CONVEGNO ALIG - PISA 13/05/2011

NUOVE TECNOLOGIE RADAR
COLLAUDO MONITORAGGIO E INDAGINI NON INVASIVE PER MANUFATTI

Interventi Relatori	Foto Convegno ALIG - PISA

Breve presentazione di IDS Ingegneria dei Sistemi SpA e della Divisione Georadar

Ing. Francesco Coppi (IDS)
Principi teorici della tecnologia interferometrica

Dott. Paolo Farina (IDS)
Le applicazioni della tecnologia interferometrica da terra ed alcuni casi di studio M, L , S

Prof. Carmelo Gentile (Politecnico di Milano)
La tecnologia radar interferometrica da terra applicata ai ponti: innovazione, vantaggi ed esempi applicativi

Dott. Paolo Papeschi (IDS)
Principi teorici della tecnologia GPR; le configurazioni georadar di IDS specializzate per il controllo NDT di ponti e strade. Ris Hi Bright, Ris Hi-Pave
Parte 1°
Parte 2°
Parte 3°

Dott. P. Papeschi Dott. G. Manacorda Dott. A. Simi (IDS)
La tecnologia georadar per la diagnostica non distruttiva dei manufatti
Parte 1°
Parte 2°

Inviare a alig@associazionealig.it un messaggio di posta elettronica contenente domande o commenti su questo sito Web.
Aggiornato il: 22 maggio 2011

CONVEGNO ALIG

13 maggio 2011 ore 9^{00}-18^{00}

sede del convegno

P I S A

Loc. Montacchiello via E. Calabresi, 24

NUOVE TECNOLOGIE RADAR

COLLAUDO. MONITORAGGIO E INDAGINI NON INVASIVE PER MANUFATTI

con il patrocinio :

ORDINE GEOLOGI REGIONE TOSCANA

con la collaborazione :

IDS Ingegneria dei Sistemi SpA

POLITECNICO DI MILANO

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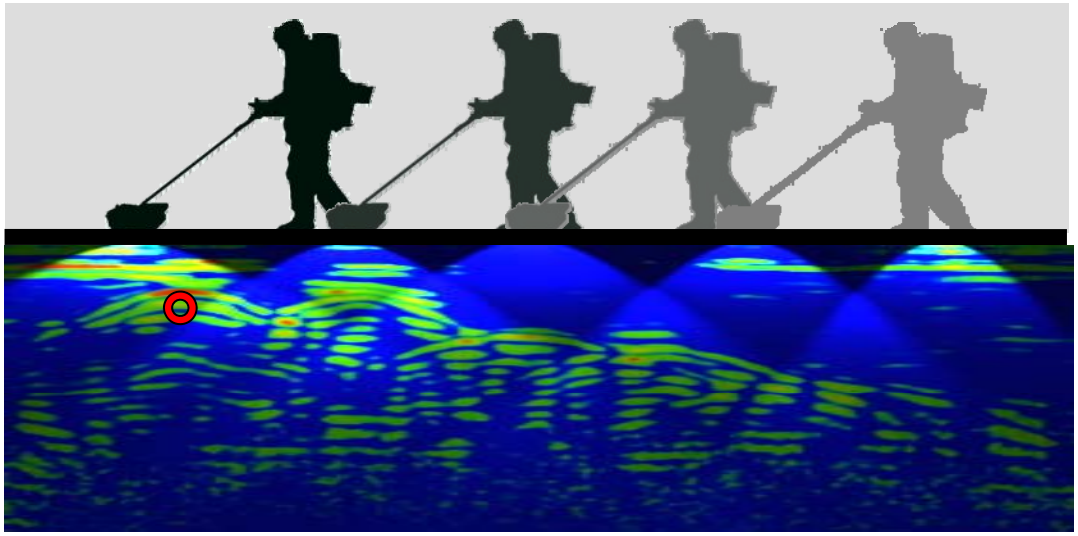
Breve presentazione di IDS Ingegneria dei Sistemi SpA e della Divisione Georadar

Innovative radar technology for engineering, environment and security



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IDS Ingegneria dei Sistemi S.p.A.

- Founded in 1980
- About 380 employed
- Main expertise in Applied Electromagnetics, Radar Systems, System Engineering

The offices:

- Headquarter in Pisa - Montacchiello
- GeoRadar office in Pisa - Montacchiello
- Branch office in Rome
- Subsidiary in Brisbane (IDS-Australasia)
- Subsidiary in Southampton (IDS-UK)
- Subsidiary in Sao Paulo (IDS-Brazil)
- Subsidiary in Montreal (IDS-North America)

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Organization

IDS UK | IDS Brazil | IDS North America | IDS Australasia

Local offices across the world provide expertise, services and 24/7 support for industries with time, quality and cost critical requirements.

Highly trained agents and distributors worldwide extend the IDS network over 40 countries.

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Customers

Naval Division

Aeronautical Division

Aeronavigation Division

Georadar Division

IDS Laboratories

Computer Science & Information Technology Lab.

EM Design Framework Lab.	Avionics Lab.	RADAR Systems Lab.	Air Navigation Systems Lab.	Signatures Techologies Lab.

Measurements & Trials Lab.

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Naval Division

Mission

*To provide Navies and Industries with an **innovative design capability** aimed at optimizing ship EM performances and signature control.*

That means:

Maximizing mission success probability

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Aeronautical Division

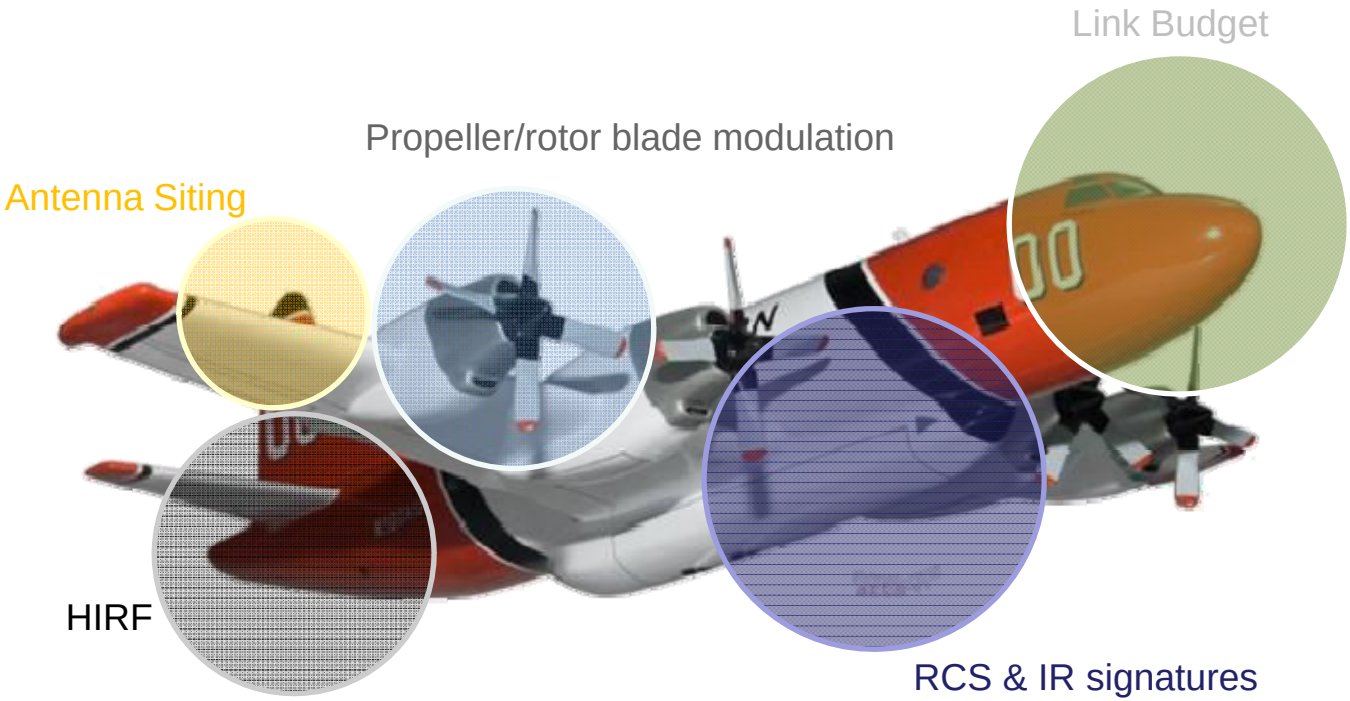
To support governmental authorities and aeronautic industry with product and services aimed at improving design process' efficiency, especially in conceiveng stealth aircrafts .

To provide also flight control systems and avionics design services for fixed/rotary wing platforms and UAVs.

Aeronautical Division

Analysis and EM design

EM design means to deal with the following matters:



*A **different approach** in the design phase, integrating EM simulation and innovative prediction tools ensure the attainmnet of the **desired performances**.*

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Aeronautical Division

Main programs

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Air Navigation Division

Mission, product

Delivering systems and performing services for the air transport market segment and specifically targeted to Air Navigation Service Providers and Aviation Authorities (Civil, Military)

Systems are mainly **built and maintained in house** with minor off-the-shelf components from third party providers

Operating worldwide through and with the four IDS subsidiaries and through a number of dealers/partners

IDS Aeronavigation Systems are now installed in about **30 countries** for a total of **40 accounts**

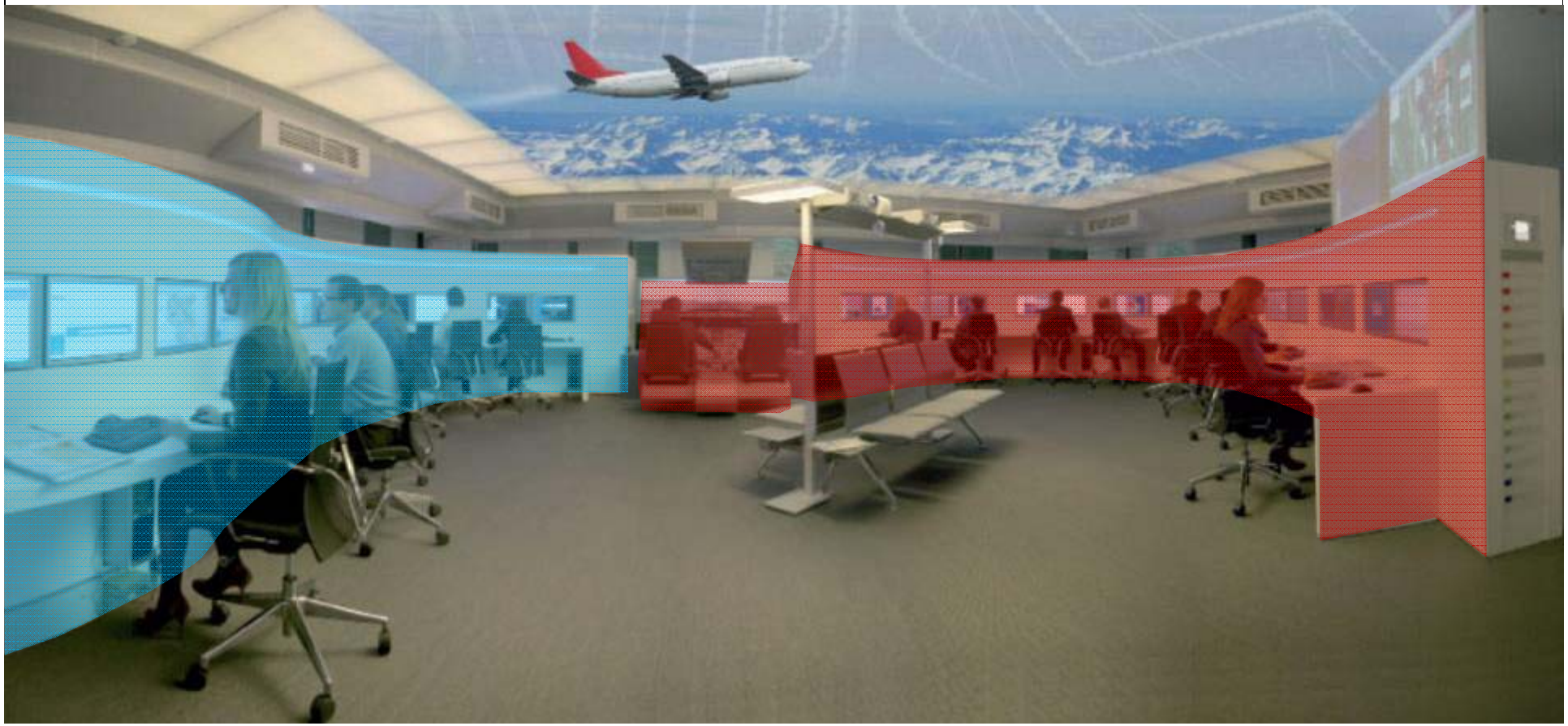
"..IDS has the largest installed base of any supplier in the field, including four of the five most influential operators in air navigation. Customers, including all the organisations represented here and more, range from large standard setting ANSPs on four continents to specialist service providers…"

