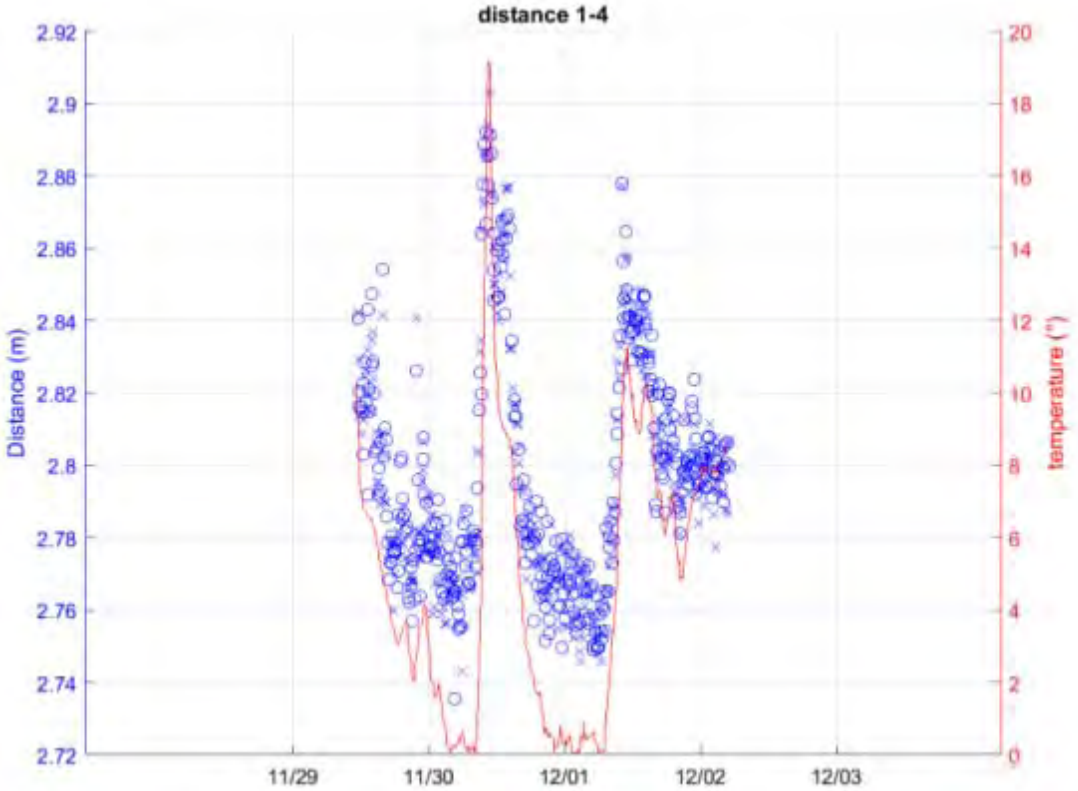

Rapid installation
Low cost
Versatility
Autonomy
Modularity
Real time (EW)
Re-adaptability
Low vulnerability
24 h
High deformations
Low environmental impact

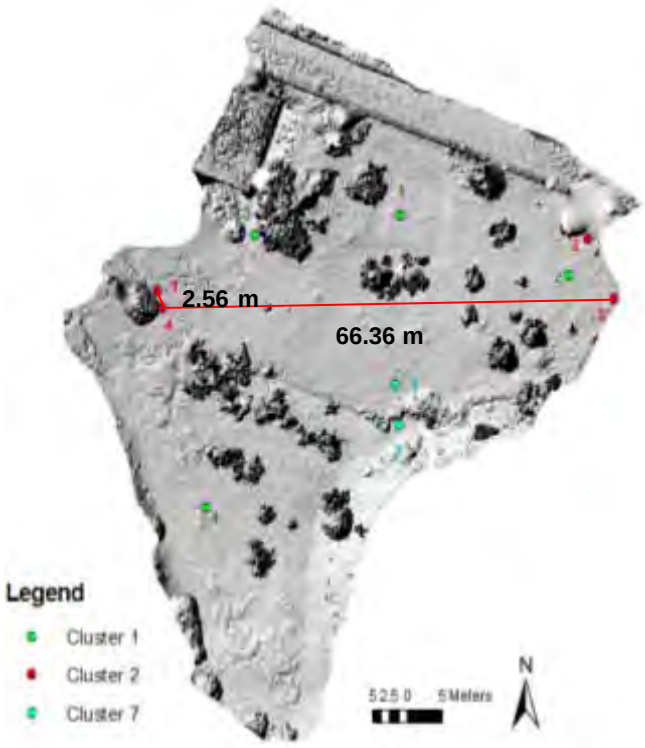
Stress tests

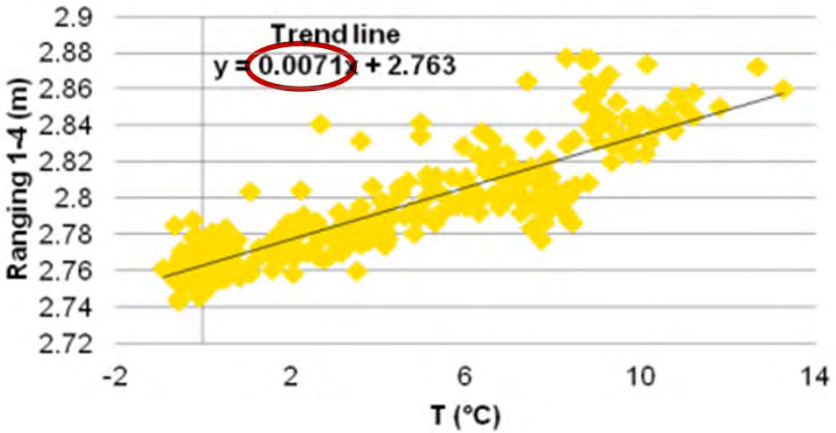


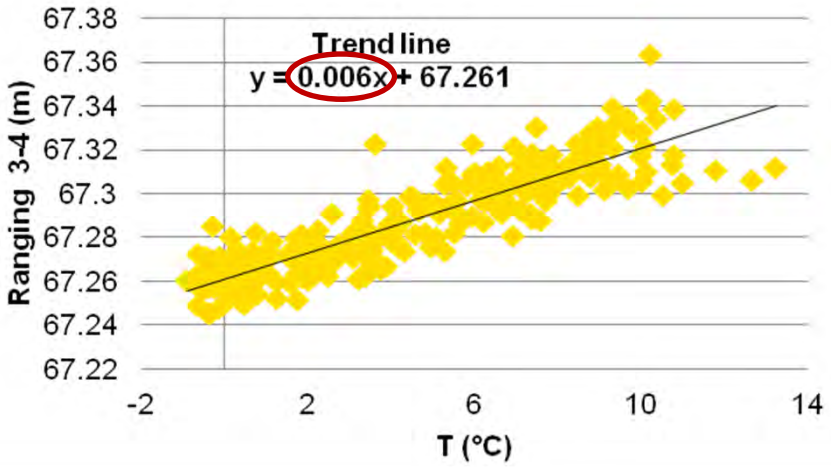

Legend
Cluster 1
Cluster 2
Cluster 7
5 2.5 0 5 Meters
N


2.56 m
66.36 m
Legend
Cluster 1
Cluster 2
Cluster 7
5 2.5 0 5 Meters
N


distance 1-4
Distance (m)
temperature (°)
2.92
2.9
2.88
2.86
2.84
2.82
2.8
2.78
2.76
2.74
2.72
20
18
16
14
12
10
8
6
4
2
0
11/29
11/30
12/01
12/02
12/03





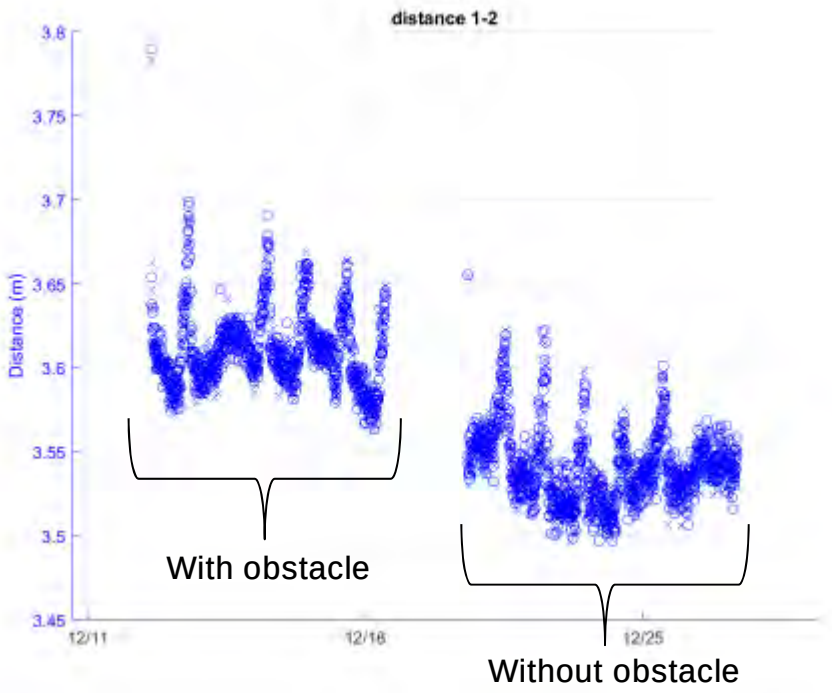


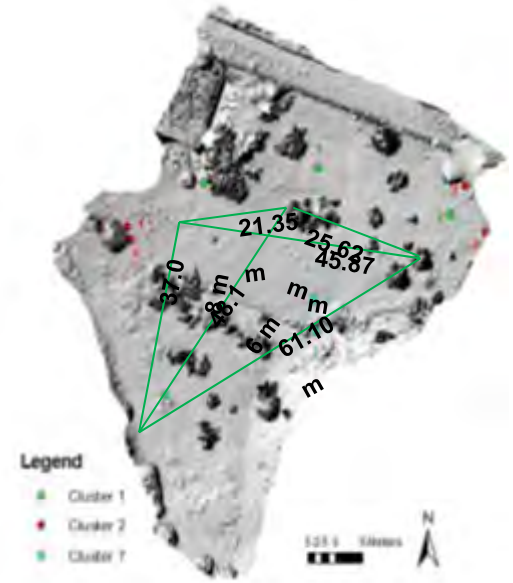
No relation with the distance was observed

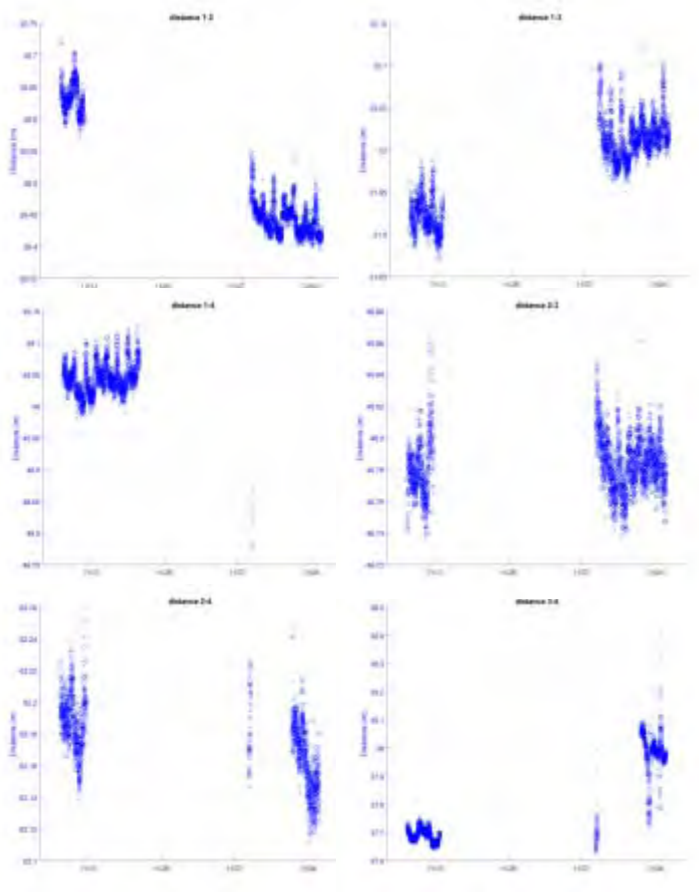
On 20/12 the obstacle was removed:

- Increased accuracy

- Precision unaffected




21.35 m
25.63 m
45.87 m
37.0 m
48.1 m
6 m
61.10 m
Legend
Cluster 1
Cluster 2
Cluster 7
N



Roncovetro test site

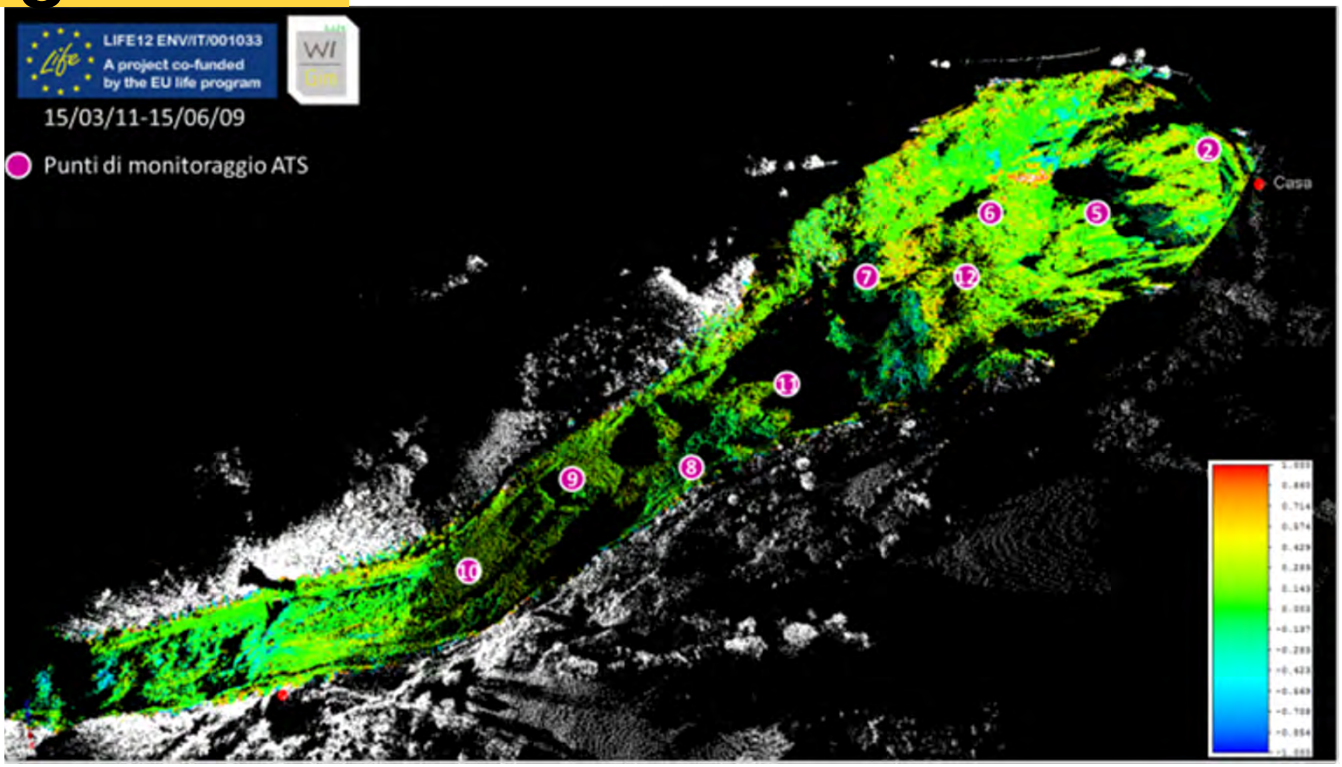
- Emilia-Romagna (Italy)
- 2.5 km long mudflow
- Average velocity of a few decameters per year
- Velocity up to 10 m/day
- $3 \cdot 10^6$ m^3 volume