Airnavigation Division

Operational testing room

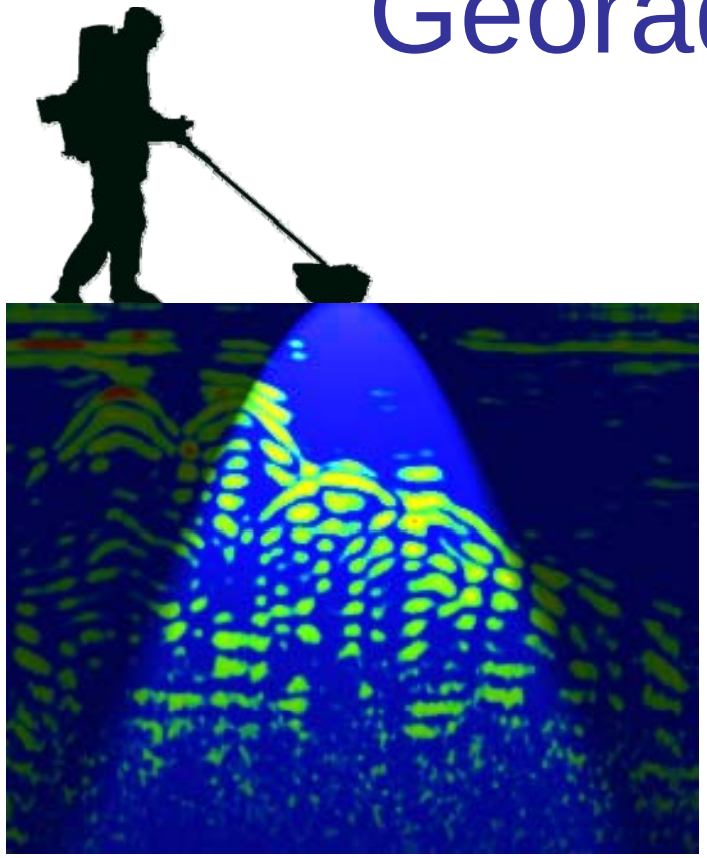
AIS Production Systems
(Information Management and Data Distribution)

Engineering Systems
(Design and Validation)



Georadar Division

Mission



To transfer IDS competencies in the radar field and system engineering to "low power" ***radar systems for engineering, environmental and security applications***

Pursuing the product excellence through the creation of application-specific, innovative products, able to bring valuable benefits to the user

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IDS GeoRadar Division

- ***Leader nei Sistemi GPR multi-canale e multi-frequenza per applicazioni specifiche***
- IDS ha iniziato a studiare la tecnologia GPR sin dal 1991, su incarico di Telecom Italia. Il Progetto Socrate richiedeva infatti lo sviluppo di soluzioni GPR specifiche per migliorare le prestazioni di localizzazione dei Sottoservizi
- IDS è stata la prima ad introdurre nel mercato GPR I sistemi ad array multi-canale e multi-frequenza, migliorando in maniera decisiva le prestazioni di mappatura dei Sottoservizi
- Dal 1999 IDS ha iniziato l'introduzione su scala mondiale dei suoi sistemi
- IDS è ad oggi uno dei principali costruttori mondiali di soluzioni GPR, differenziandosi per lo sviluppo di soluzioni altamente specializzate per applicazione
- ***Tecnologia Radar Interferometrica per il monitoraggio del territorio e delle strutture***
- Nel 2007 IDS introduce sul mercato il primo radar intereferometrico per il monitoraggio dei fronti instabili e dei movimenti/vibrazioni di grandi strutture

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Linee di prodotti

Ground Penetrating Radar (GPR):

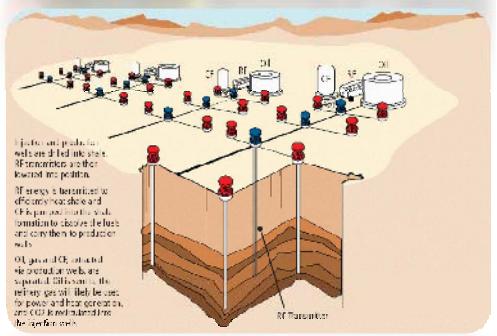
Innovative, application-specific products for geo-applications

Interferometric Radar:

A new approach, through radar interferometric technology, for monitoring ground and structure displacements

Solutions:

Provide high-level, specialized solutions and services, based on the Division technology and know-how



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La nostra presenza nei mercati internazionali

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PROGRAMMA DELLA GIORNATA

9.30 – 10.00	Ing. Francesco Coppi (IDS)	Principi teorici della tecnologia interferometrica
10.00 - 10.30	Dott. Paolo Farina (IDS)	Le applicazioni della tecnologia interferometrica da terra ed alcuni casi di studio M, L , S
10.30 – 10.45	Pausa Caffè	
10.45 – 11.45	Prof. Carmelo Gentile (Politecnico di Milano)	La tecnologia radar interferometrica da terra applicata ai ponti: innovazione, vantaggi ed esempi applicativi
11.45 – 12.30	Dott. Paolo Papeschi (IDS)	Principi teorici della tecnologia GPR; le configurazioni georadar di IDS specializzate per il controllo NDT di ponti e strade. Ris Hi Bright, Ris Hi-Pave.
12.30-13.00	Discussione	
13.15	Pranzo	
14.15 – 14.30	Visita ai laboratori di IDS	
14.45 – 15.15	Dott. Cristian Altobelli (IDS)	Dimostrazione IBIS S
15.20 – 16.00	Ing. Alessandro Simi Dott. Valter Baroncini	Dimostrazione con Hi-Bright
16.00	Saluti finali e ringraziamenti	

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IBIS
Image by Interferometric Survey

Working Principles

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Summary

- **IBIS Introduction**
- **Radar Basics**
- **Stepped Frequency Continuous Wave (SFCW)**
- **Synthetic Aperture Radar Technique (SAR)**
- **Differential Interferometry Technique**
- **Conclusion**

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IBIS Introduction

IBIS is a Stepped-Frequency Continuous Wave (SFCW) coherent radar with SAR and interferometric capabilities, dedicated to remote monitoring of static or dynamic displacement such as terrain deformation or structure vibrations.

For Static monitoring

IBIS – L

For Dynamic and Static monitoring

IBIS – S

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- Differential Interferometry Technique
- Conclusions

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Radar Basics

Radar stands for:

RAdio **D**etection **A**nd **R**anging

An instrument able to detect the presence of object and able to measure the distance between the apparatus and an object

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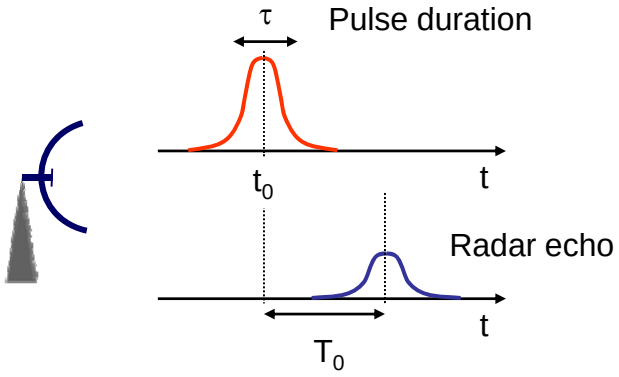
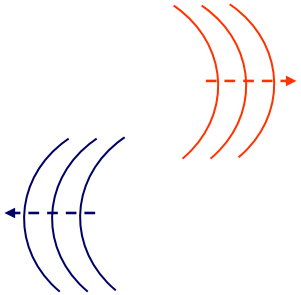
Pulse Radar

Pulse Radar working principle





Time space equivalence for range determination:

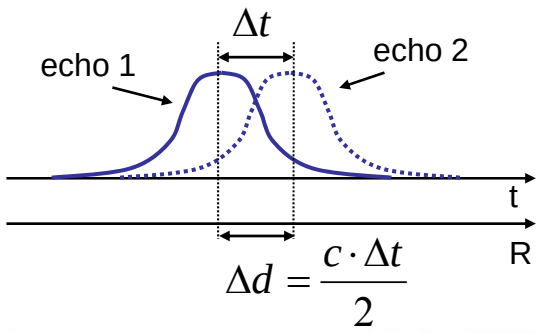
Echo delay

$$T_0$$

$$R_0 = \frac{c \cdot T_0}{2}$$

Range resolution concept:

$$\Delta R = \frac{c \cdot \tau}{2}$$



The radar is able to resolve two targets if:

$$\Delta t > \tau \Leftrightarrow \Delta d > \Delta R$$

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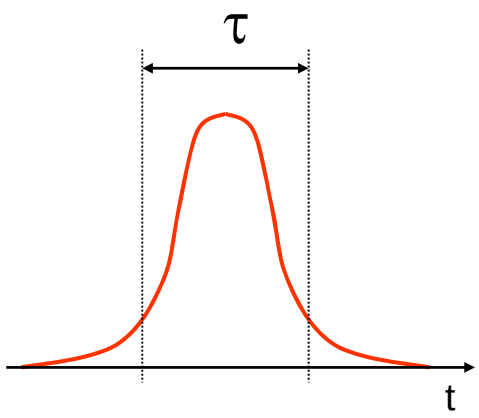
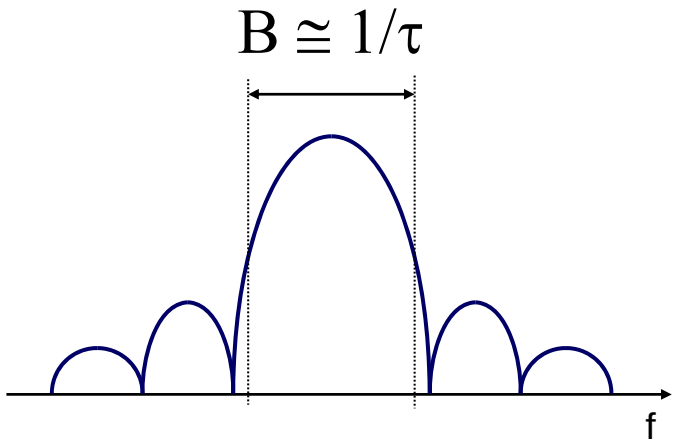
Time-Frequency Duality

Time Domain



Frequency Domain



The range resolution can be expressed either in term of pulse duration or pulse bandwidth:

$$\Delta R = \frac{c\tau}{2} = \frac{c}{2B}$$

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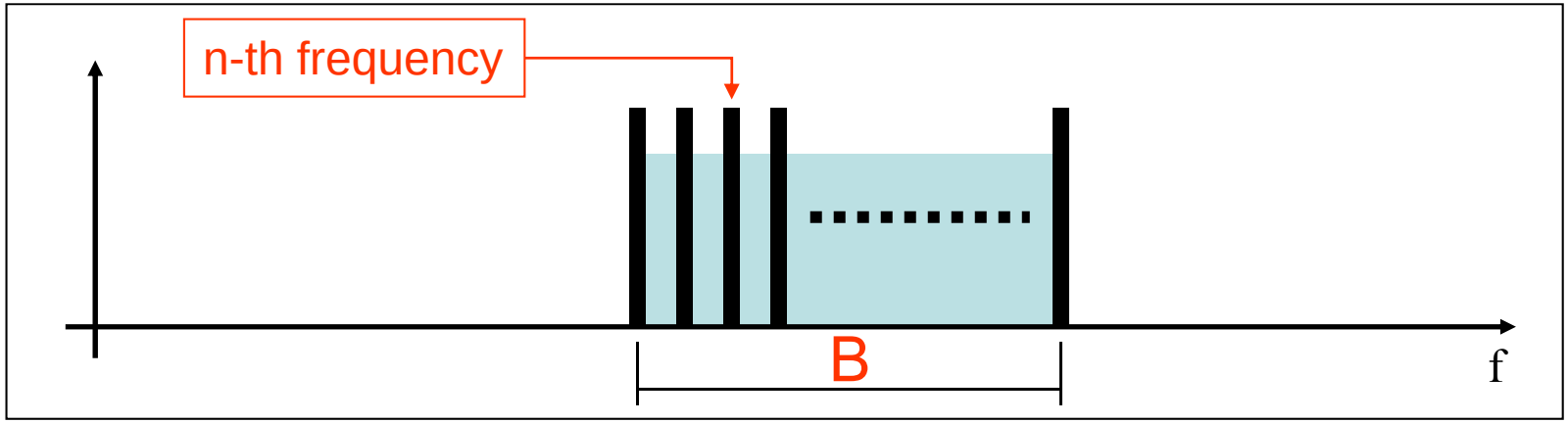
Stepped Frequency Continuous Wave (SFCW)

The system transmits a sweep consisting of N electromagnetic waves of T_{tone} duration (*Continuous Wave*) at different frequencies (*Stepped Frequency*).



The SFCW technique allows IBIS to obtain the same performance of a synthetic pulse of duration $\tau = \frac{1}{B}$ to which corresponds a range resolution of $\Delta R = \frac{c \cdot \tau}{2}$

IBIS provides a Range resolution up to 0.5m

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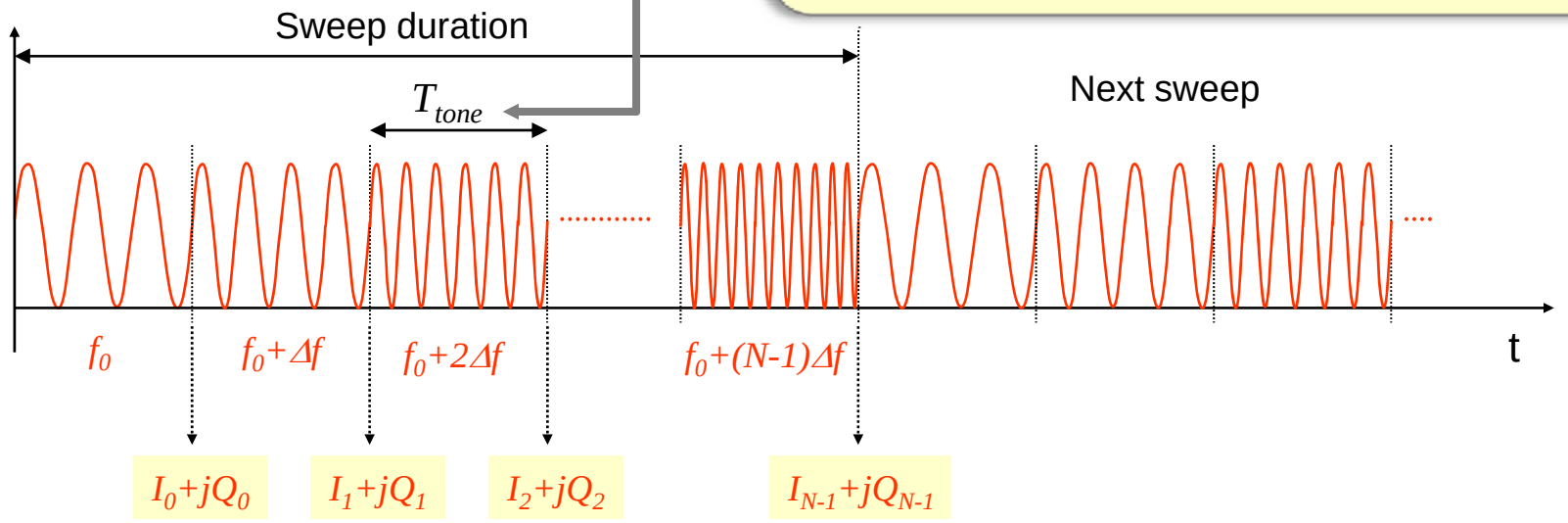
Stepped Frequency Continuous Wave (SFCW)

Time representation of a SFCW signal:

The tone duration must be large enough to receive the echo from furthest useful target located at R_{max}:

$$T_{tone} > \frac{2R_{max}}{c}$$



At the end of a sweep IBIS has acquired a vector of complex numbers that corresponds to a frequency sampling of the observed scenario.

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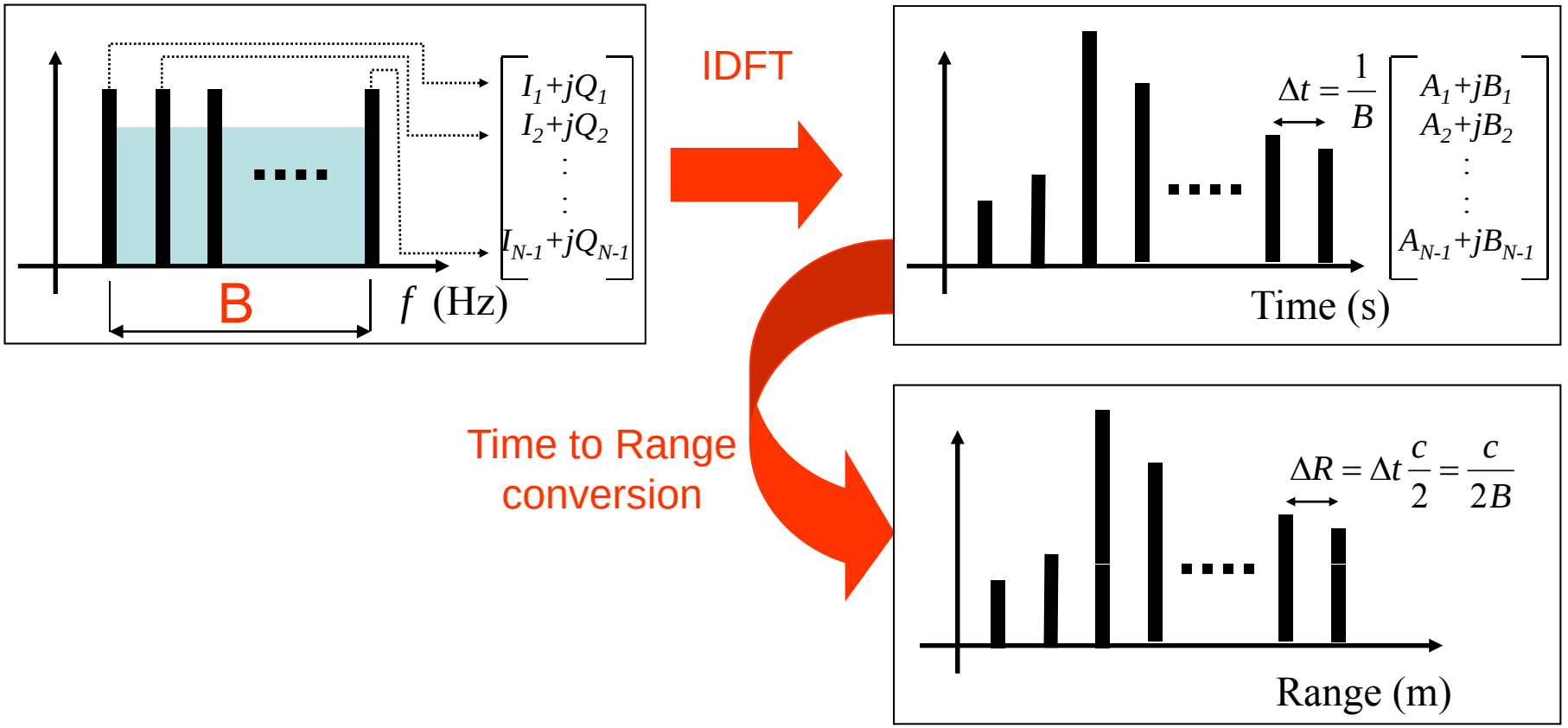
Stepped Frequency Continuous Wave (SFCW)

The data elaboration that enables to synthesize the impulse is a Inverse Discrete Fourier Transform (IDFT) of the samples acquired.



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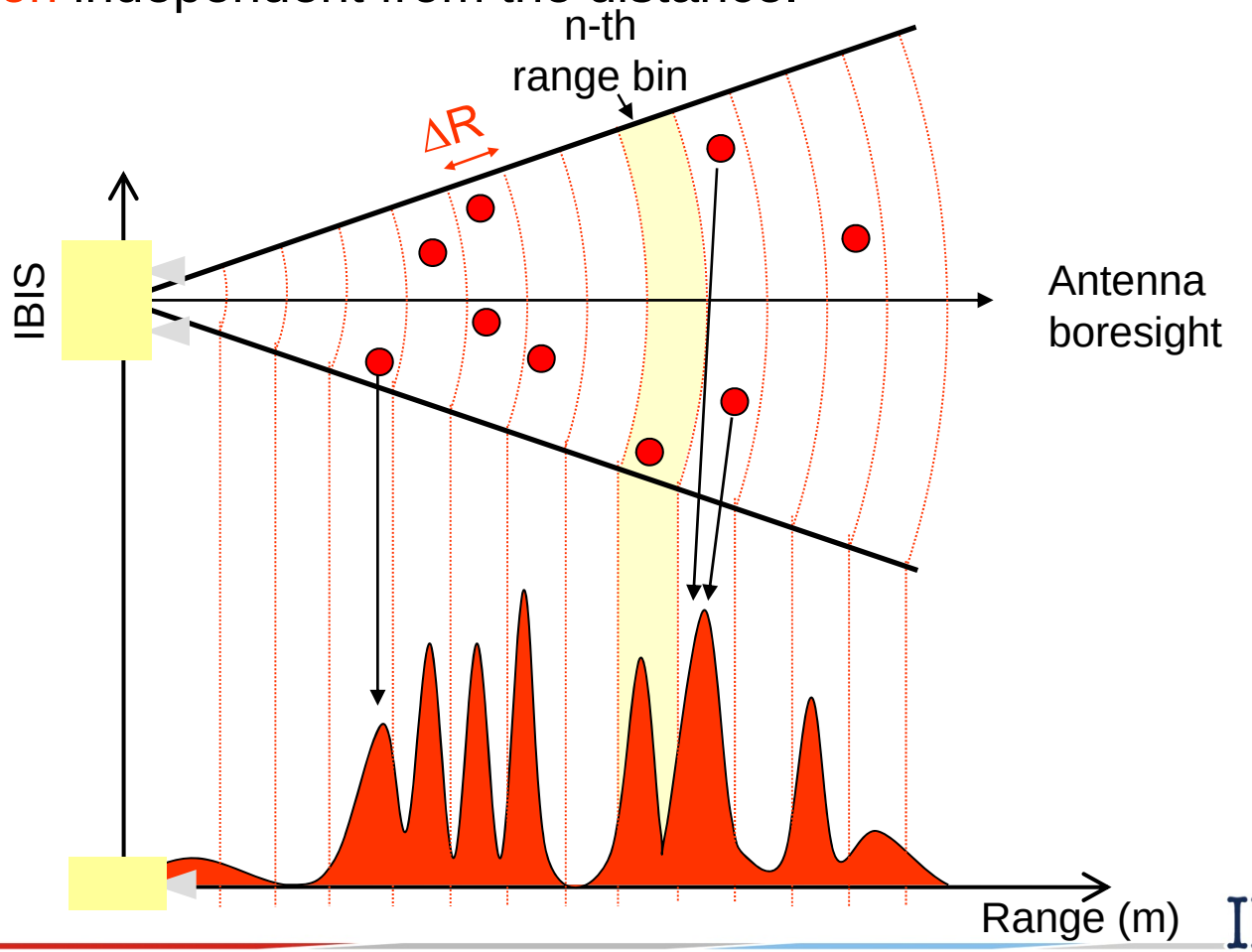
Stepped Frequency Continuous Wave (SFCW)

Through SFCW IBIS builds a one dimensional image, called Range Profile, where the targets in the illuminated scenario are resolved with a range resolution independent from the distance.