Photo by G. Bertolini

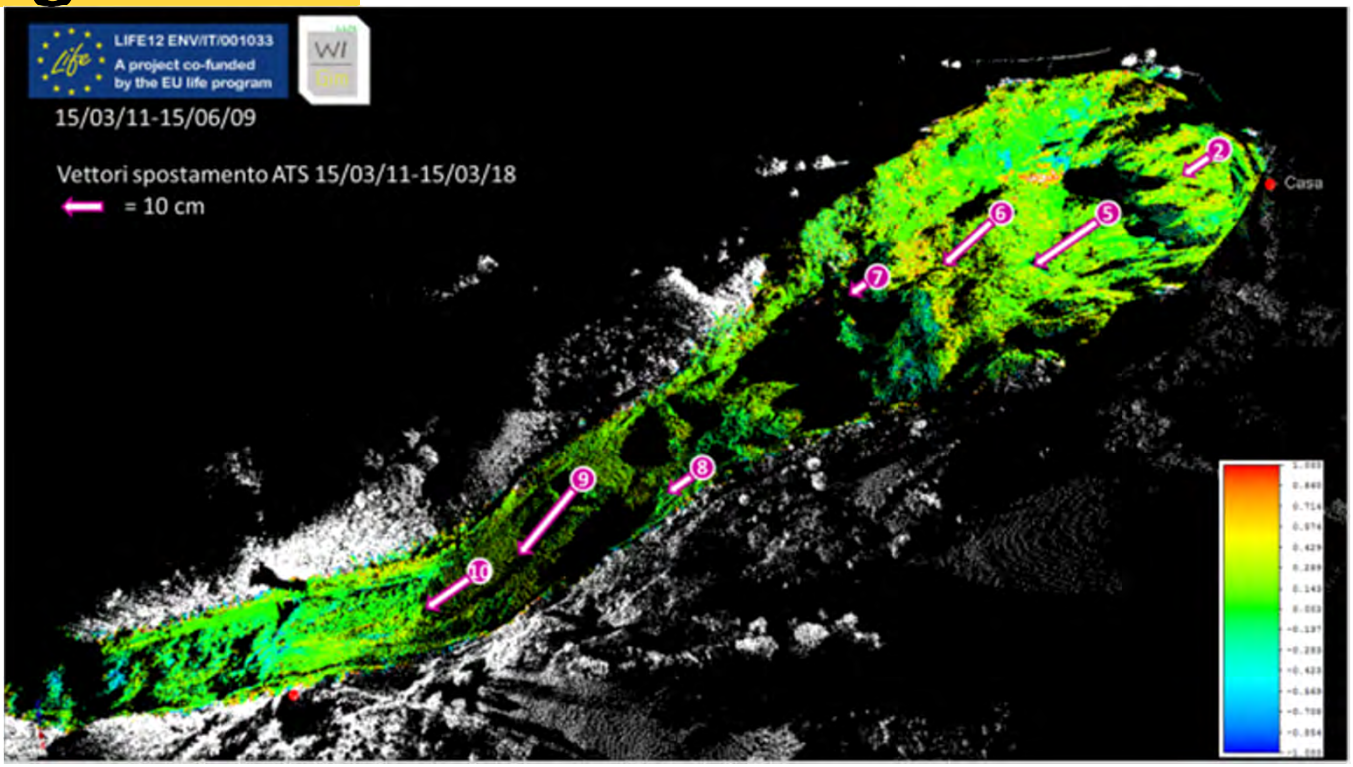
2001

2014

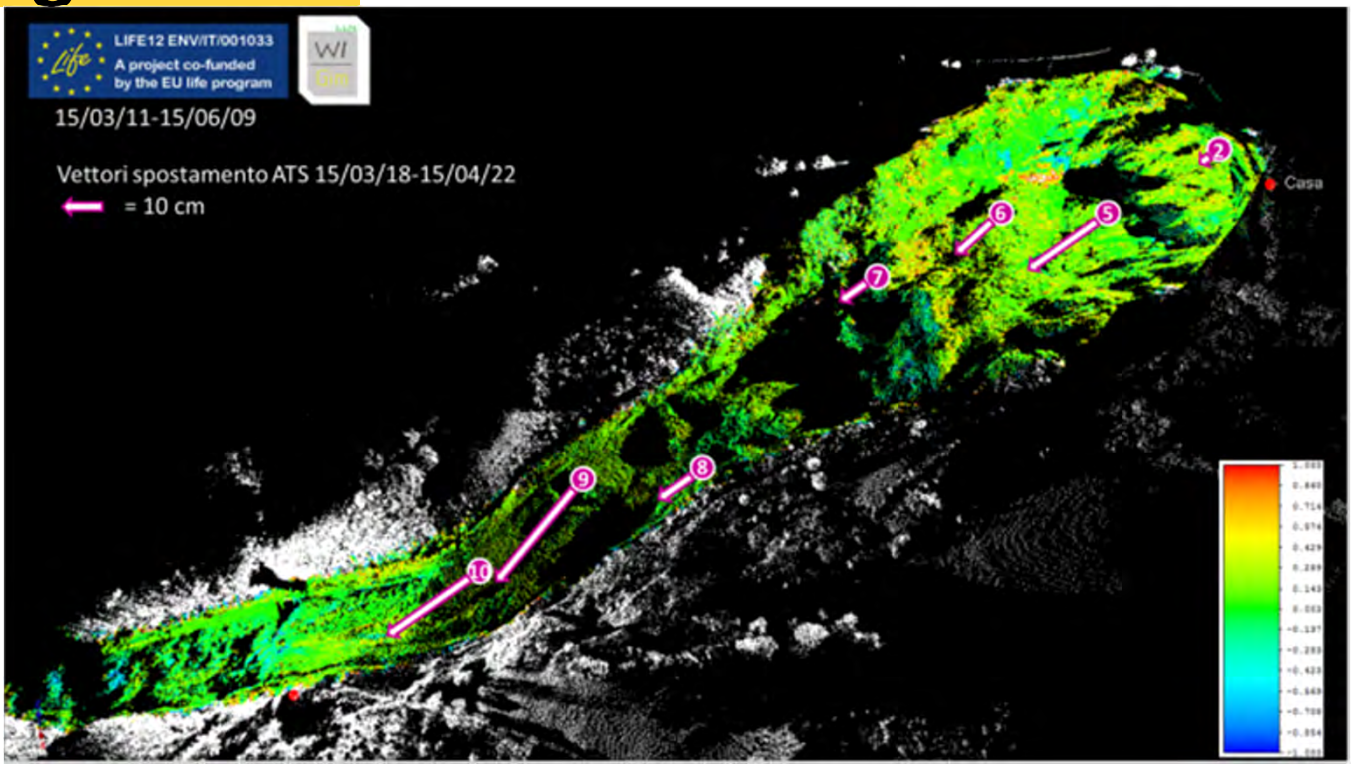
Propedeutical monitoring



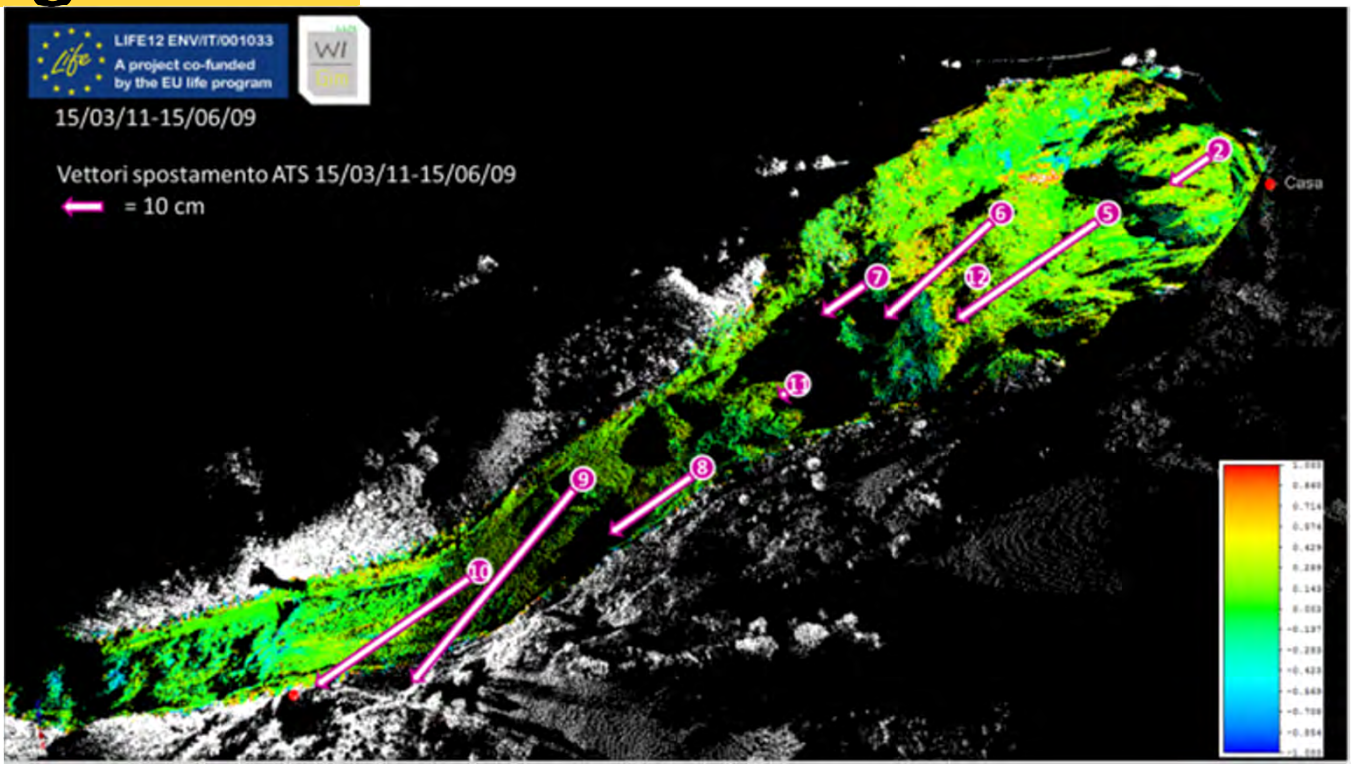
Propedeutical monitoring



Propedeutical monitoring

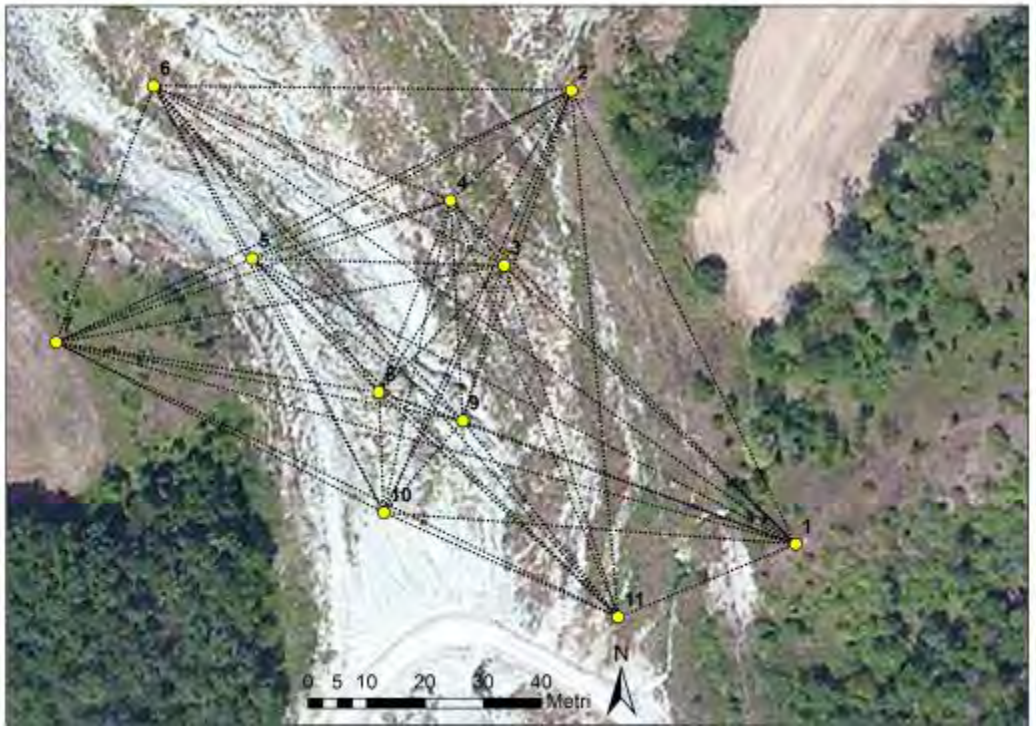


Propedeutical monitoring

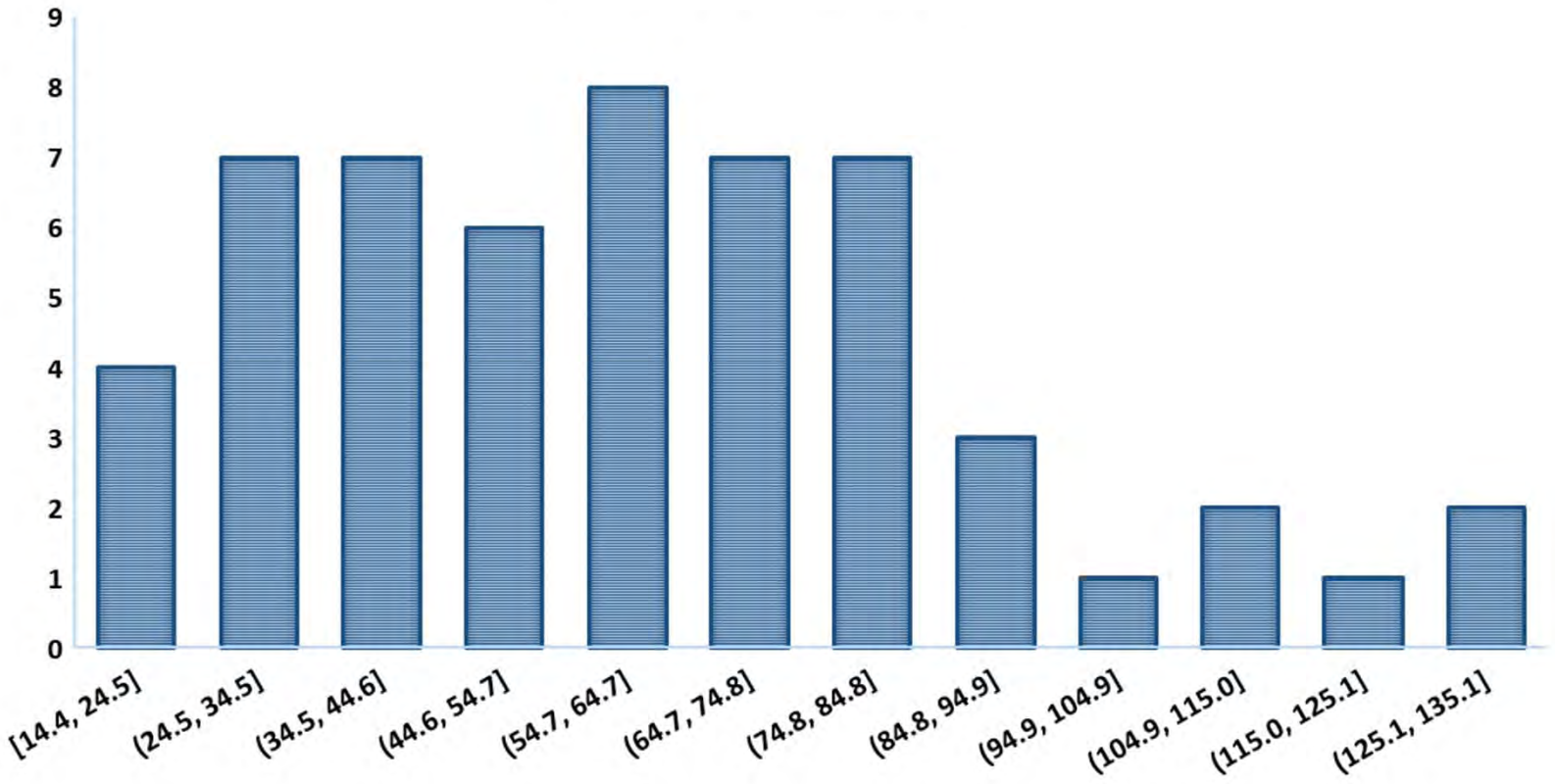


Wi-GIM installation