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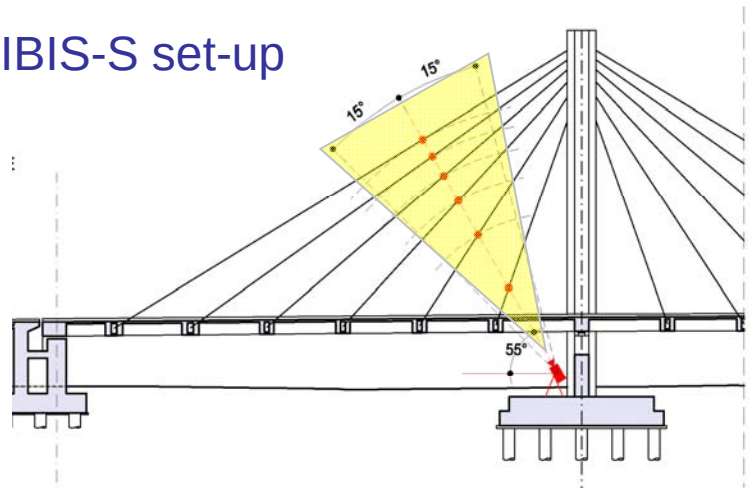
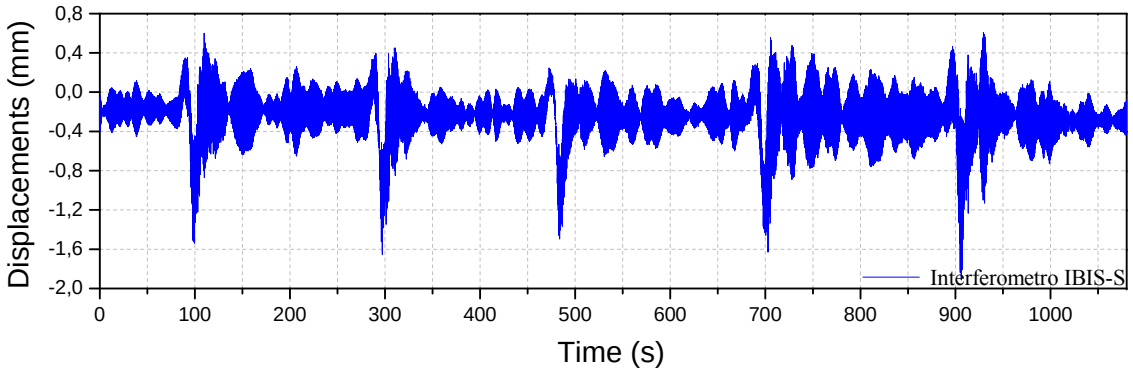
Range Profile Example

Olginate bridge (Italy)

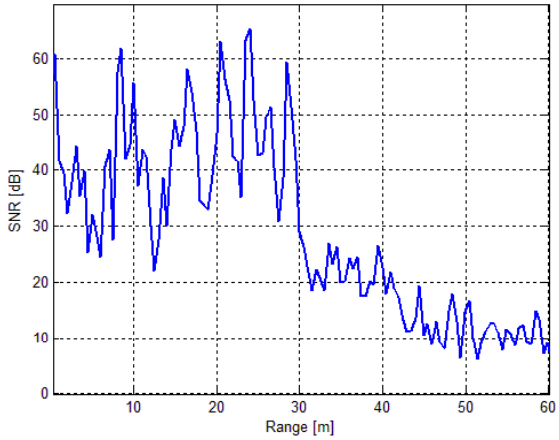
IBIS-S set-up



Displacement graph



Range Profile



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Synthetic Aperture Radar (SAR)

SAR technique is performed by moving the sensor through a 2mt long motorized axis and enables IBIS to provide angular resolution

Using 2 m rail
IBIS provides 4.5mrad
angular resolution
(Cross-Range Resolution)

$$\Delta\varphi = \frac{\lambda}{2 \cdot L} = 4.5mrad$$

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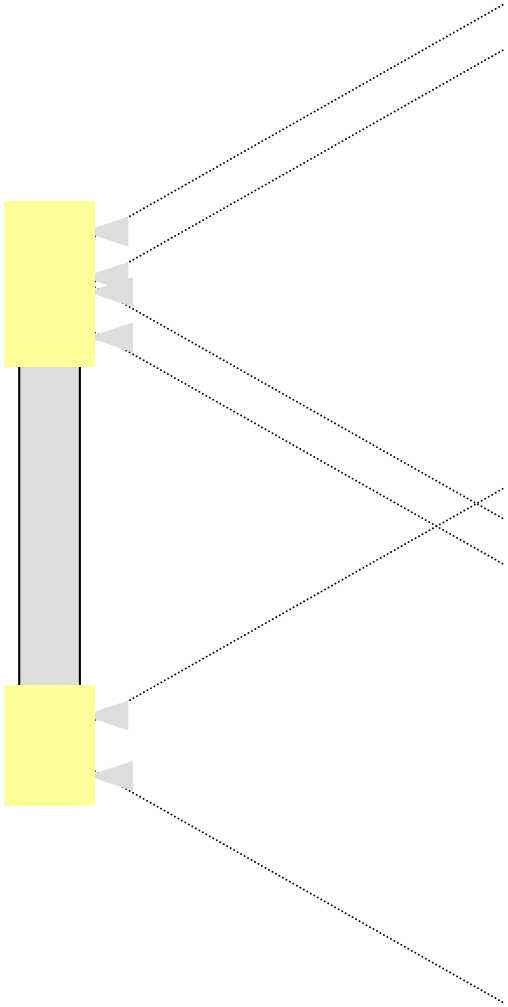
Synthetic Aperture Radar (SAR)



1st scan position | 2nd scan position | Mth scan position

$$\begin{bmatrix} I_{1,1}+jQ_{1,1} & I_{1,2}+jQ_{1,2} & \cdots\cdots & I_{1,M}+jQ_{1,M} \\ I_{2,1}+jQ_{2,1} & I_{2,2}+jQ_{2,2} & \cdots\cdots & I_{2,M}+jQ_{2,M} \\ \vdots & \vdots & & \vdots \\ I_{N-1,1}+jQ_{N-1,1} & I_{N-1,2}+jQ_{N-1,2} & \cdots\cdots & I_{N-1,M}+jQ_{N-1,M} \end{bmatrix}$$

Column IDFT

$$\begin{bmatrix} A_{1,1}+jB_{1,1} & A_{1,2}+jB_{1,2} & \cdots\cdots & A_{1,M}+jB_{1,M} \\ A_{2,1}+jB_{2,1}: & A_{2,2}+jB_{2,2} & \cdots\cdots & A_{2,M}+jB_{2,M} \\ \vdots & \vdots & & \vdots \\ A_{N-1,1}+jB_{N-1,1} & A_{N-1,2}+jB_{N-1,2} & \cdots\cdots & A_{N-1,M}+jB_{N-1,M} \end{bmatrix}$$

Row IDFT

CR1	CR2		CRM	
$C_{1,1}+jD_{1,1}$	$C_{1,2}+jD_{1,2}$	.....	$C_{1,M}+jD_{1,M}$	Rbin1
$C_{2,1}+jD_{2,1}$	$C_{2,2}+jD_{2,2}$	.....	$C_{2,M}+jD_{2,M}$	Rbin2
:	:		:	
$C_{N-1,1}+jD_{N-1,1}$	$C_{N-1,2}+jD_{N-1,2}$	.....	$C_{N-1,M}+jD_{N-1,M}$	RbinN

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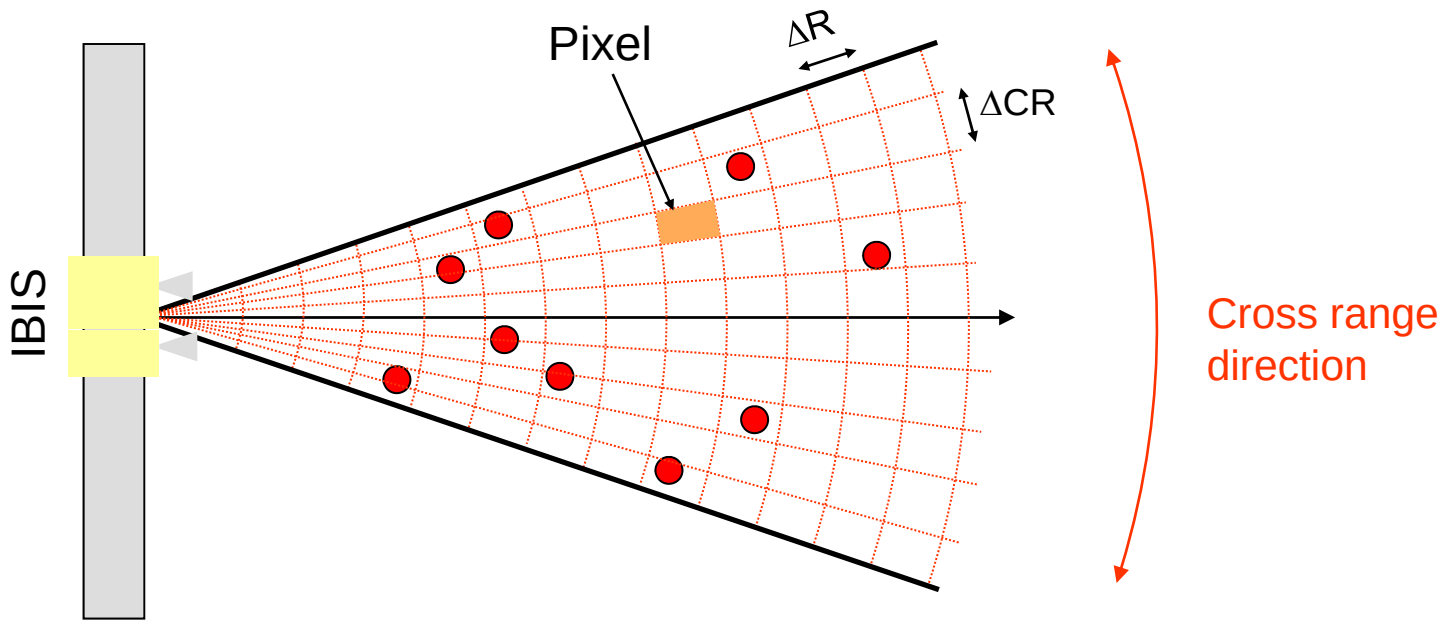
IBIS-L Resolution

The combination of SAR and SF-CW techniques allows IBIS to build a two-dimensional image of the scenario. The image is divided into pixels, corresponding to the resolution area.



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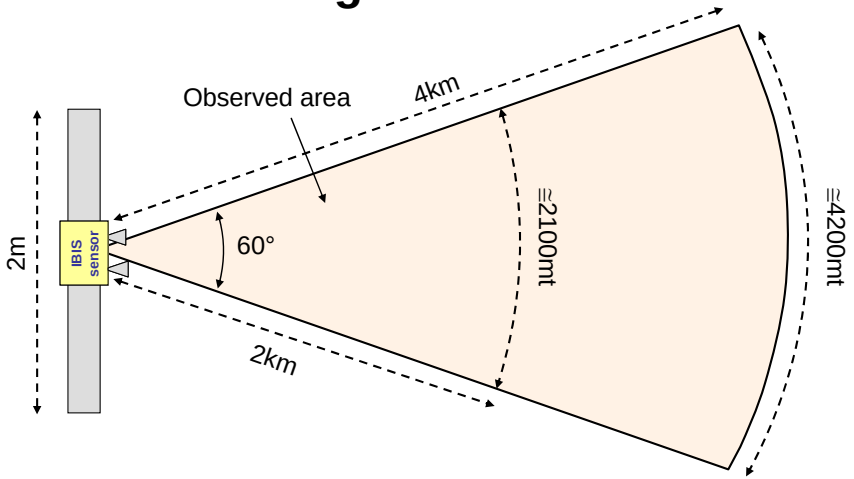
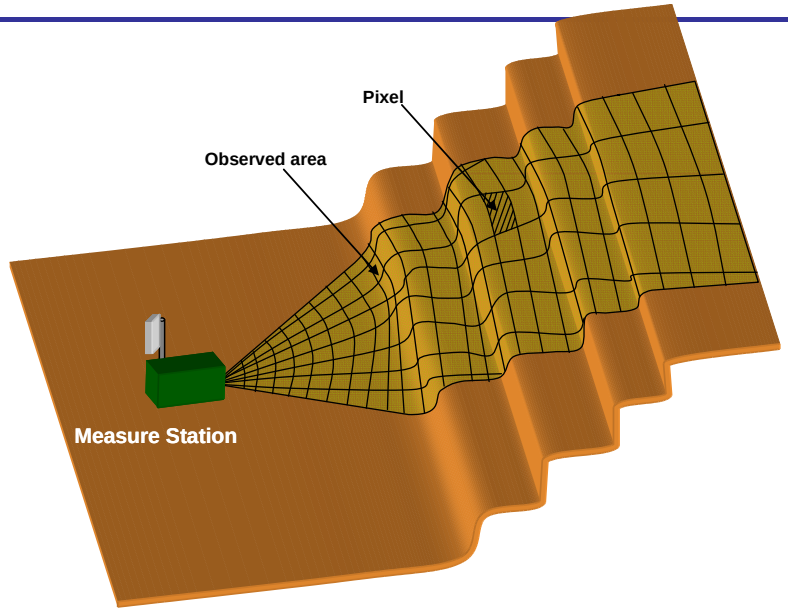
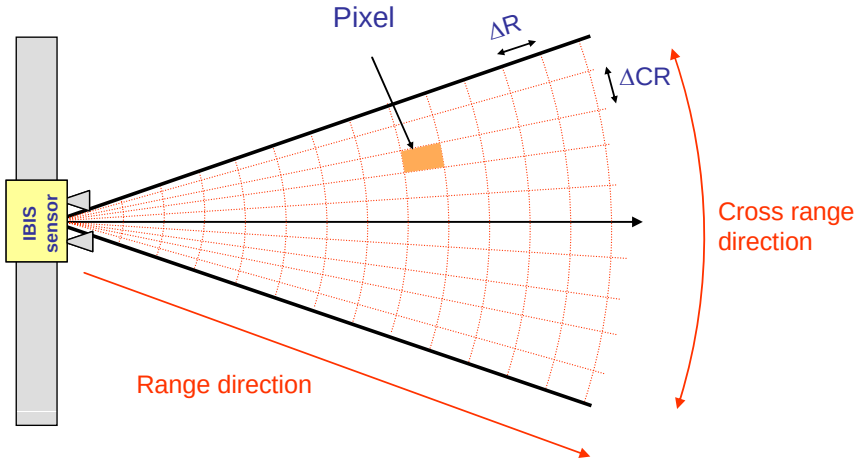
IBIS-L Resolution