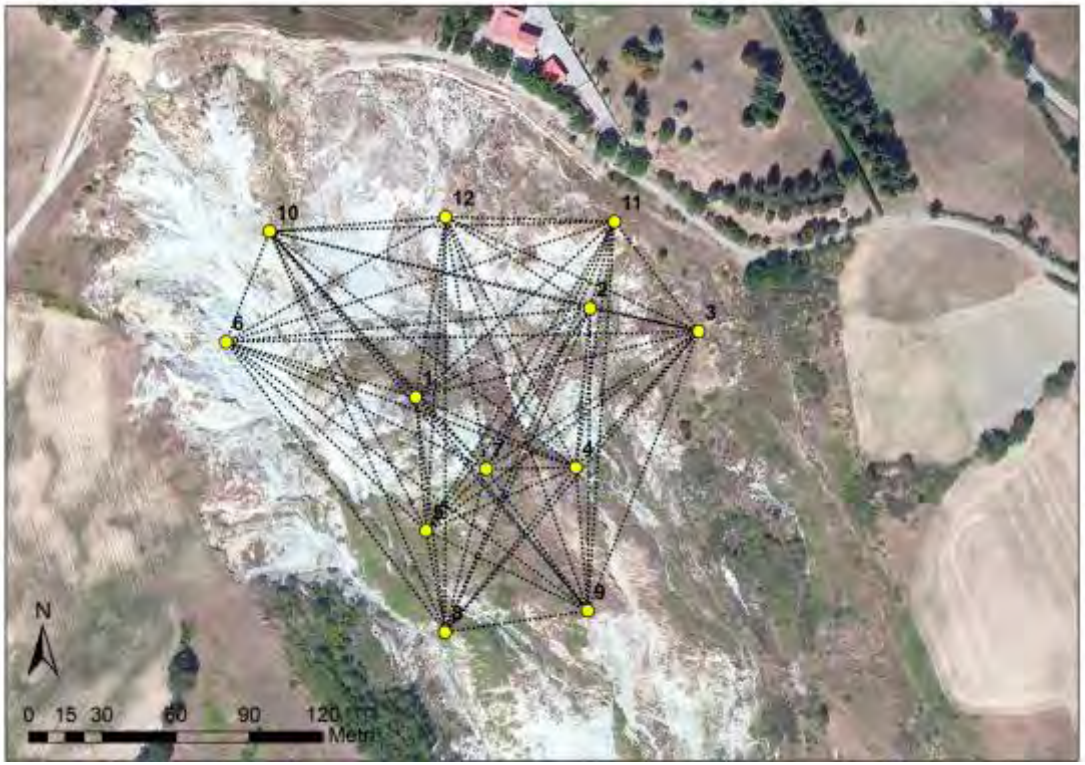
Cluster 1

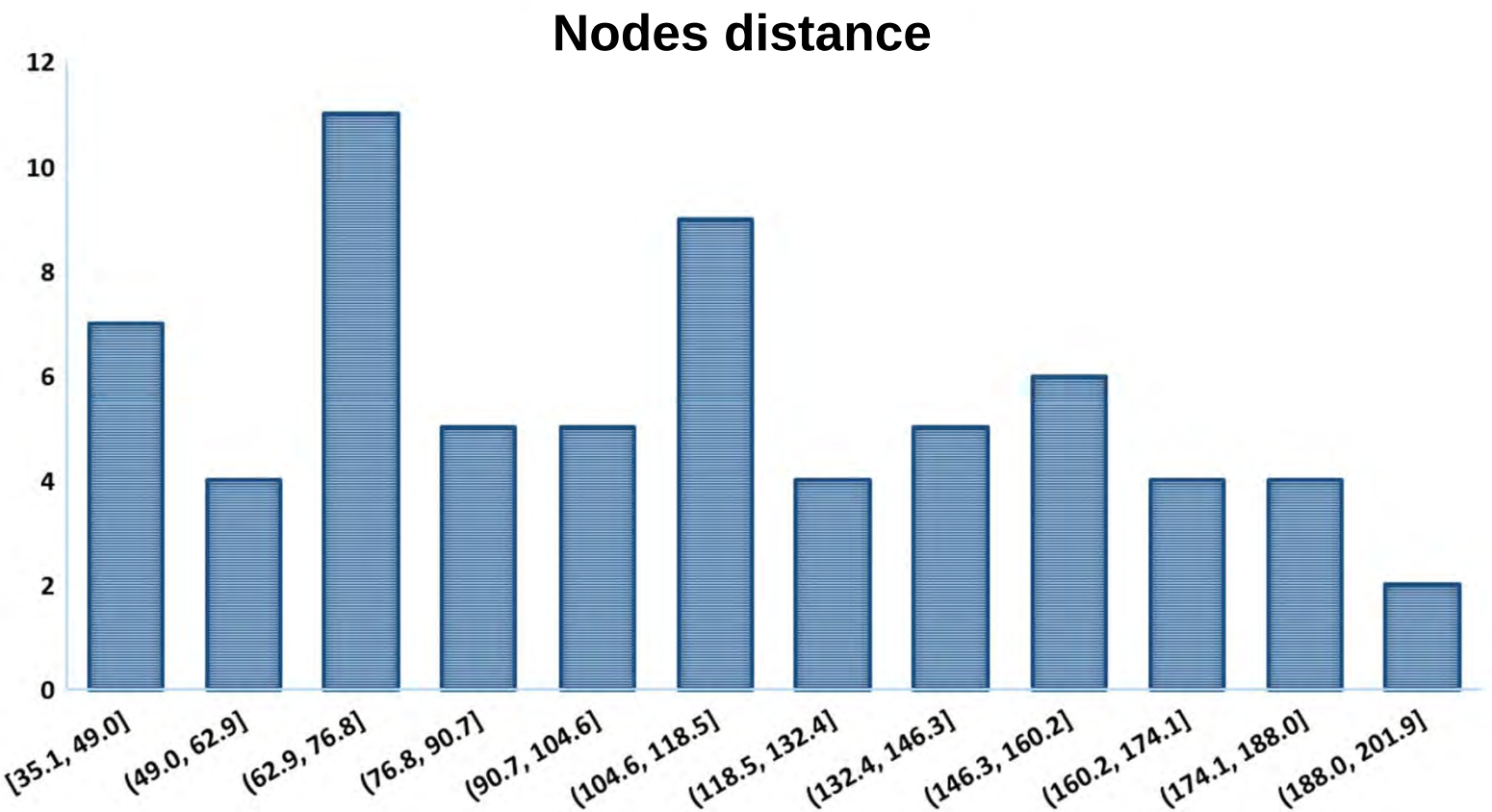


Nodes distance

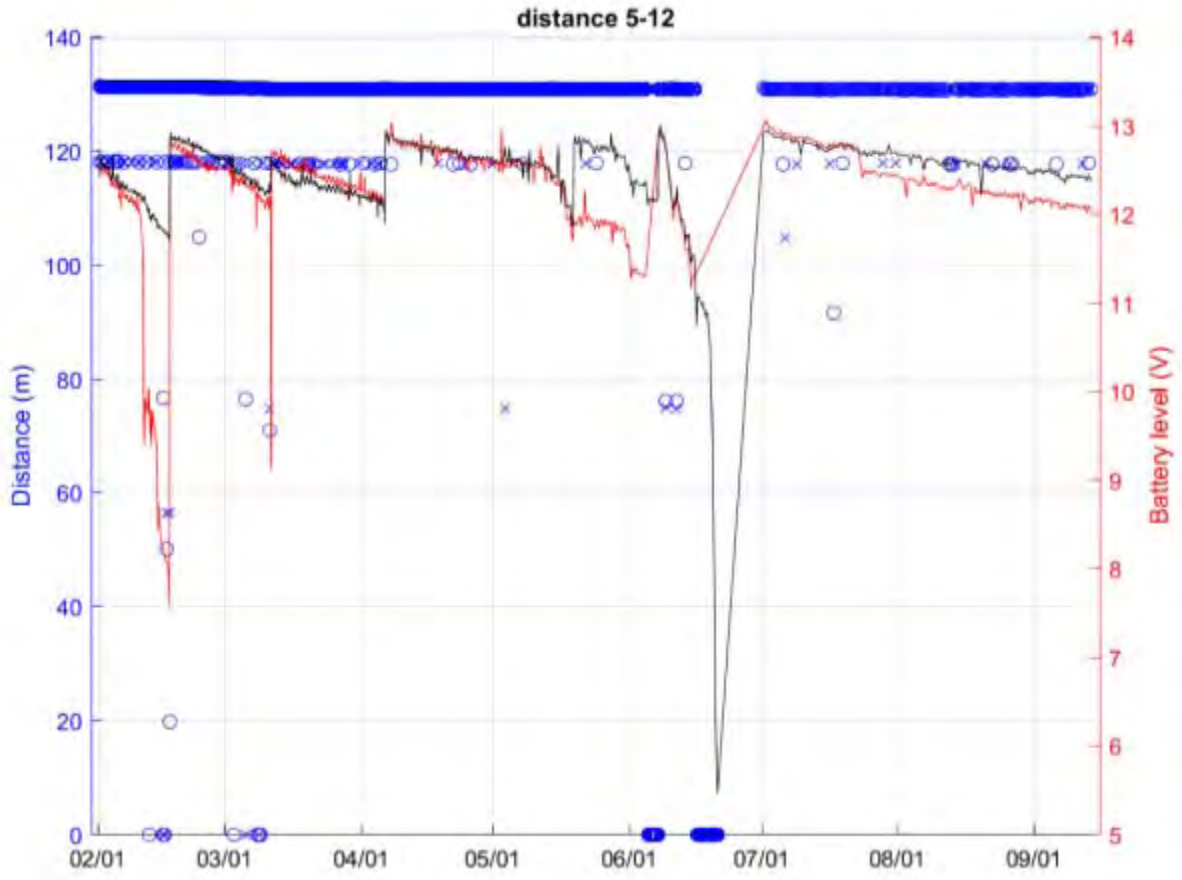


Cluster 2

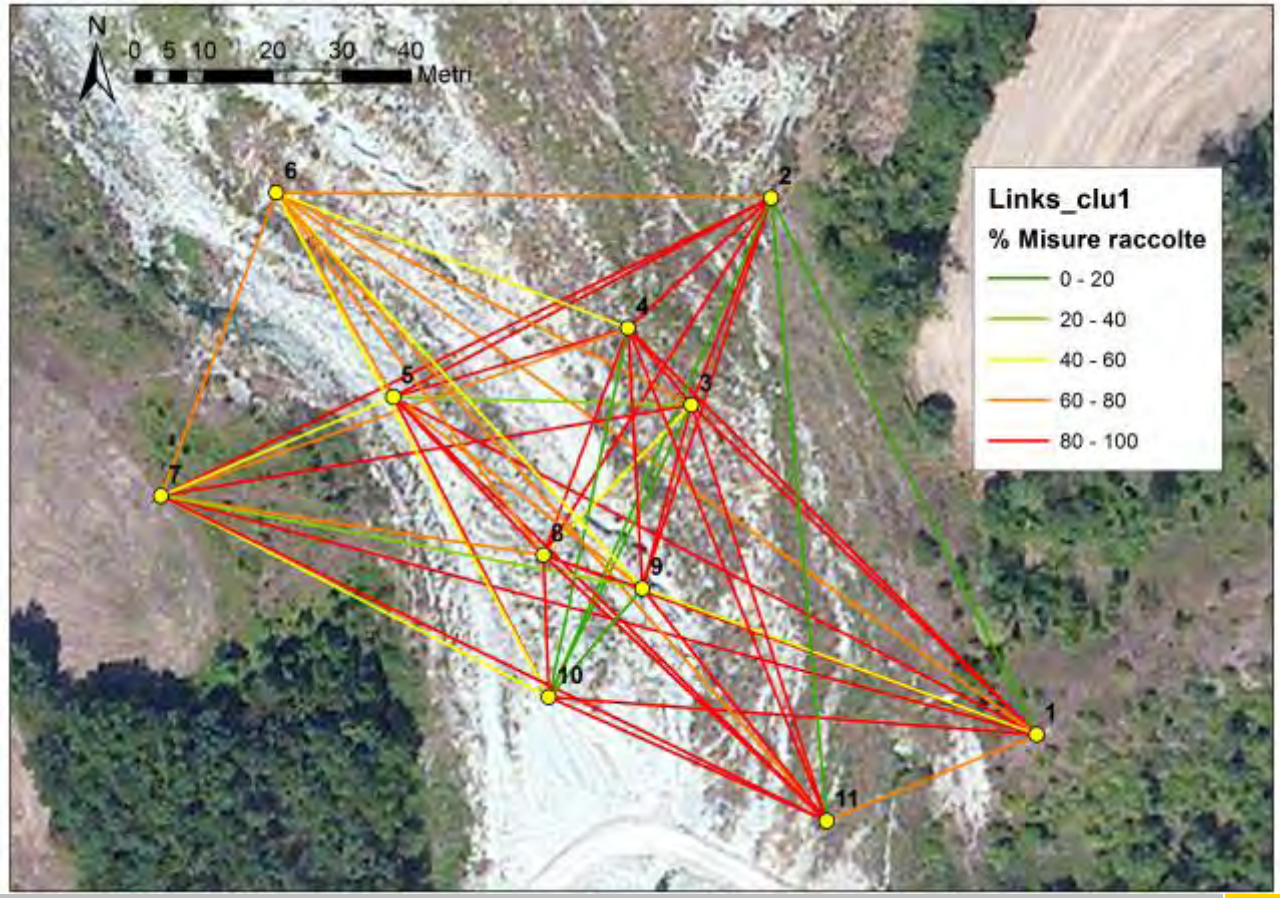



Nodes distance
12
10
8
6
4
2
0
[35.1, 49.0]
(49.0, 62.9]
(62.9, 76.8]
(76.8, 90.7]
(90.7, 104.6]
(104.6, 118.5]
(118.5, 132.4]
(132.4, 146.3]
(146.3, 160.2]
(160.2, 174.1]
(174.1, 188.0]
(188.0, 201.9]

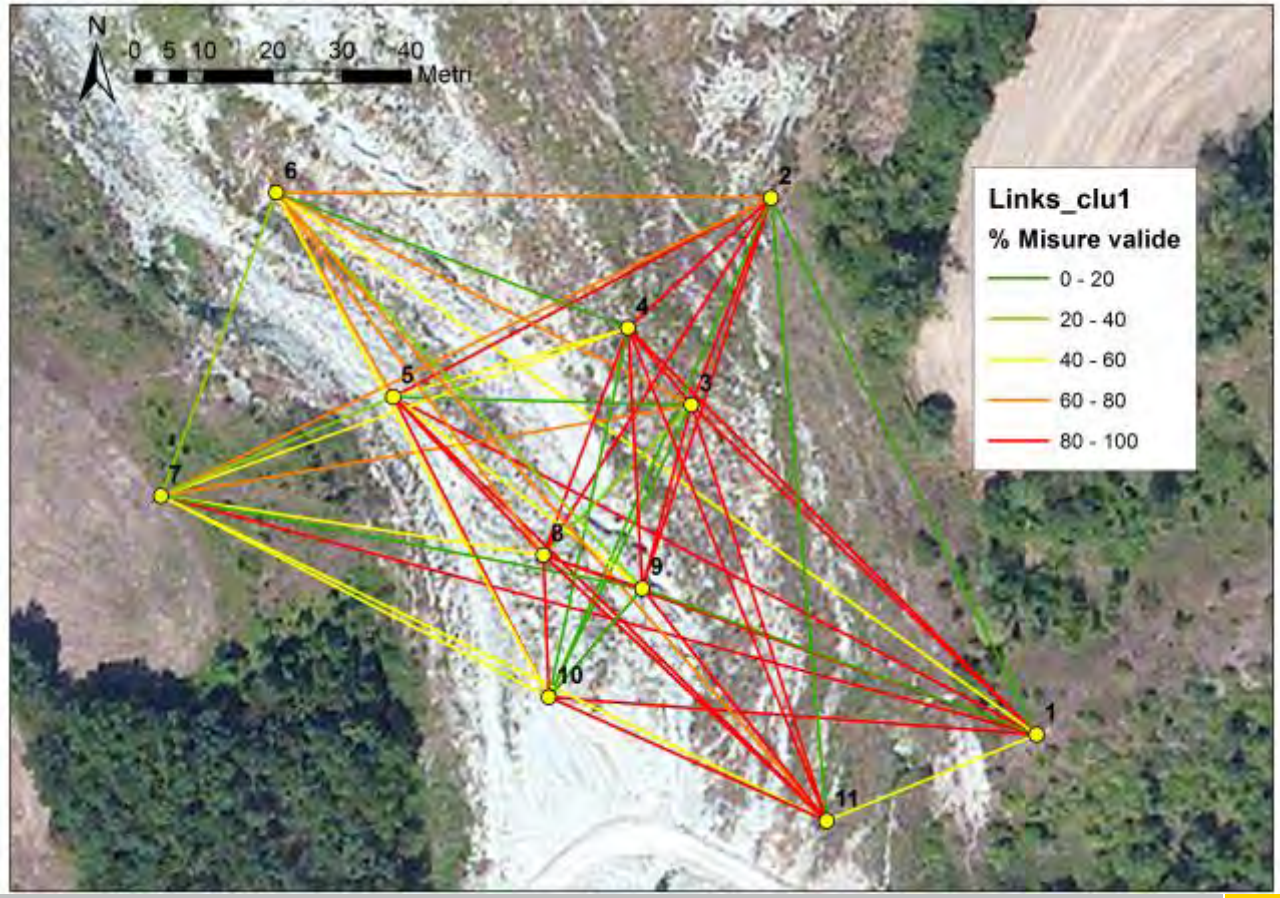
Raw data


distance 5-12
Distance (m)
Battery level (V)
140
120
100
80
60
40
20
0
14
13
12
11
10
9
8
7
6
5
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01