Area coverage dimensions





Spatial resolution



Typical spatial resolutions:

- range: 0.5 m
- cross-range: 4.5 m at 1000 m

High spatial resolution enables the identification of small failures.

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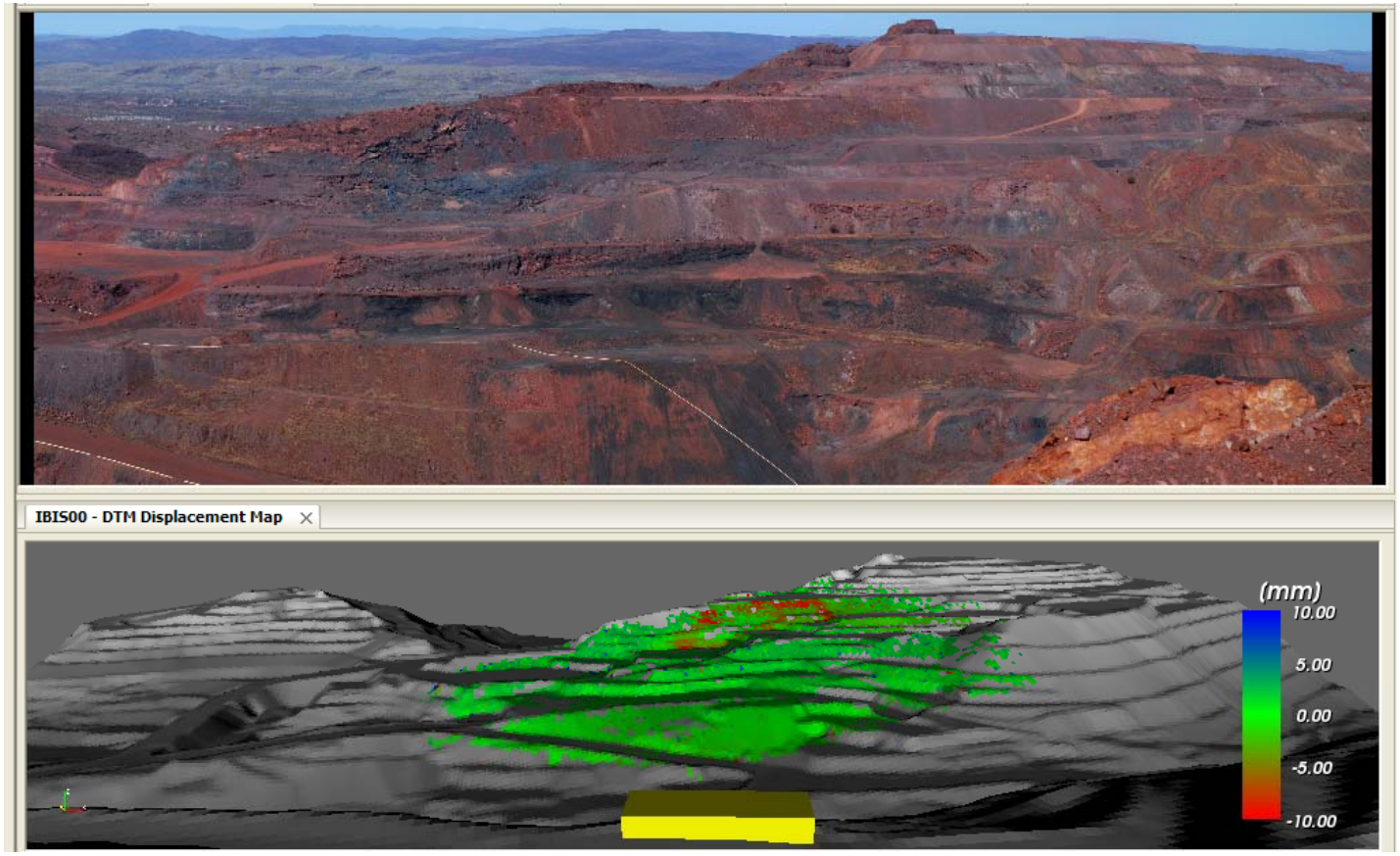
IBIS-L Resolution

The radar image can be geocoded over Digital Terrain Model to help the interpretation



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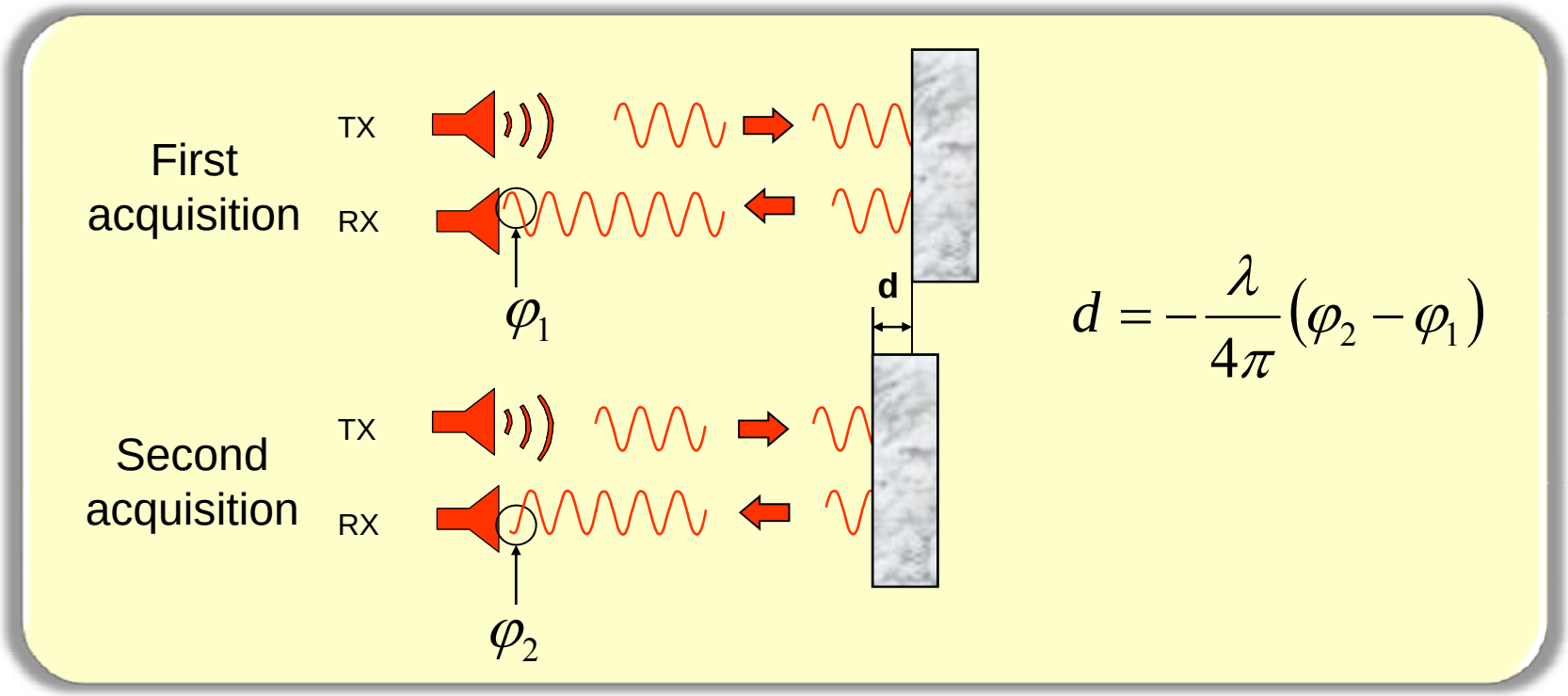
Differential Interferometry

The **differential interferometric analysis** allows object displacement measurement, by comparing phase information of the wave reflected from the object at different time instants.

IBIS provides a displacement measurement with an accuracy of less than 0.01mm (intrinsic radar accuracy in the order of 0.001 mm.)



$$d = -\frac{\lambda}{4\pi}(\varphi_2 - \varphi_1)$$

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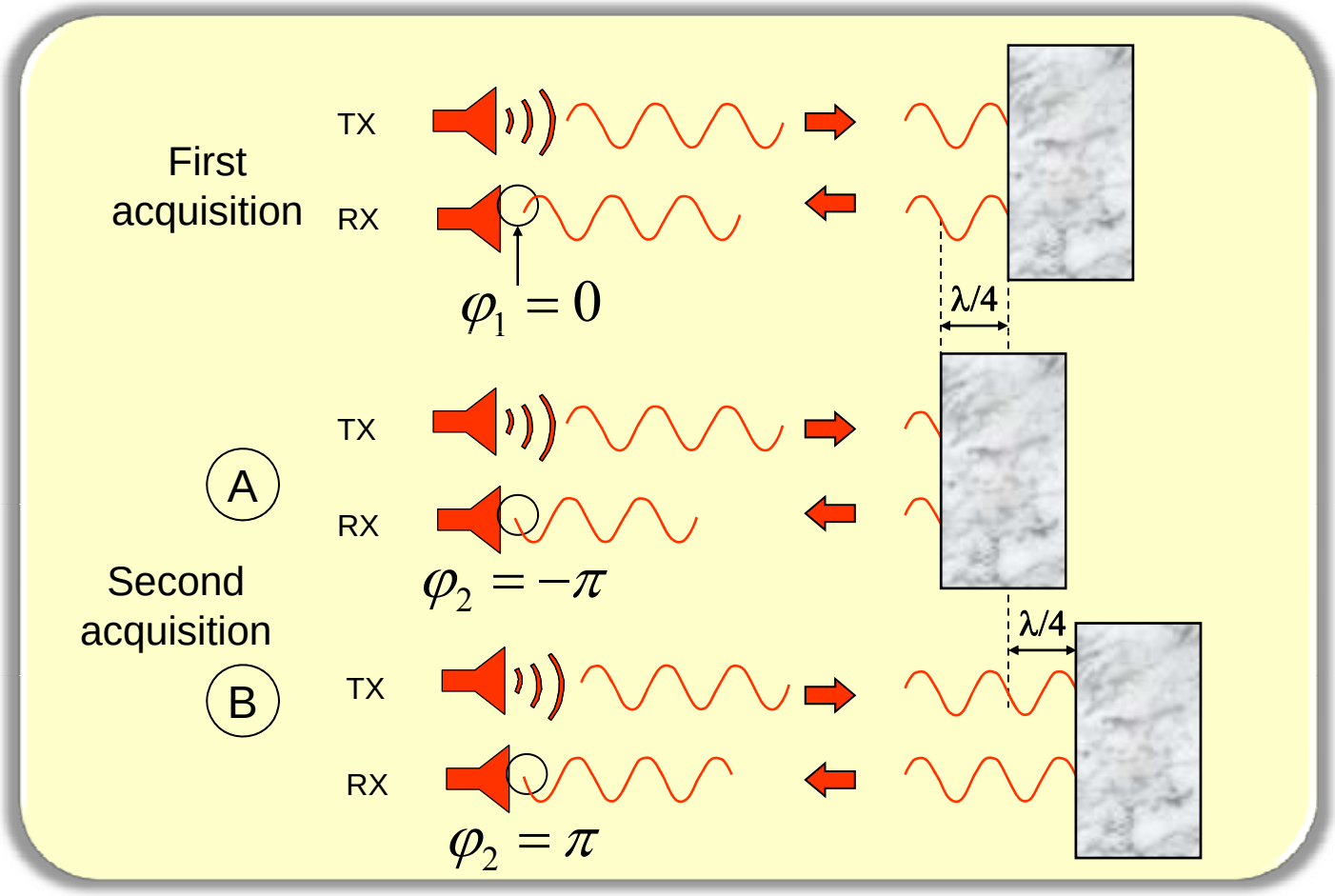
Differential Interferometry