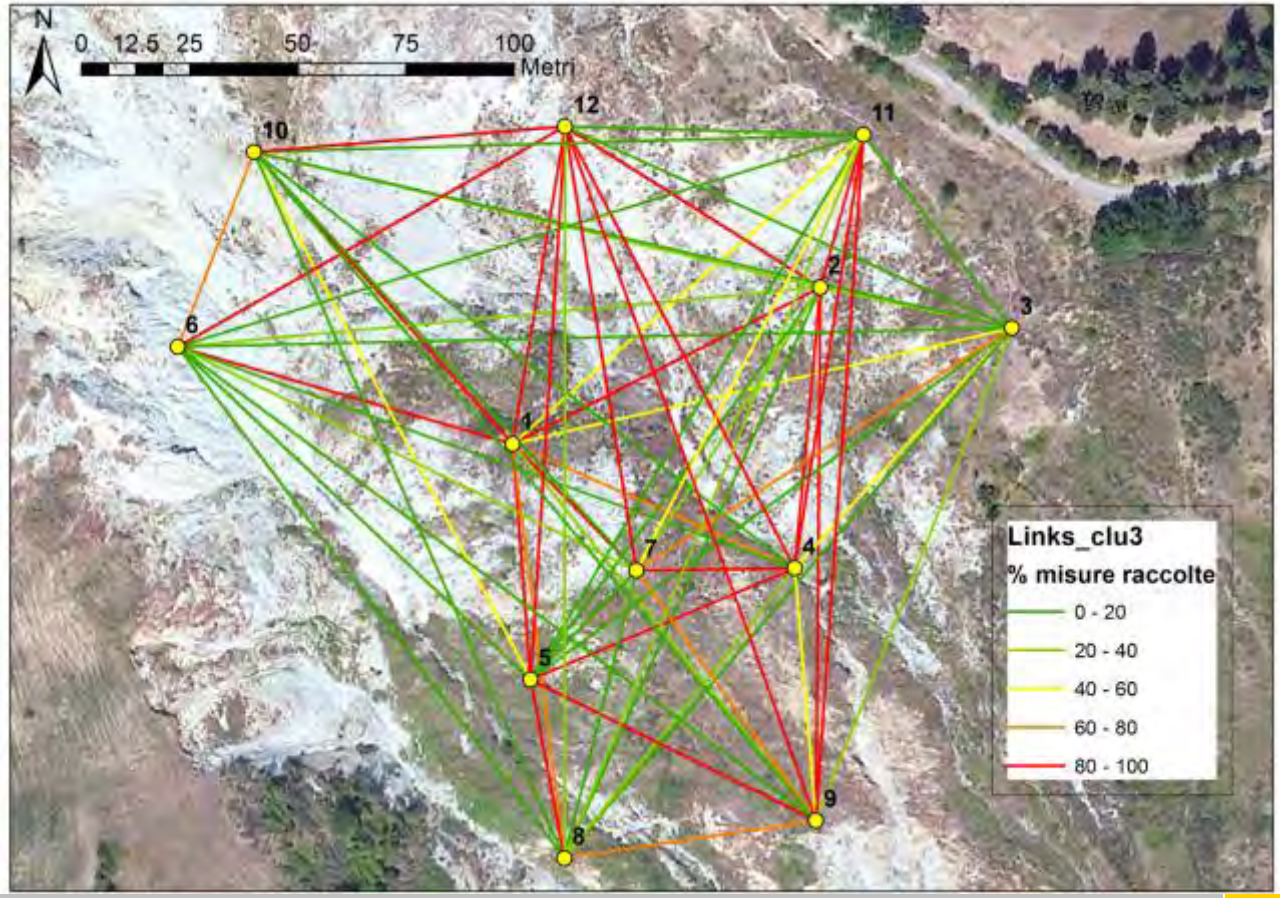
Cluster 1
Measurements made



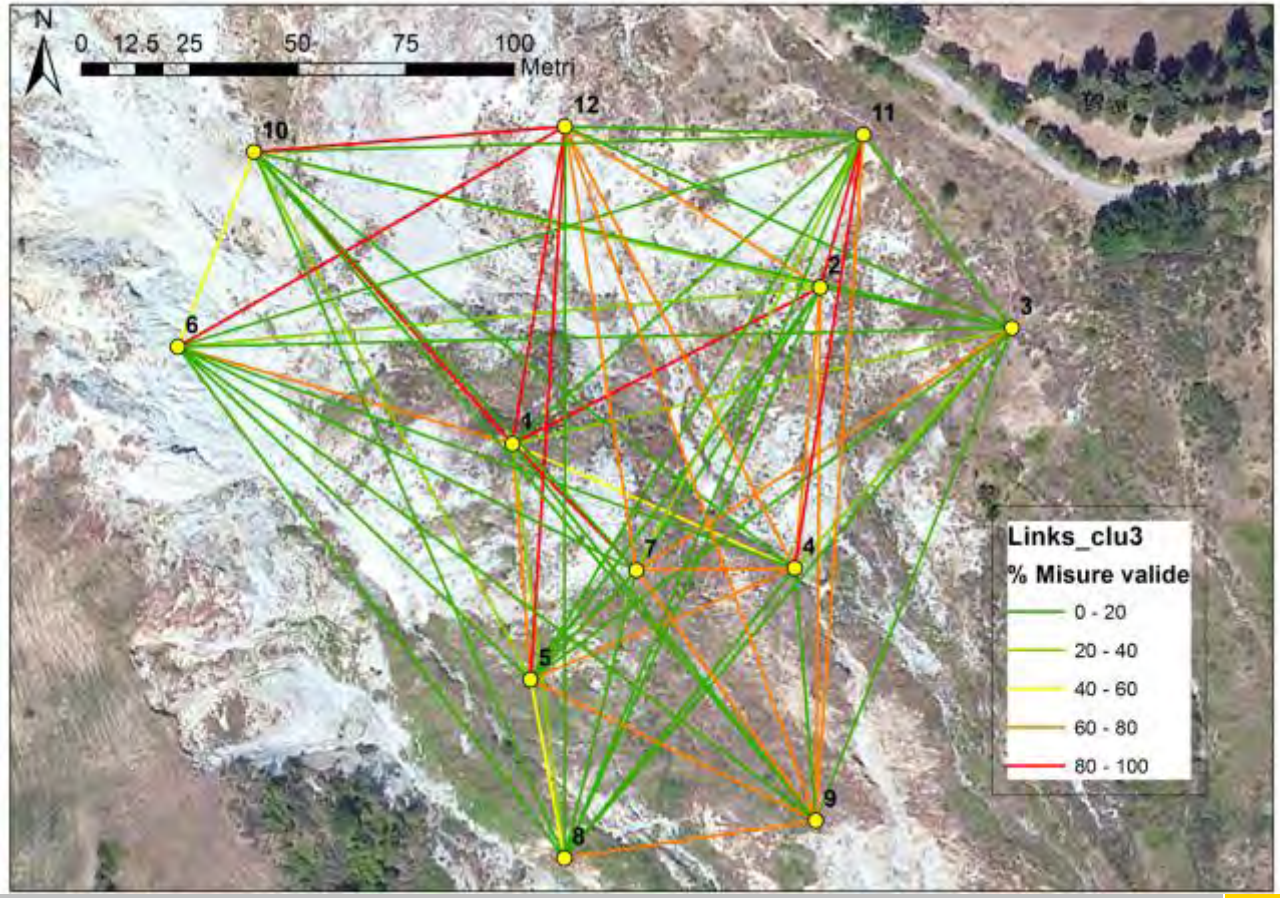
Cluster 1
Valid measurements



Cluster 2
Measurements made



Cluster 2
Valid measurements

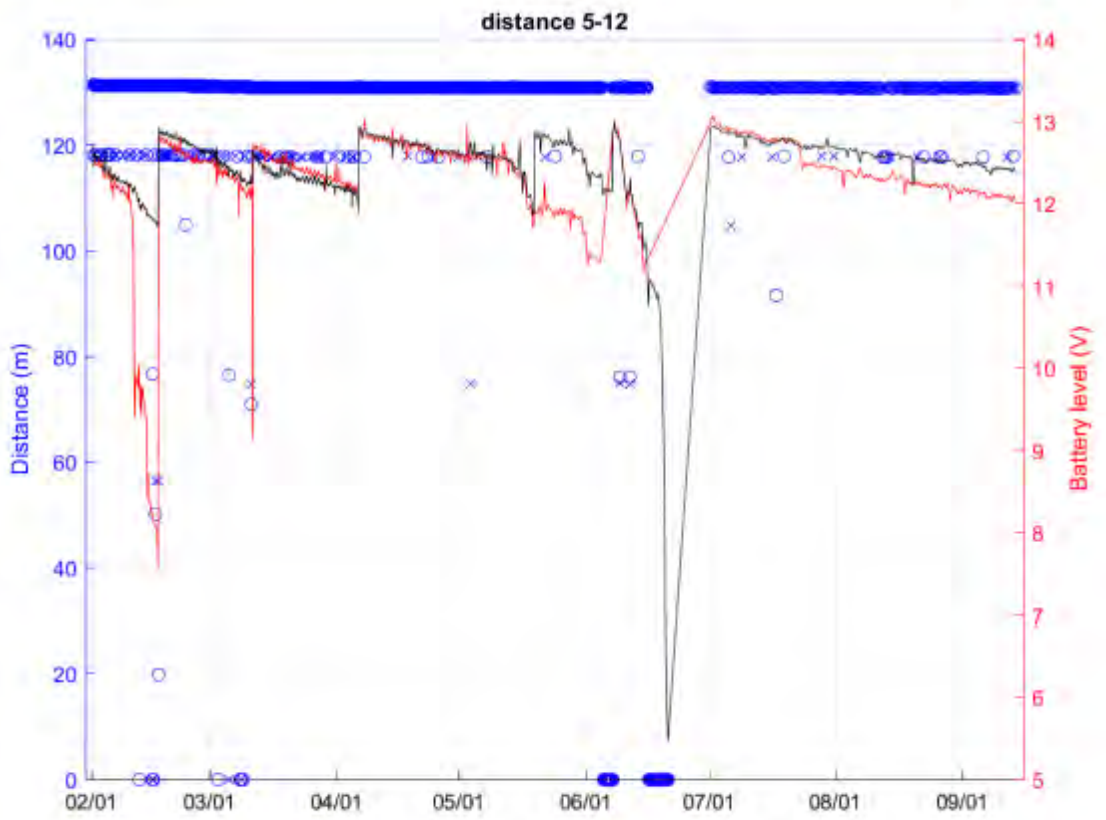


Meteorological conditions

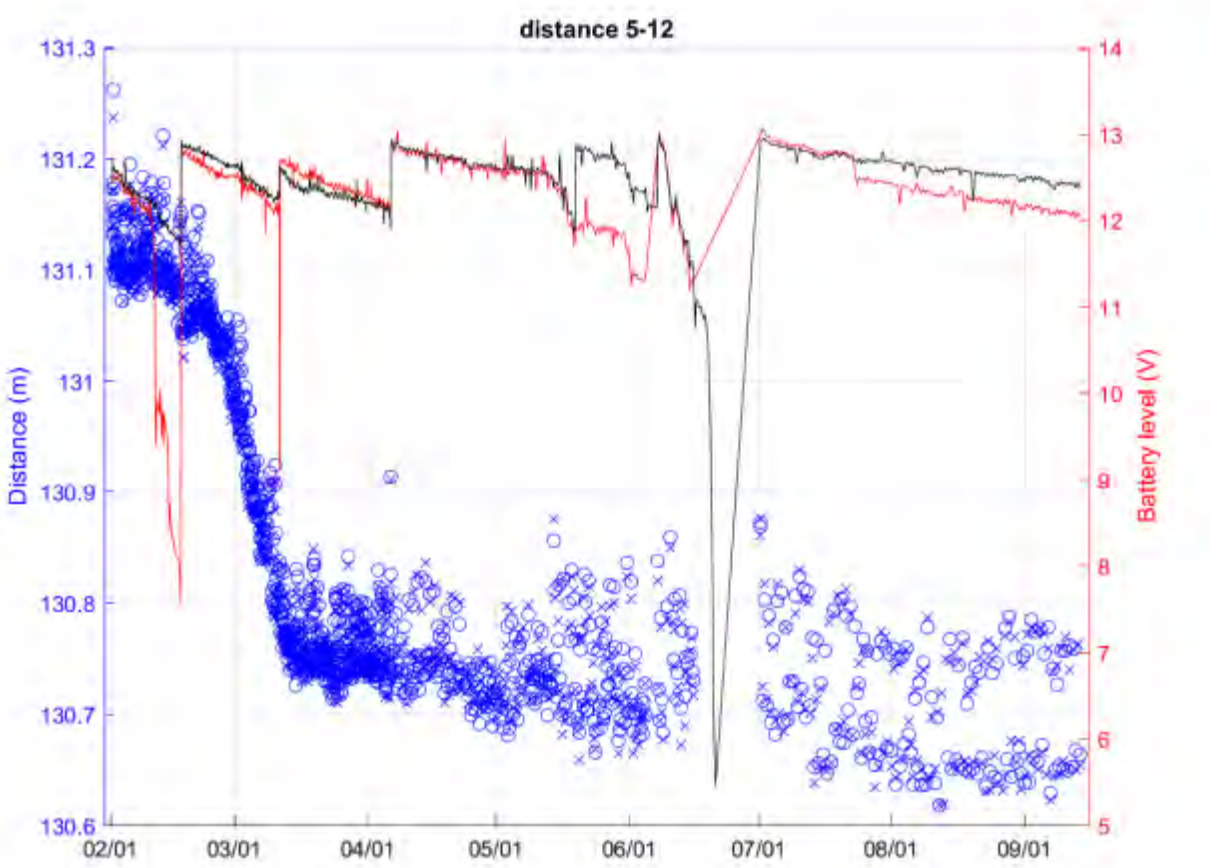
Raw data

X: distance between 3 and 7

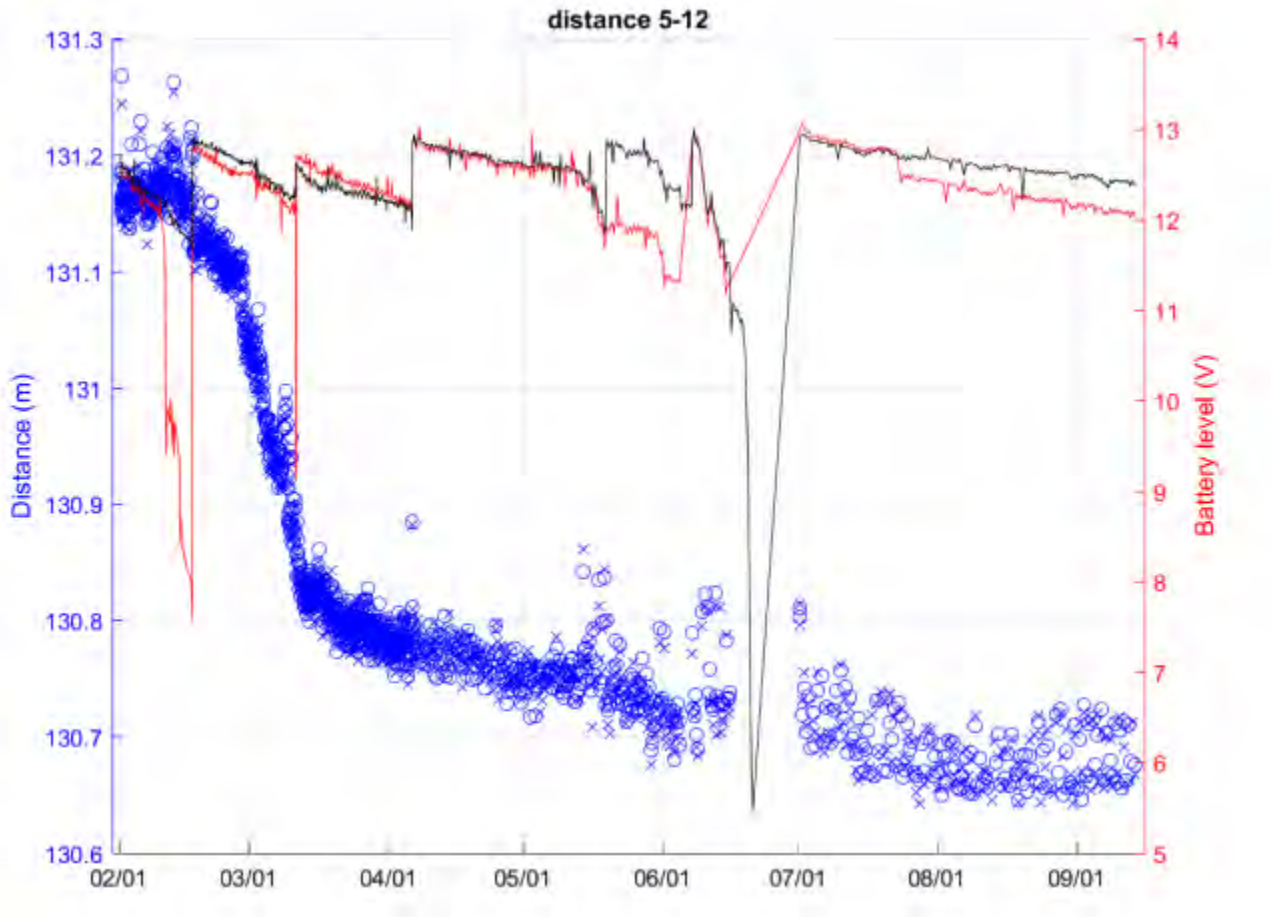
O: distance between 7 and 3



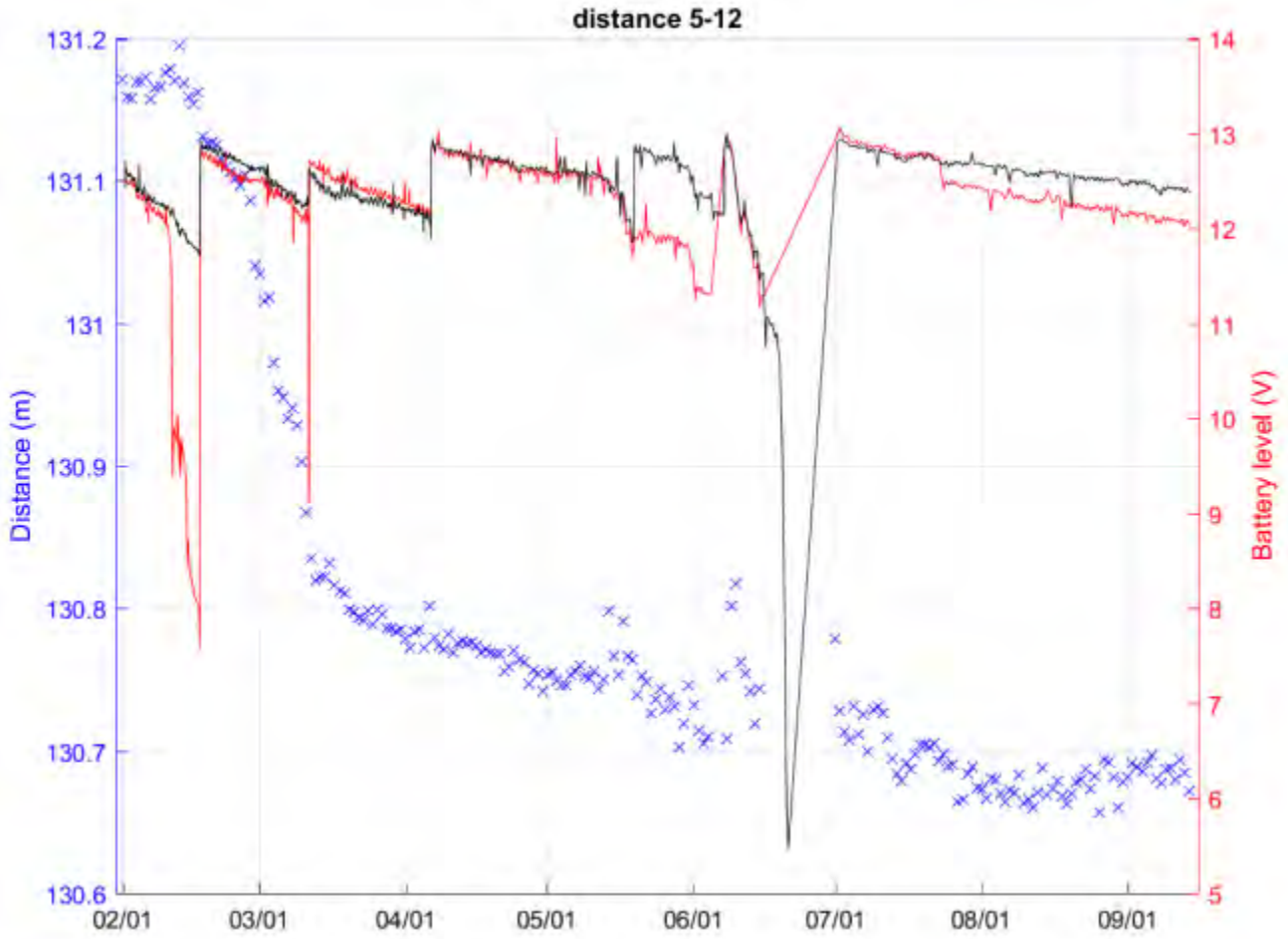
Valid measurements



Corrected measurements



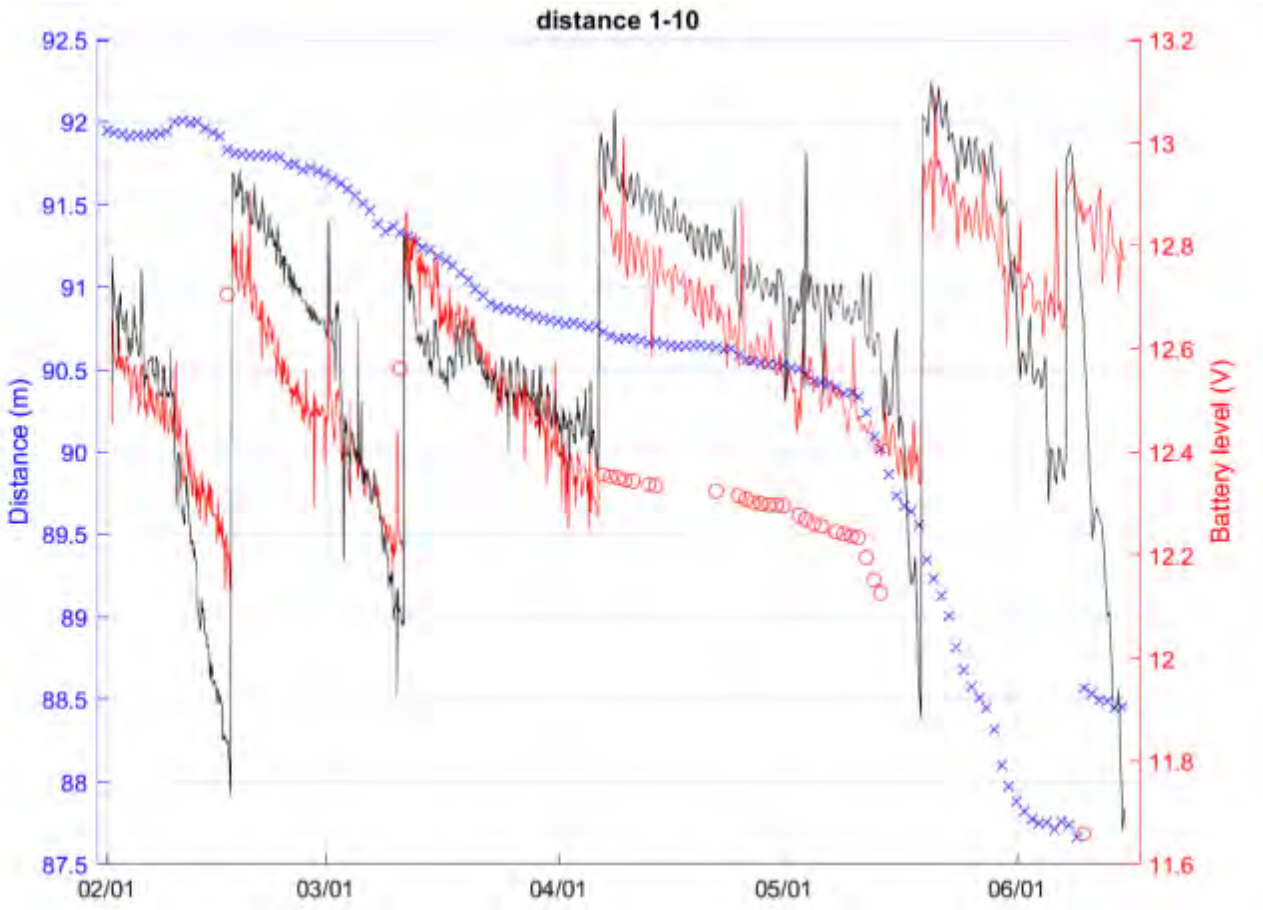
Daily averages



Data validation

X: Wi-GIM data

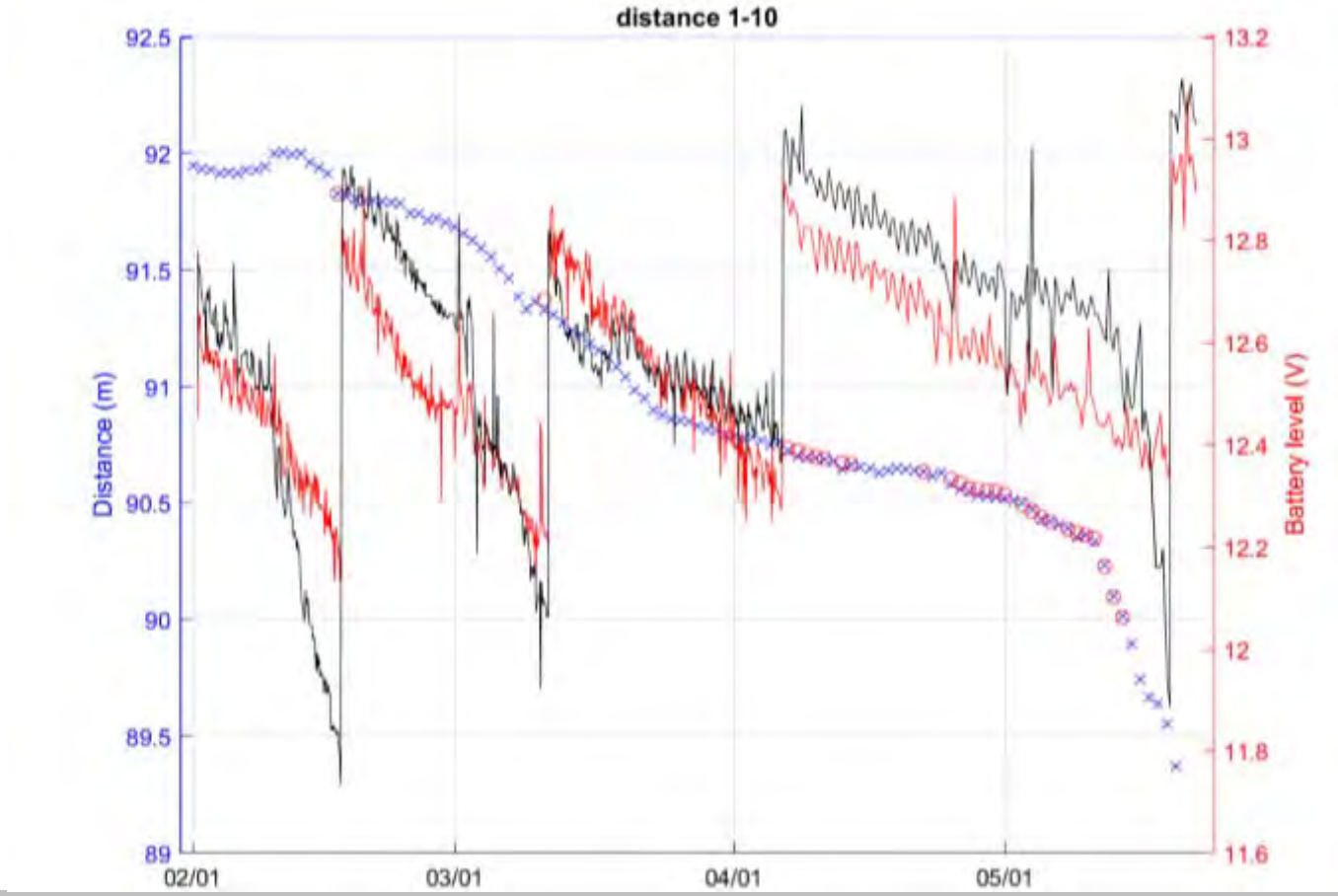
O: RTS data



Data validation

X: Wi-GIM data

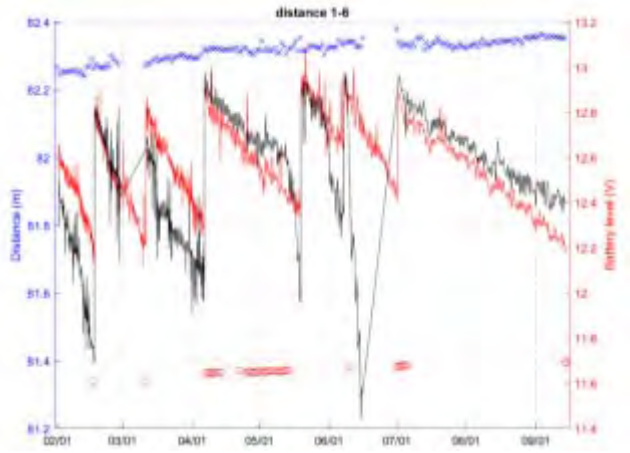
O: RTS data

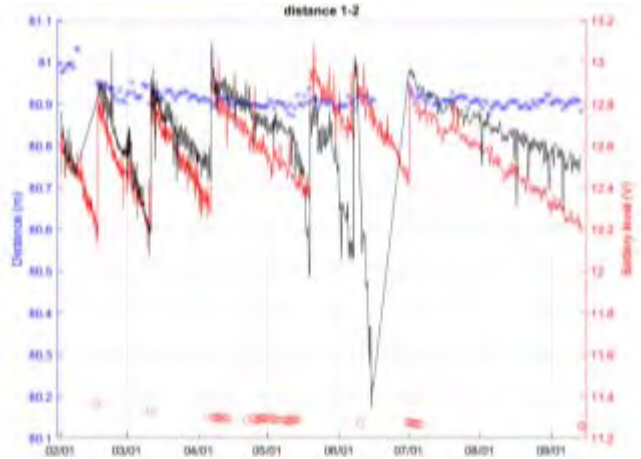


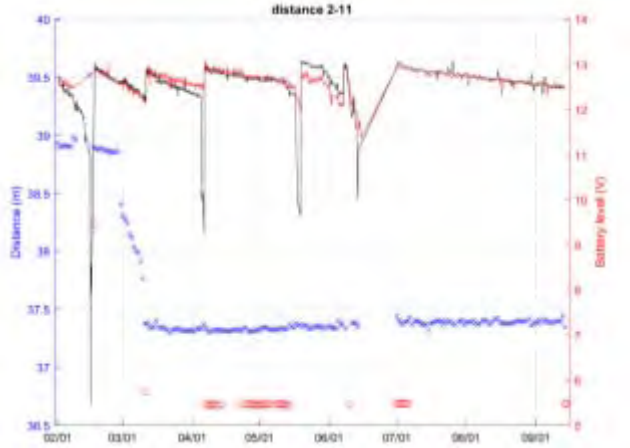
Data validation

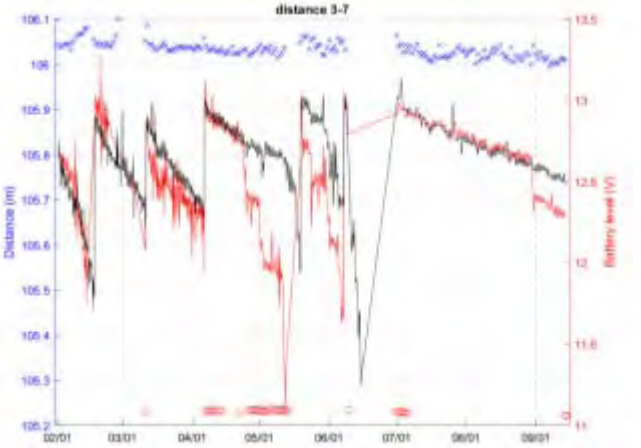
X: Wi-GIM data

O: RTS data

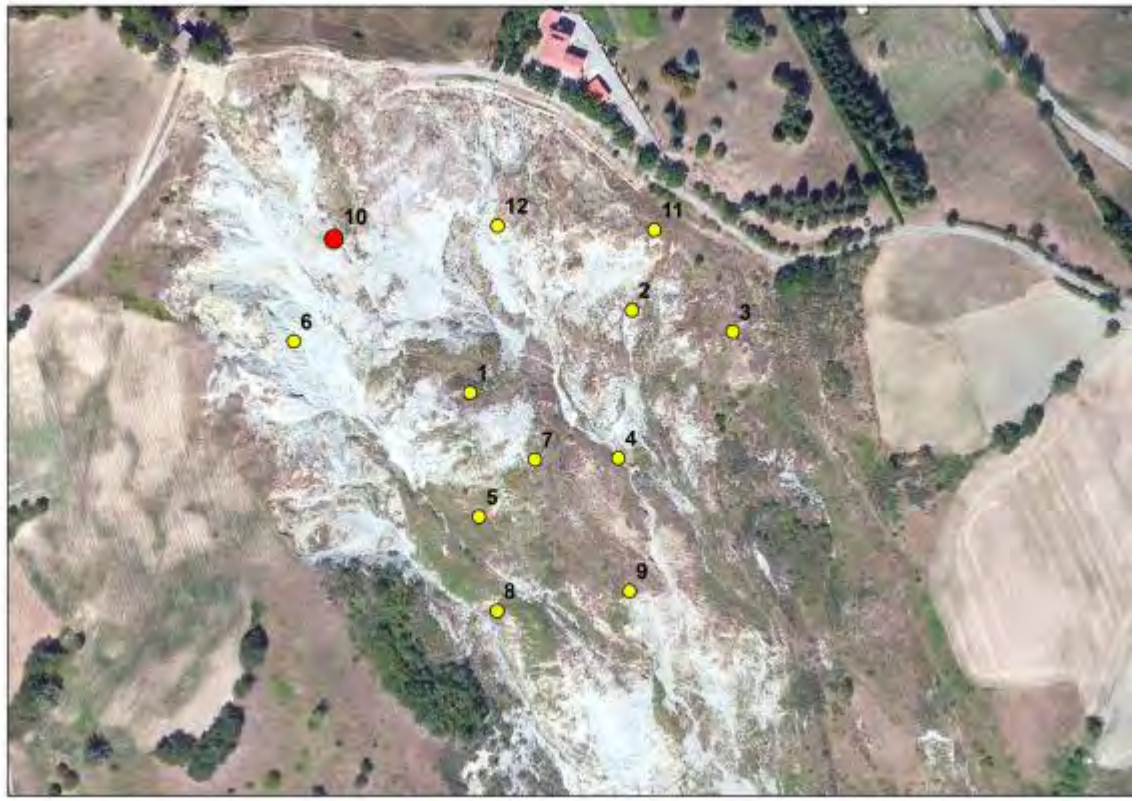








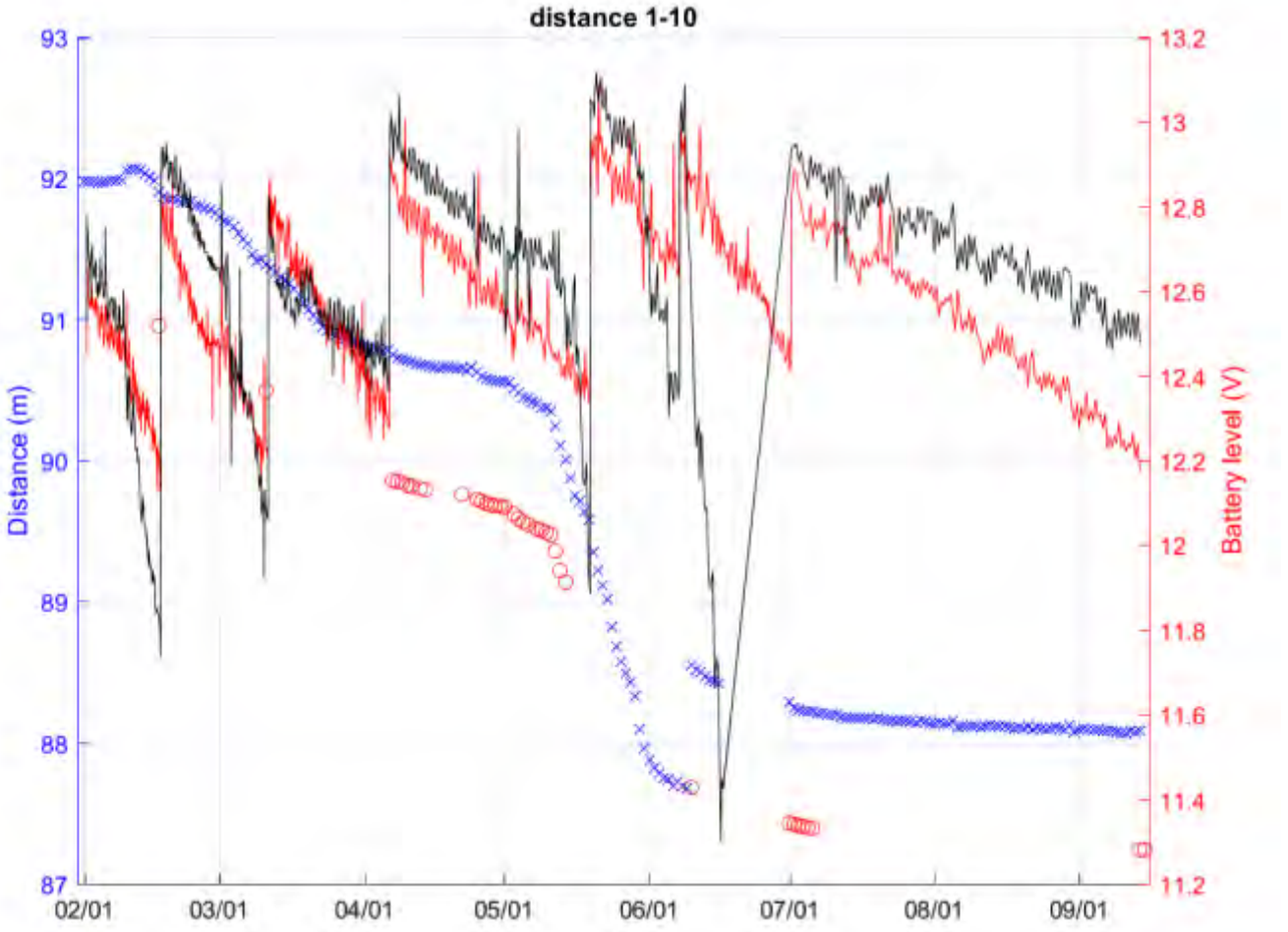
Node 10



Data validation

X: Wi-GIM data

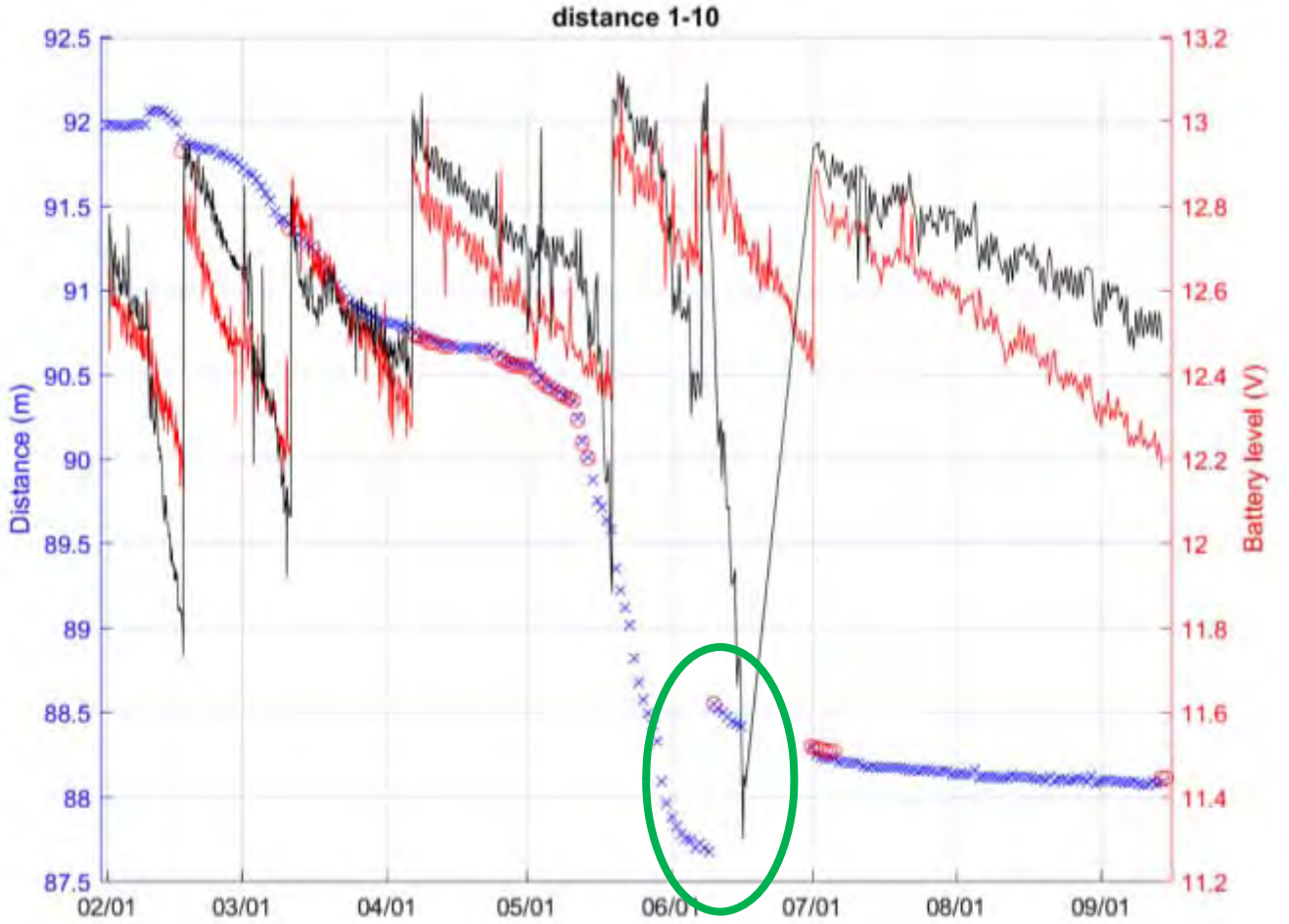
O: RTS data



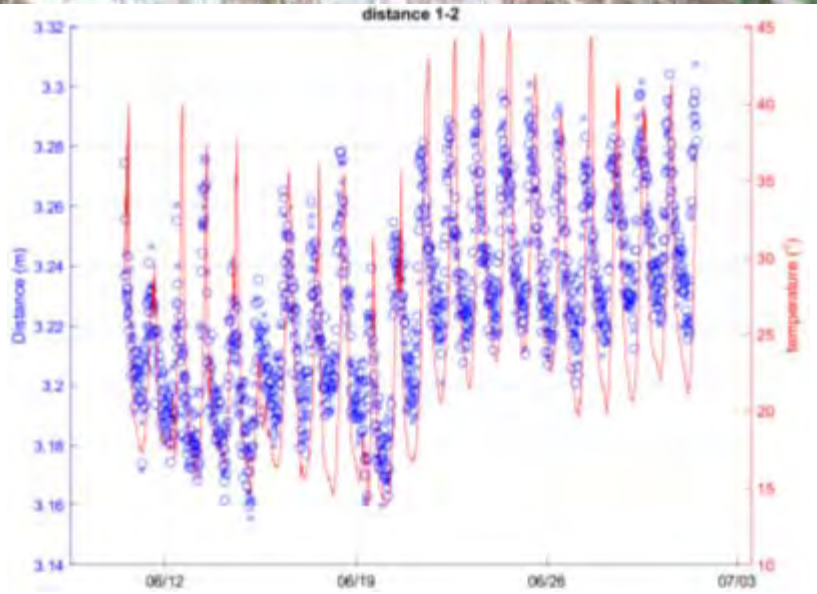
Data validation

X: Wi-GIM data

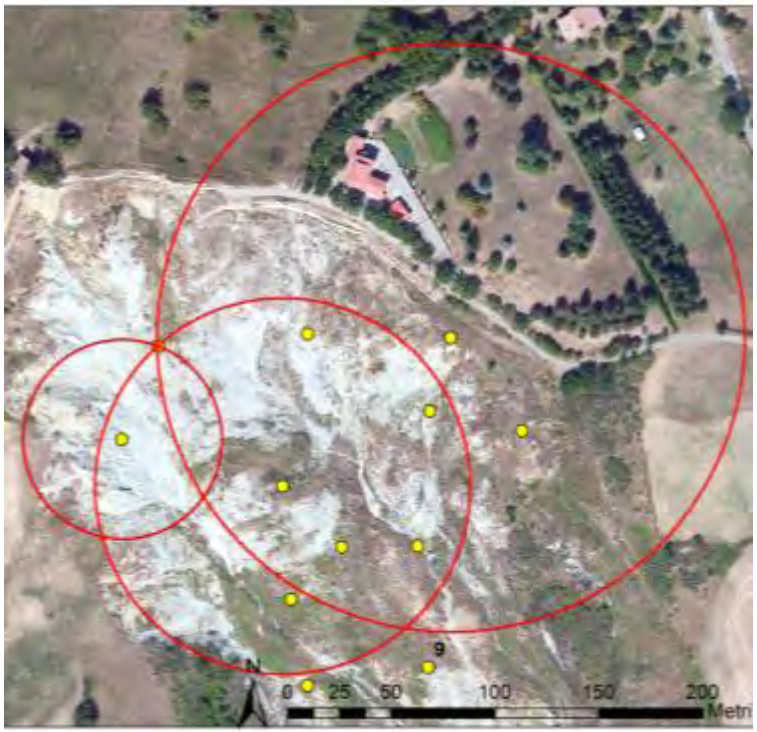
O: RTS data

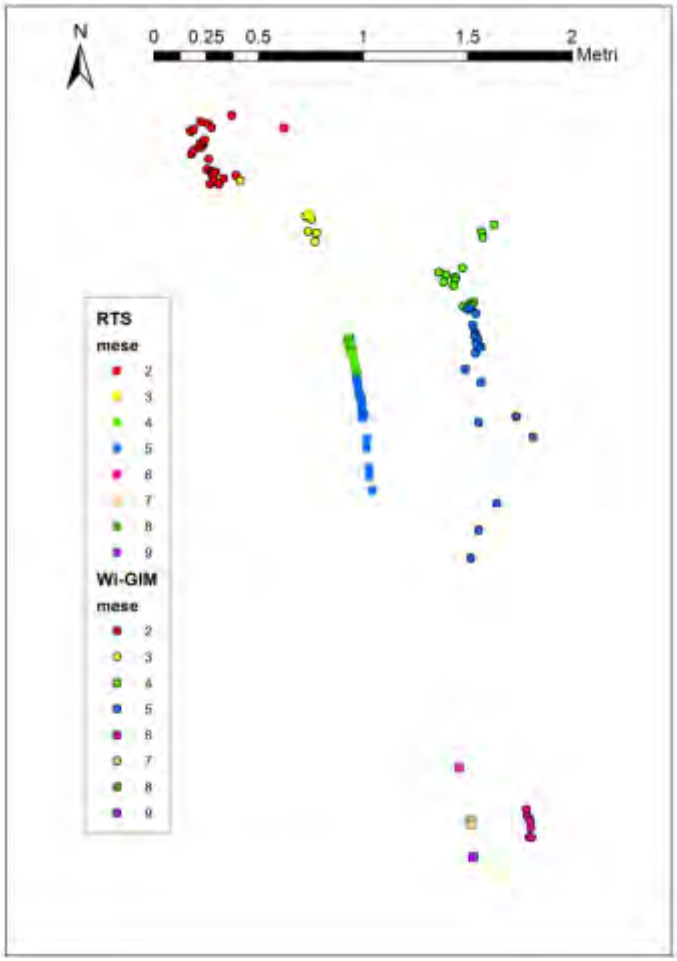


Cluster 1
Wireless extensometer