The **phase ambiguity** bounds the maximum displacement measurable between two consecutive acquisition to $\lambda/4$ (about 4,5mm)



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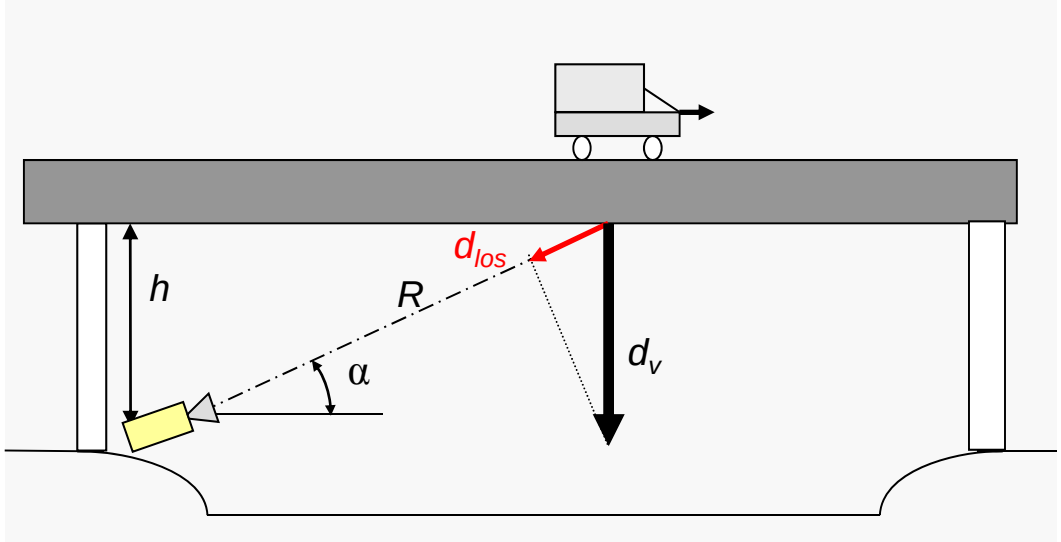
Differential Interferometry

IBIS measures the **line of sight** displacement (LoS). The real displacement evaluation requires the knowledge of the acquisition geometry and real movement direction.

d_{los} *Line of sight displacement*

d_v *Vertical displacement*

R *Measurement point distance (measured by IBIS)*



$$d_v = \frac{d_{los}}{\sin(\alpha)} \Rightarrow \sin(\alpha) = \frac{h}{R} \Rightarrow d_v = d_{los} \cdot \frac{R}{h}$$

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- Stepped Frequency Continuous Wave (SFCW)
- Synthetic Aperture Radar Technique (SAR)
- Differential Interferometry Technique
- Conclusions

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Conclusions

- The Stepped Frequency Continuous Wave techniques allows the resolution of the scenario along range direction independently from the distance.

IBIS Range Resolution up to 0.5m

- The Synthetic Aperture Radar technique allows the resolution of the scenario along cross-range direction.

IBIS CrossRange Resolution up to 4.5mrad

- The Differential Interferometry technique enables the measure of the displacement of the resolved objects

IBIS Displacement accuracy 0,01mm (intrinsic 0,001mm)

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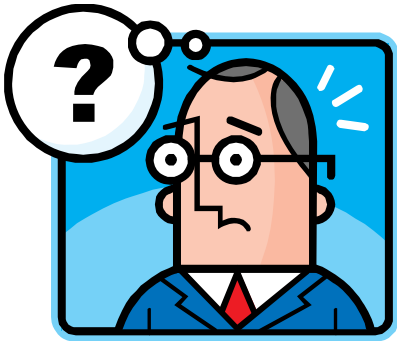
Questions ?



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IBIS
Image by Interferometric Survey

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IDS INGEGNERIA DEI SISTEMI

IBIS: radar interferometrici terrestri

IDS presenta IBIS:

Un'innovativa famiglia di avanzati strumenti geodetici basata sulla tecnica dell'interferometria radar terrestre progettati per fornire misure accurate di spostamento su vaste aree

I sistemi IBIS sono stati progettati per rispondere alle specifiche esigenze dei settori dell'ingegneria civile, della geotecnica e dell'industria mineraria.

L'approccio rivoluzionario di questa tecnica consente all'utente di ottenere misure accurate da remoto senza la necessità di accedere all'area di interesse ed in qualsiasi condizione meteo.

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Configurazioni disponibili IBIS

PRODOTTO	APPLICAZIONE
IBIS - L	**MONITORAGGIO FRANE E DIGHE**
IBIS - M	**MONITORAGGIO FRONTI DI SCAVO**
IBIS - S	**MONITORAGGIO E COLLAUDO STRUTTURE**

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IBIS-S: sistema e campi di applicazione

IBIS-S

COLLAUDI DI PONTI

BENI CULTURALI

IMPIANTI INDUSTRIALI

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IBIS-L: sistema e campi di applicazione

IBIS-L

MONITORAGGIO FRANE

MONITORAGGIO DIGHE

MONITORAGGIO CEDIMENTI/SUBSIDENZA

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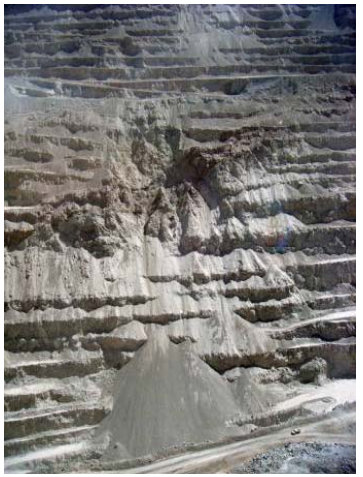
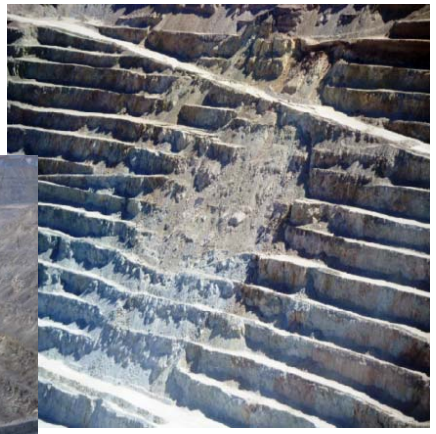
IBIS-M: sistema e campi di applicazione

IBIS-M





MONITORAGGIO FRONTI DI SCAVO IN CAVE E MINIERE A CIELO APERTO

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IDS INGEGNERIA DEI SISTEMI

IBIS: principali vantaggi

I più importanti vantaggi dei sistemi IBIS sono I seguenti:

- possibilità di effettuare le misure senza accedere all'area di misura
- ottenere misure dall'intera area illuminata dal fascio delle antenne
- elevata accuratezza delle misure di spostamento, fino a 0,02 mm
- Monitoraggio in continuo in qualsiasi condizione
- Sistema completamente autonomo
- Elevata frequenza di acquisizione, minuti for IBIS-L, IBIS-M msec per IBIS-S

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IBIS-L: monitoraggio frane

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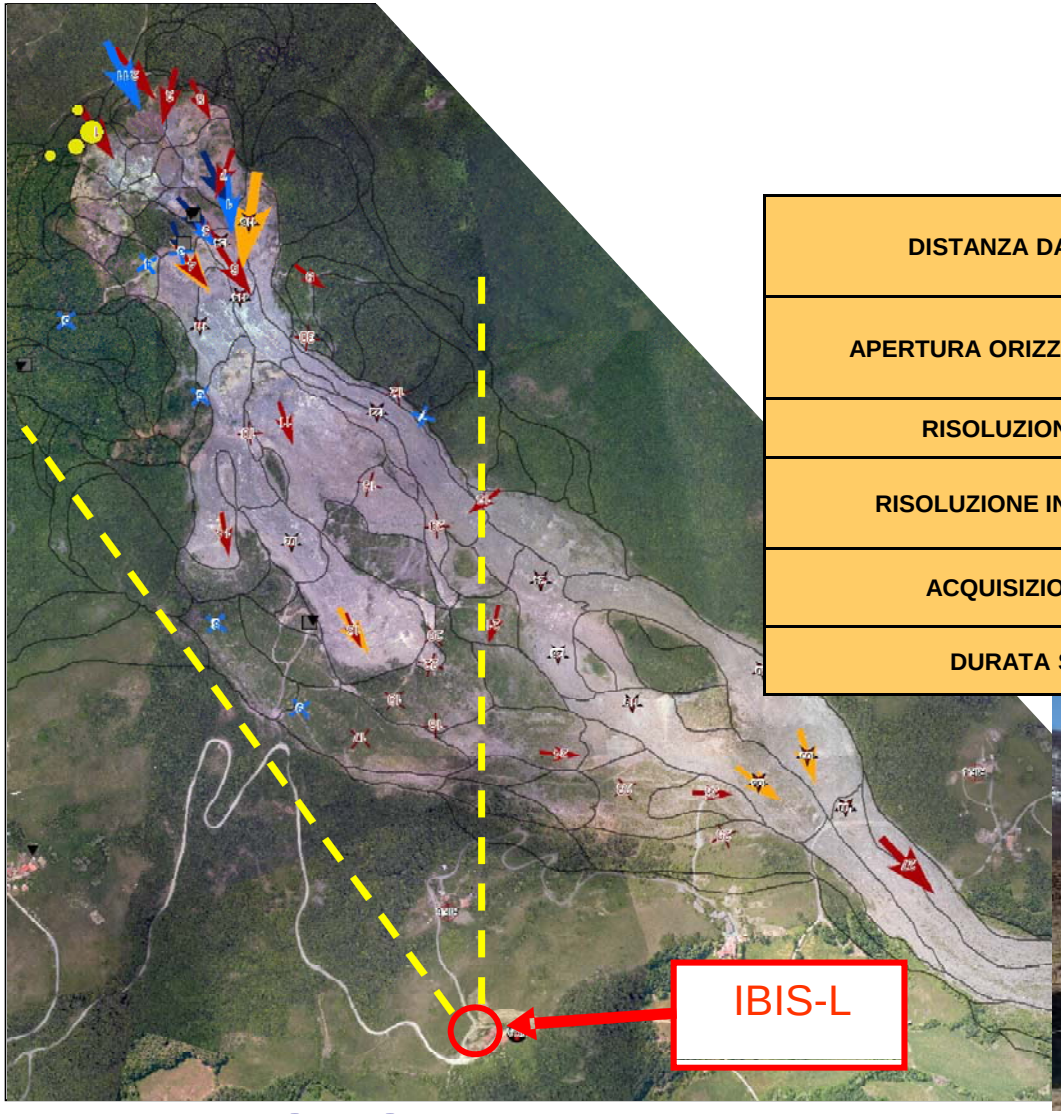
IBIS-L: monitoraggio frane