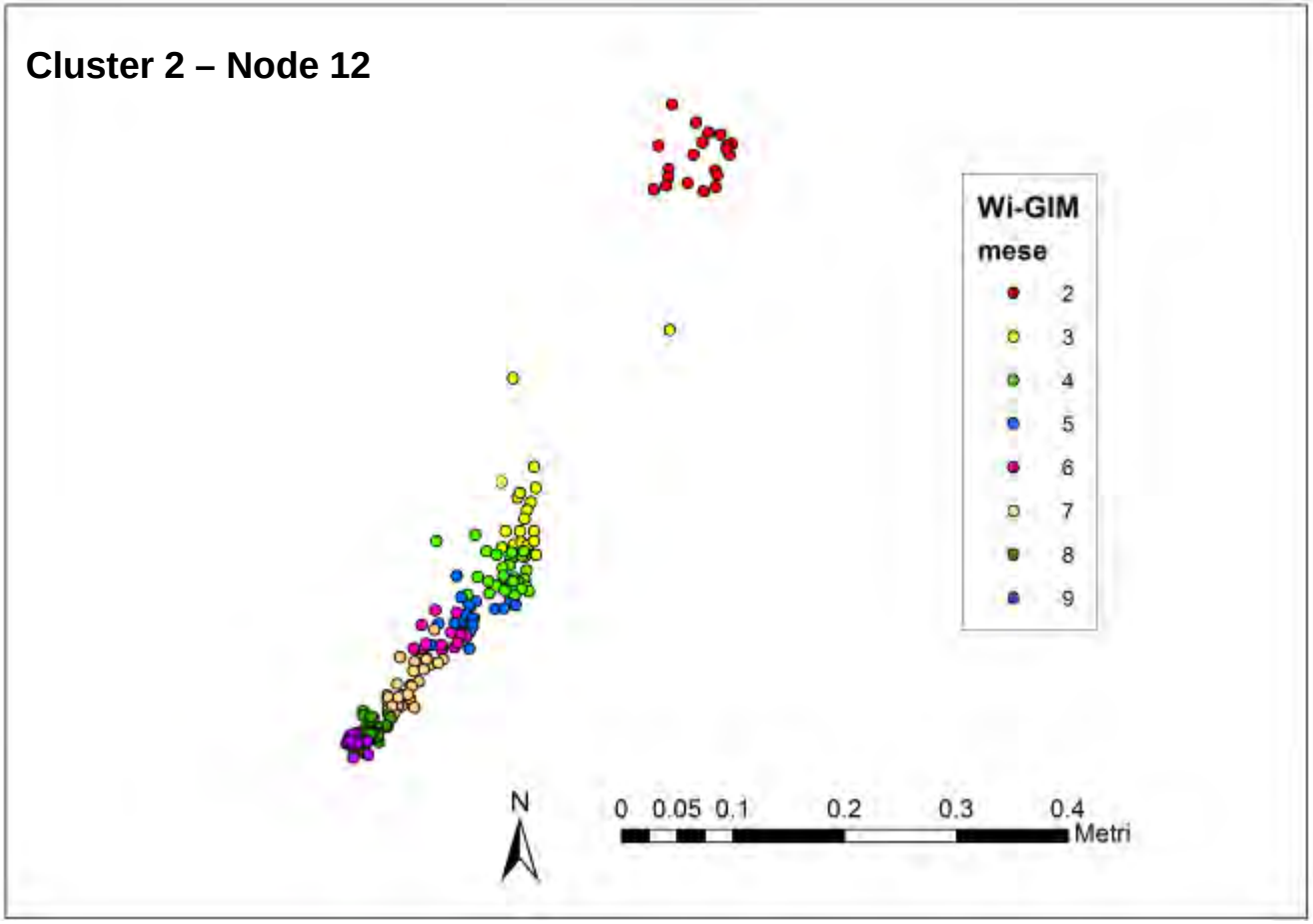


Motion tracking



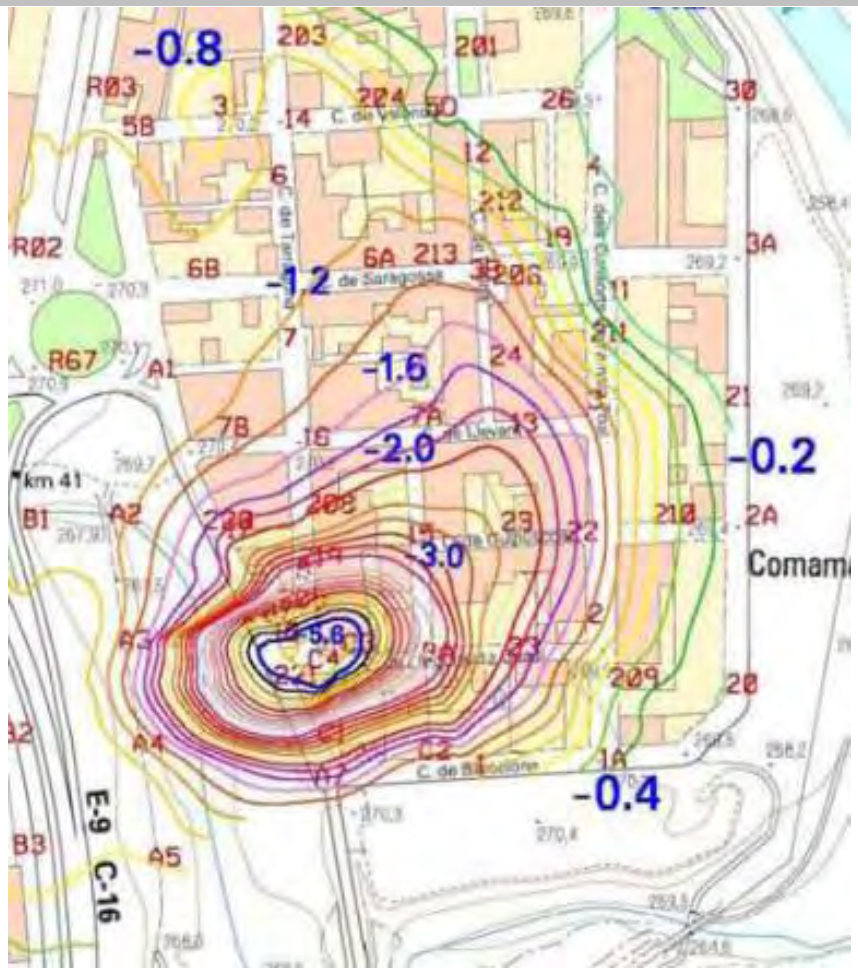


Motion tracking



Sallent test site

- Catanulya (Spain)
- Old underground potash mine
- 40 m large 110 m high natural cavity
- 50 cm vertical subsidence between 1997 and 2010



Google Earth photo 2006

Google Earth photo 2015

Master Node UWB

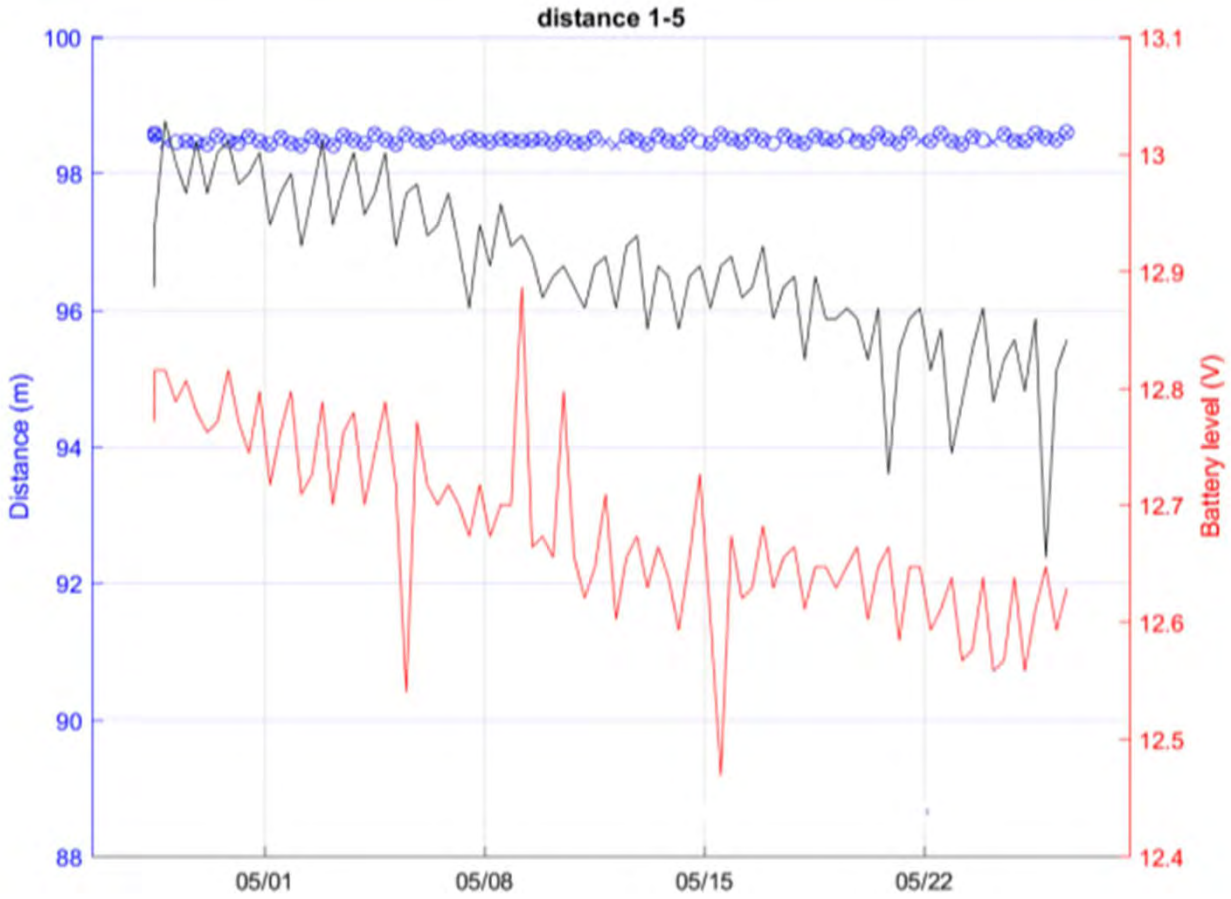
Master node with CW Radar

Monitoring data

X: distance between 1 and 5

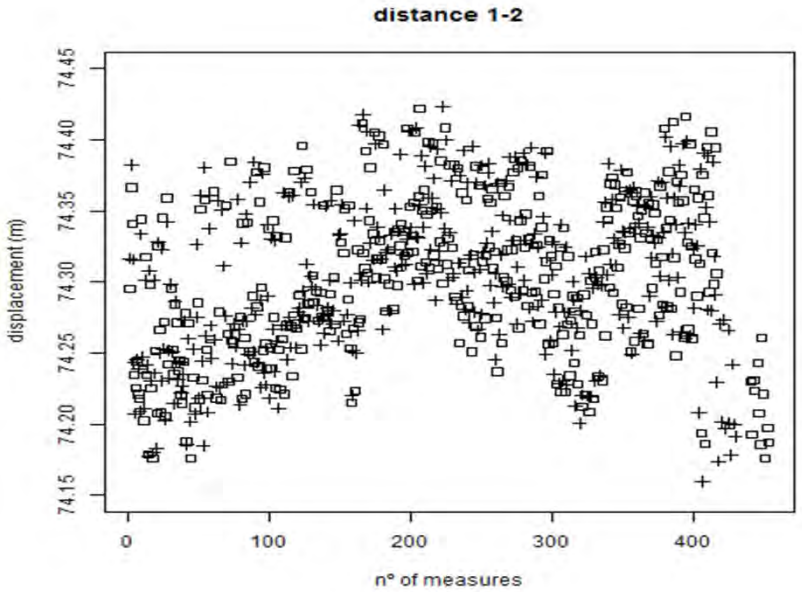
O: distance between 5 and 1

Making 1 measurement every 6 hours 4x2 readings are obtained which can be averaged to obtain 8 cm precision.