IBIS-L System set-up

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

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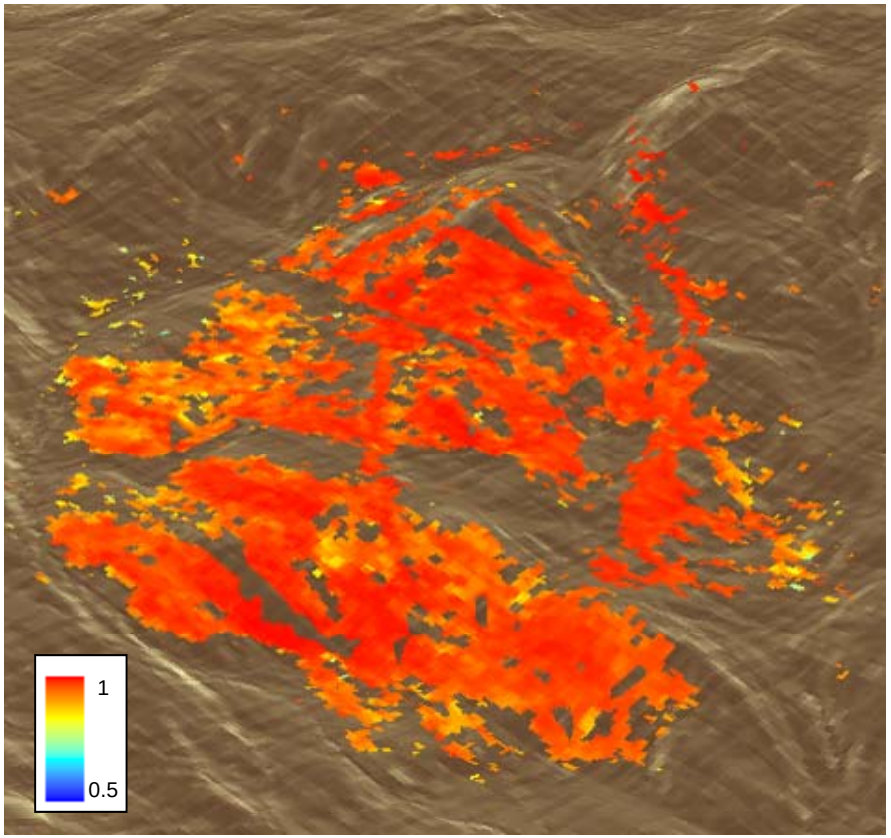
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio frane



Geocoded quality map

Picture taken from the radar location

More than 40.000 measurement points are identified on the quality map

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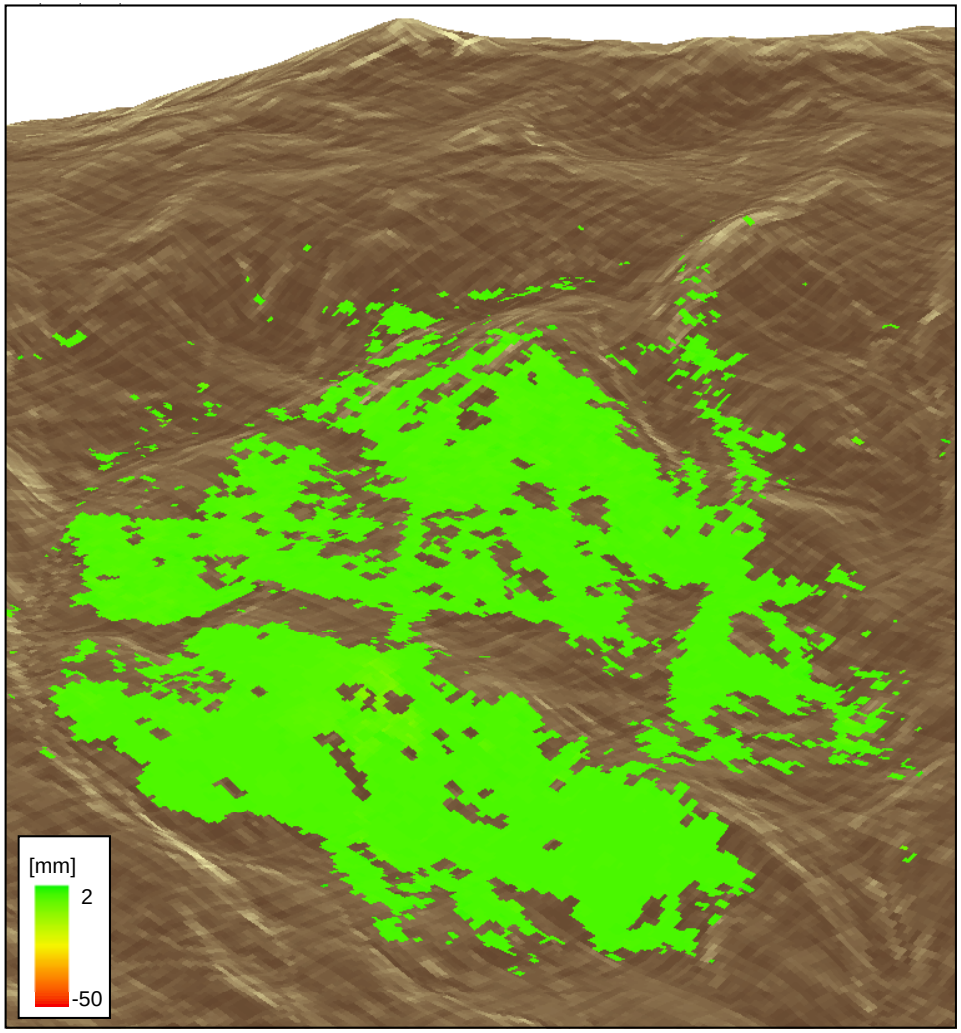
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio frane (1 h)

Geocoded Line Of Sight Displacement Map



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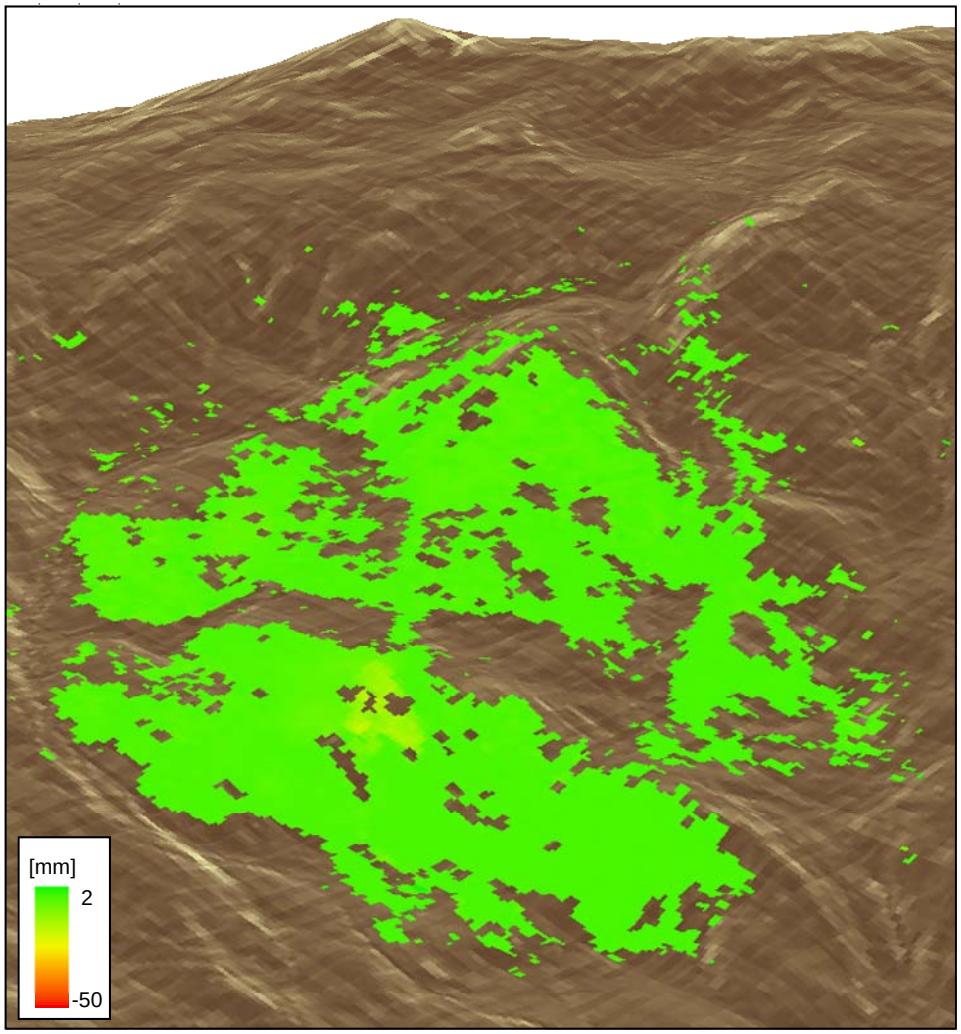
IBIS-L: monitoraggio frane (2 h)

Geocoded Line Of Sight Displacement Map



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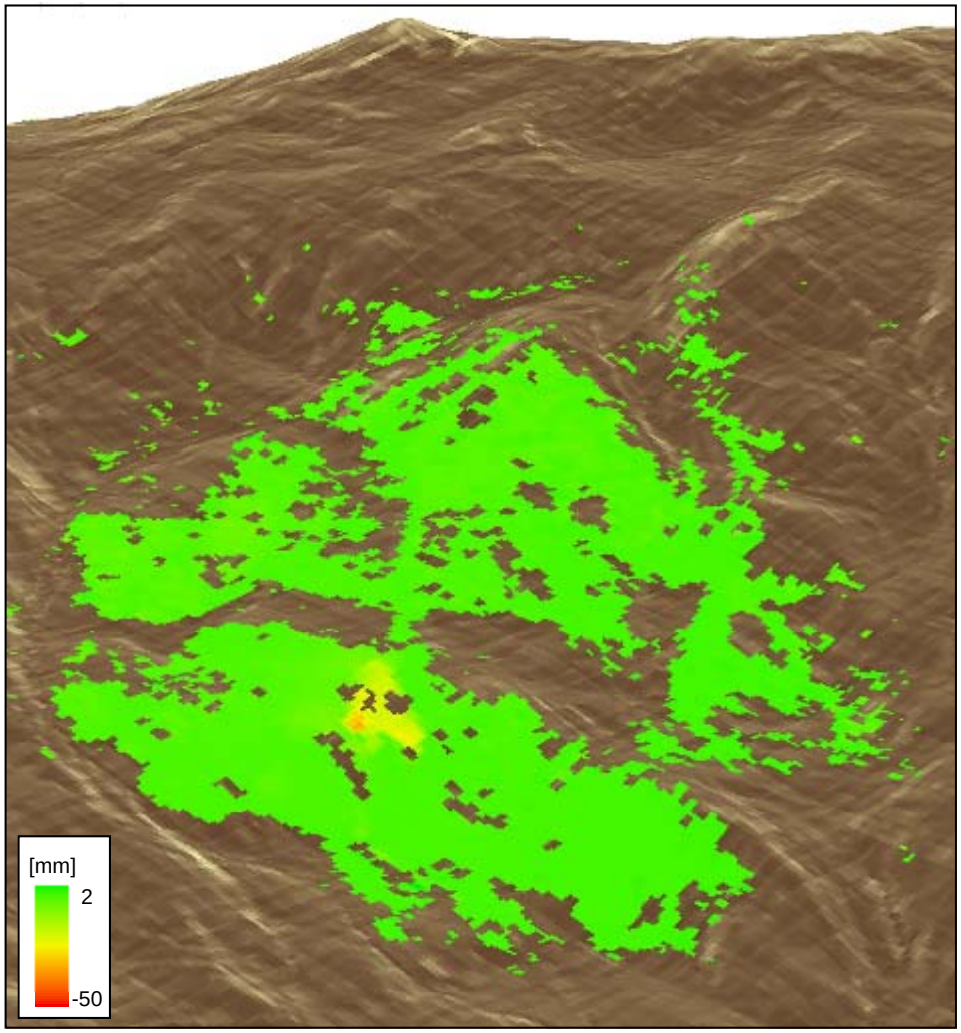
IBIS-L: monitoraggio frane (3 h)