Wi-GIM Results

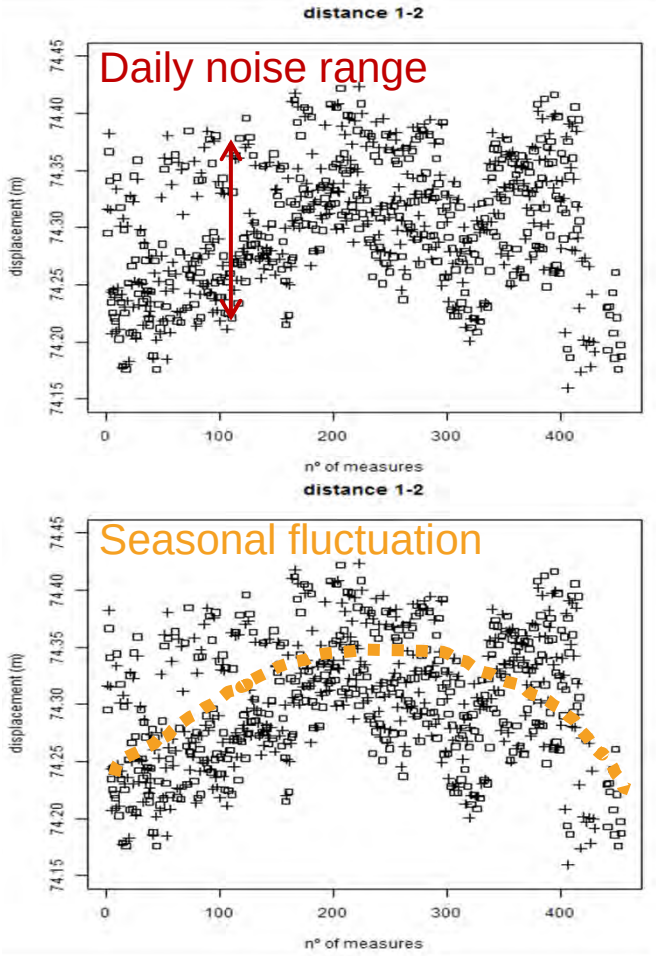
First results of Wi-GIM show raw measurement **accuracy of about 8 to 30 cm** depending the sensor location. Due the nature of subsidence dynamics (small and slow but sustained in time), this accuracy implies that this monitoring system needs some time of continuous lectures to deliver information of the terrain movement. Nevertheless, it has been observed that there are several factors with influence on the system accuracy, which can be ranged and /or corrected.



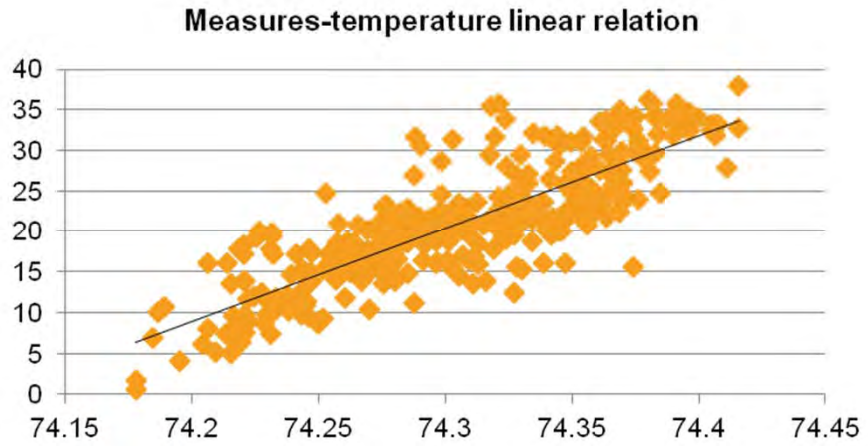
One of the main factors of data fluctuation which have been observed is **temperature** which show daily and seasonal influence.

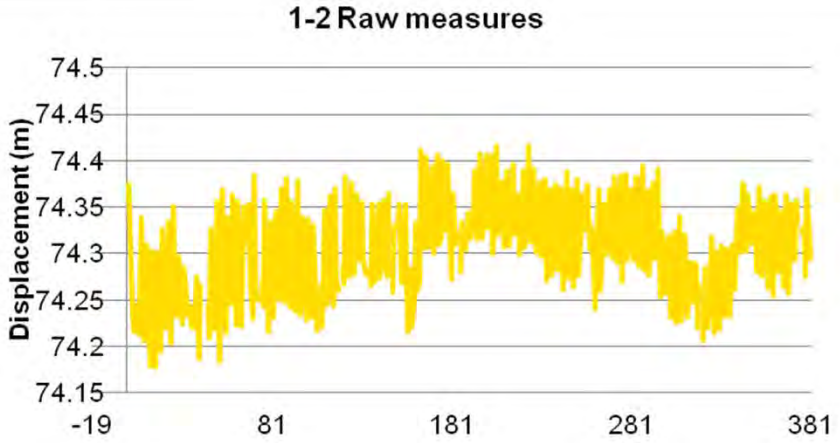
Daily, the sampling time-step of 8 hours translates into a three lectures in a fairly different temperature conditions, and hence a fairly different lectures in a temperature-affected sensor, generating a **daily range**.

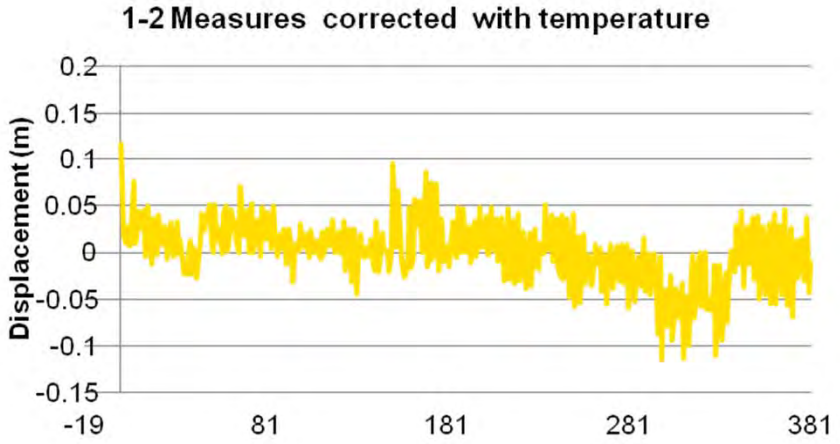
Seasonally, general temperature fluctuations affect general **trends of measures**, and require long datasets to be corrected.



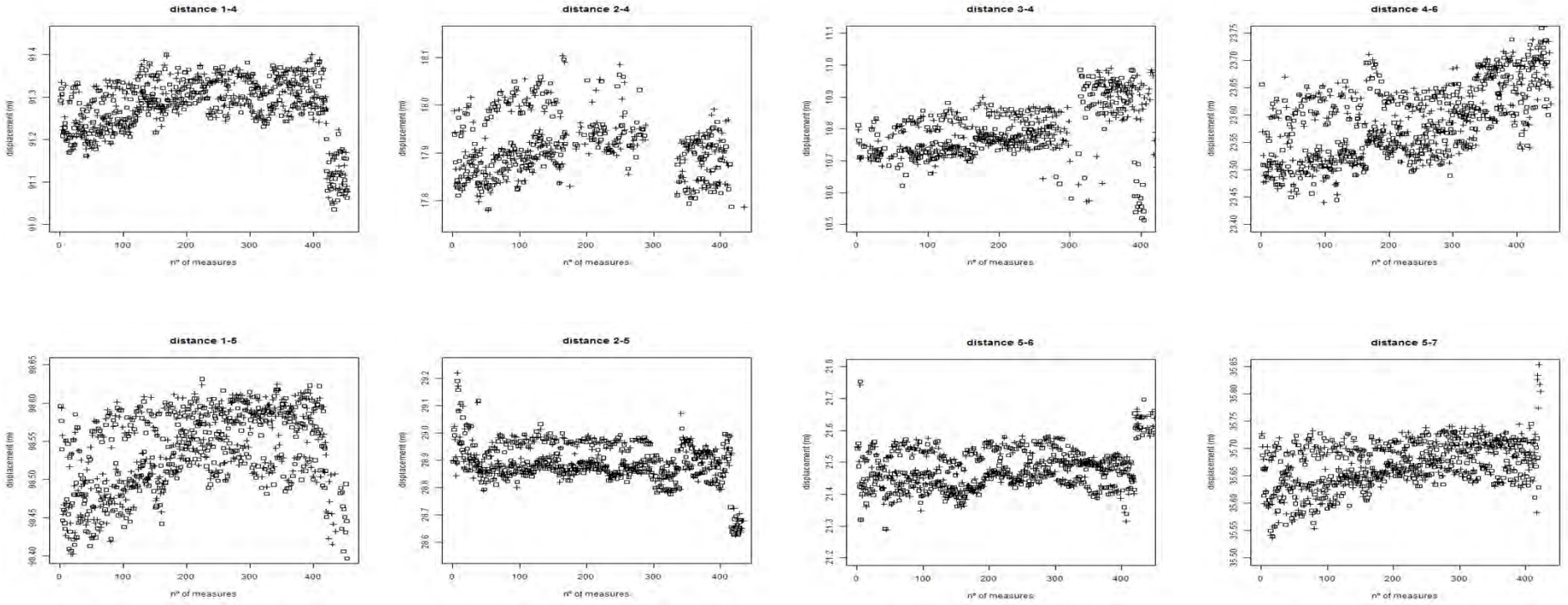
Daily fluctuation due temperature can be corrected by relating both variables. A **linear relation** between them can greatly improve accuracy to a daily fluctuations **under 5 cm**.



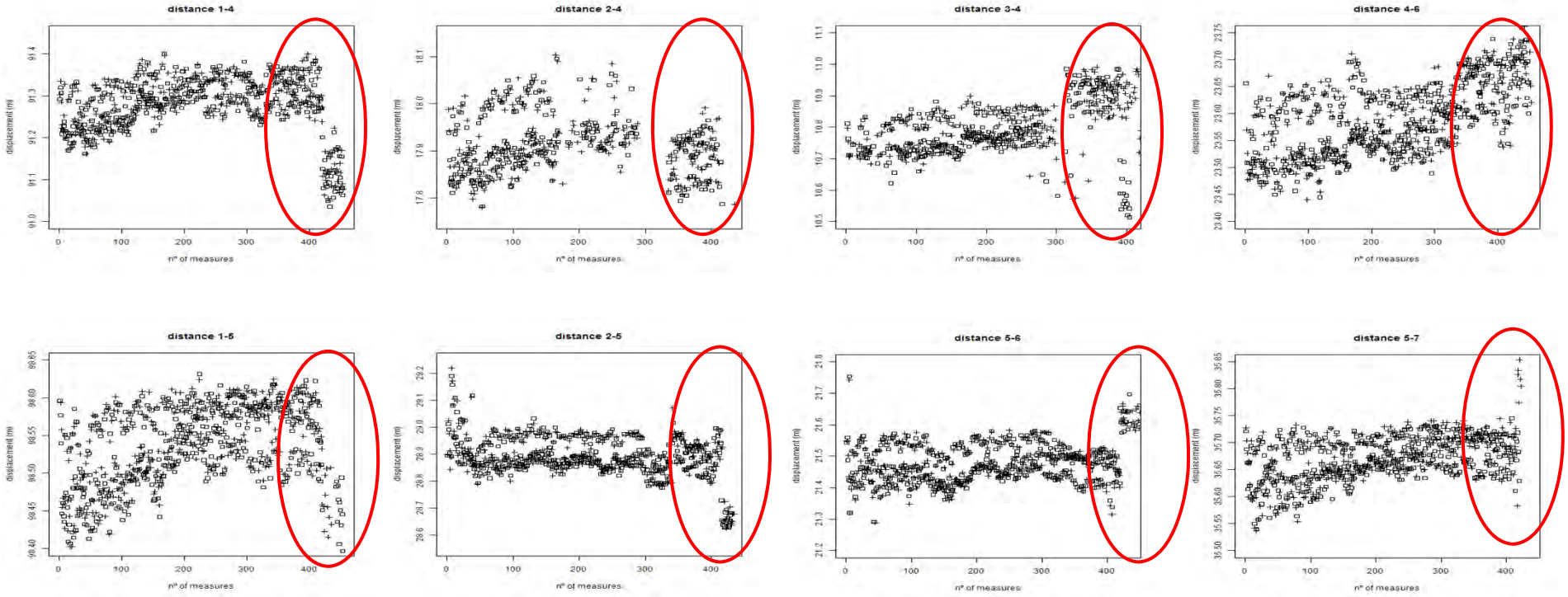




In order to gather more information about the system response to a subsidence phenomena, the displacement has been forced in two of the sensors.

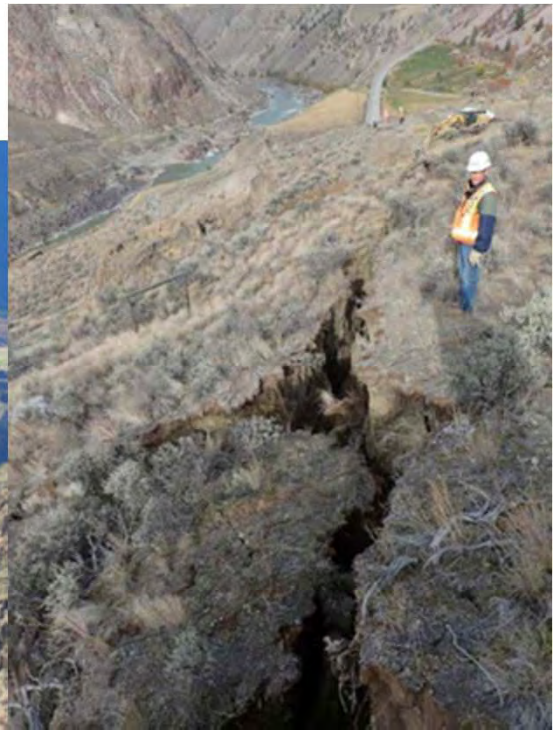


It has been seen that **system responds adequately** to the forced movement in the relation between the displaced sensors and the rest of the network within the accuracy limits.



Future of Wi-GIM

•Geotechnical Engineering Centre at University of Alberta
•Research mandate to apply and test innovative monitoring systems
•Bilateral agreement of cultural and scientific cooperation between DST-UNIFI and Department of Civil and Environmental Engineering of University of Alberta
•Application to Fountain Slide (Canada)



Future of Wi-GIM

•Oriente de Michoacán

•Deep Seated Gravitational Slope Deformation

•4 million m^3

Conclusions

NOW

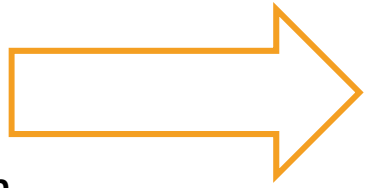
Precision (raw data): 8-10 cm

Precision (filtered): 2-3 cm

Battery duration: ≈ 1 month

Maximum range distance: 140 m

Cost : ≈ 100 €/node



FUTURE

Precision (filtered): <1 cm

Reduce node size

Increase battery duration

Cost (industrialized): ≈ 50-70 €/node

✓ **Accuratezza misure UWB**

✓ **Distanza fra nodi**

✓ **Rapida installazione**

✓ **Basso costo**

✓ **Bassa vulnerabiità**

✓ **Elevata autonomia**

In corso di approfondimento:

- **Effetto multipath**
- **Influenza fattori atmosferici**
- **Influenza direzionalità antenne**
- **Influenza ostacoli (altezza antenne)**
- **Posizionamento 3D**

Promettente per *earthflow* e grandi frane in roccia