Geocoded Line Of Sight Displacement Map



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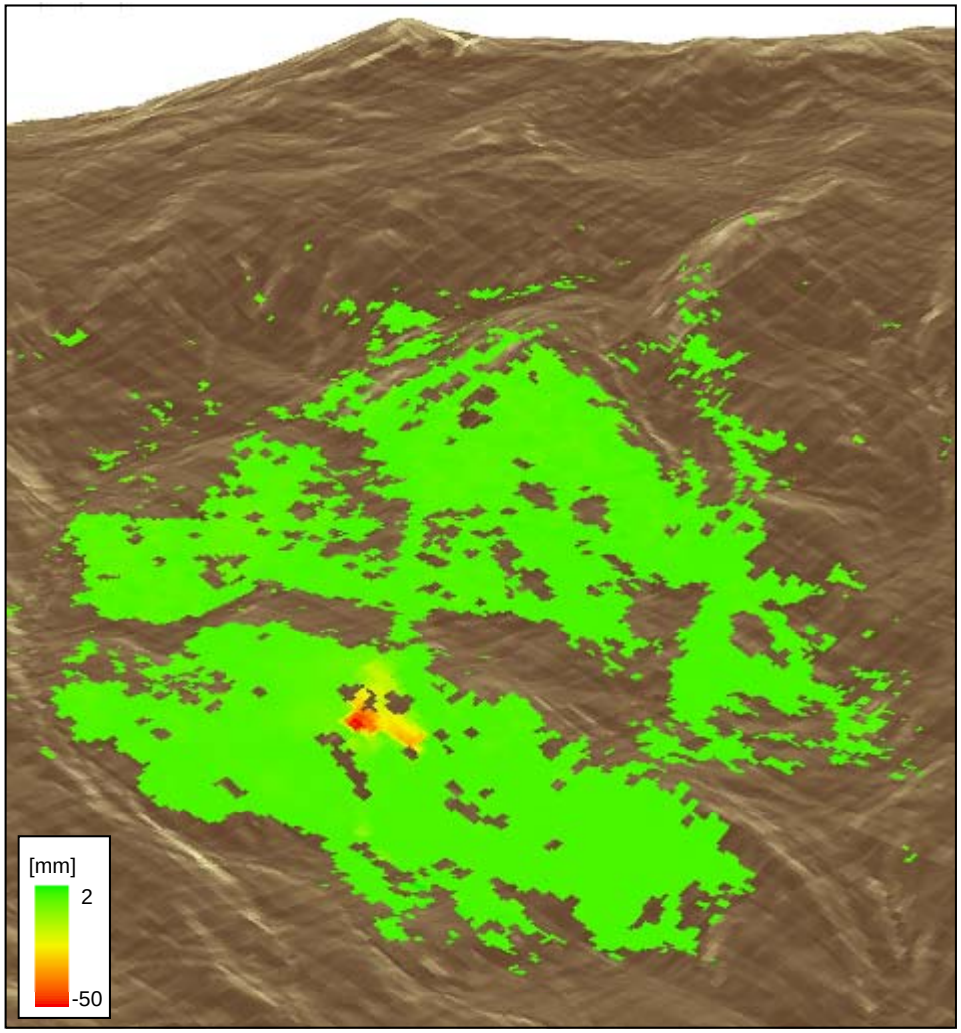
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio frane (4 h)

Geocoded Line Of Sight Displacement Map



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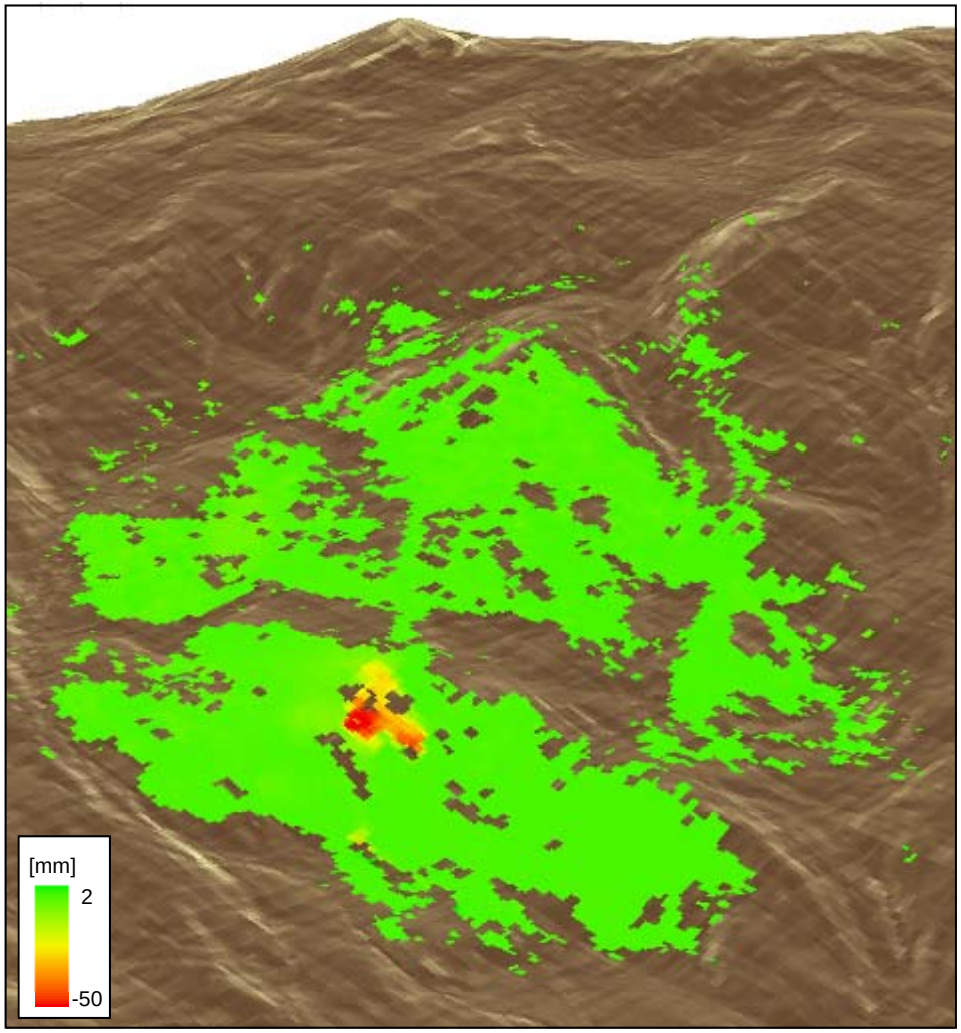
IBIS-L: monitoraggio frane (5 h)

Geocoded Line Of Sight Displacement Map



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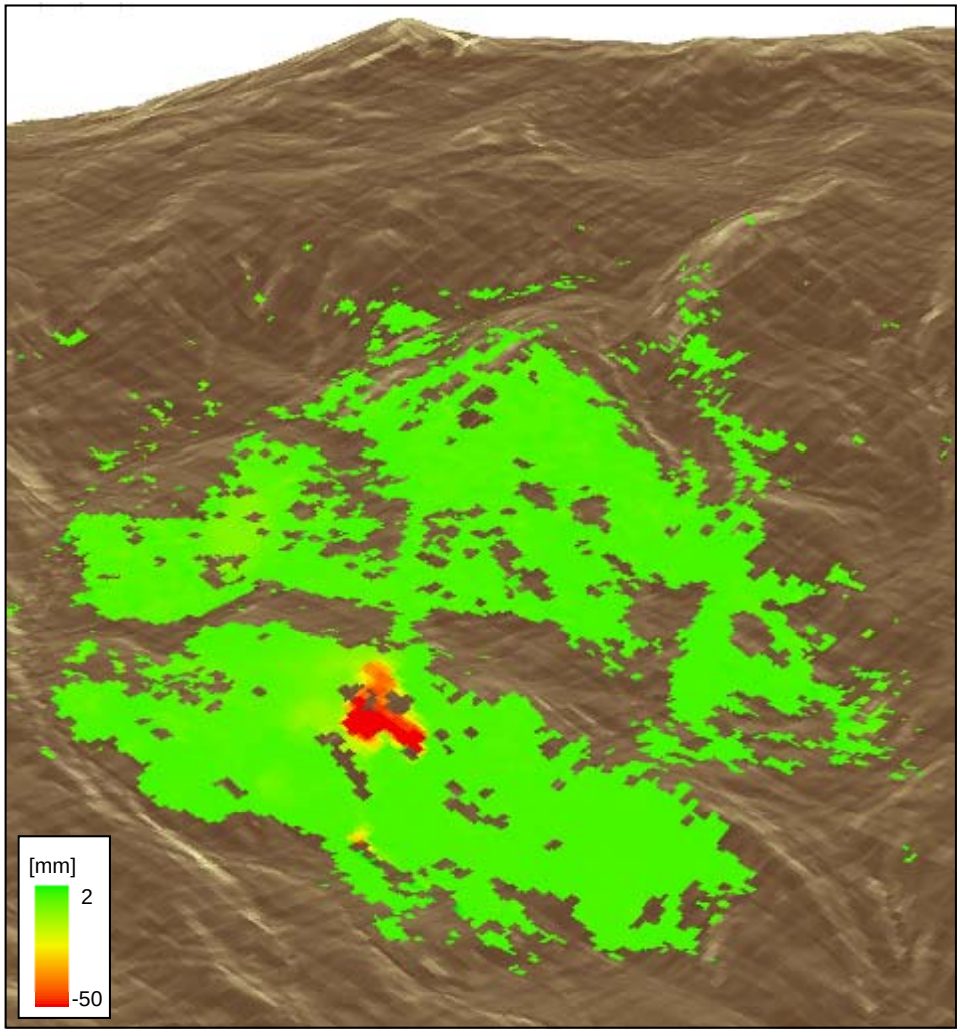
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio frane (6 h)

Geocoded Line Of Sight Displacement Map



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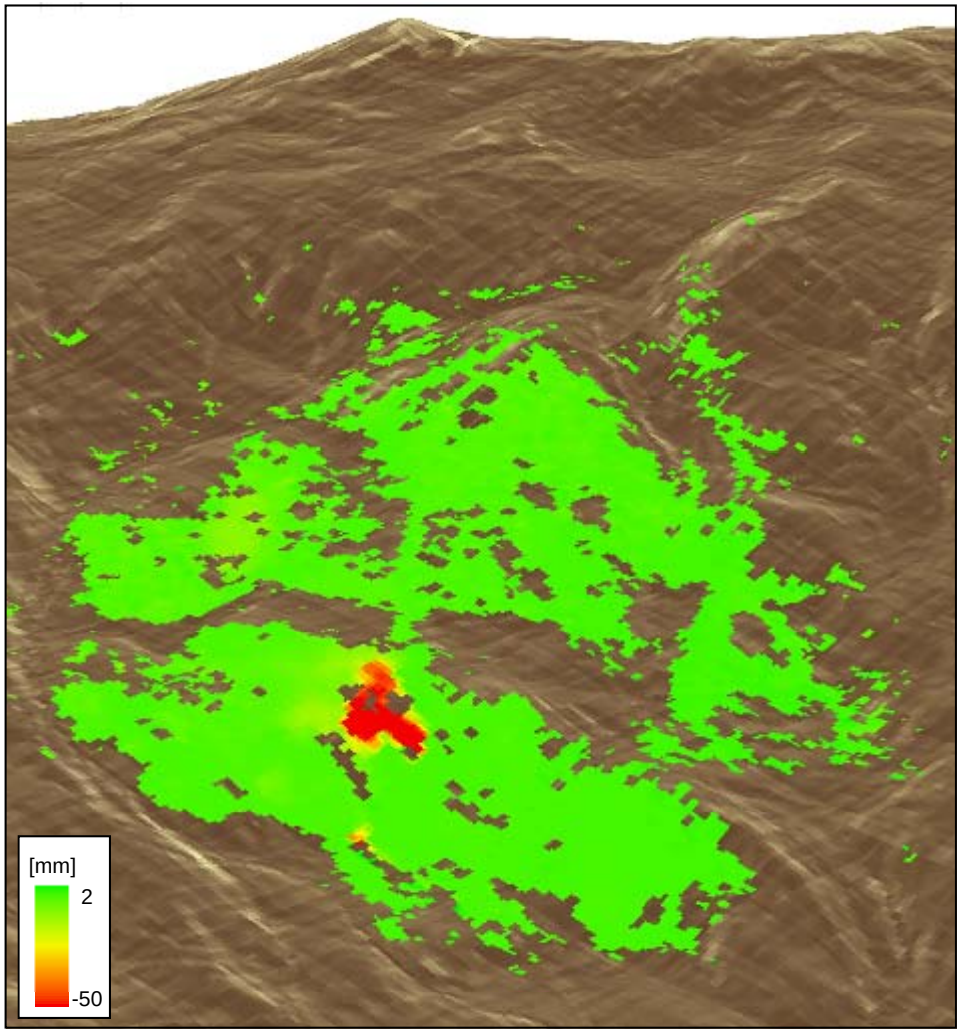
IBIS-L: monitoraggio frane (7 h)

Geocoded Line Of Sight Displacement Map



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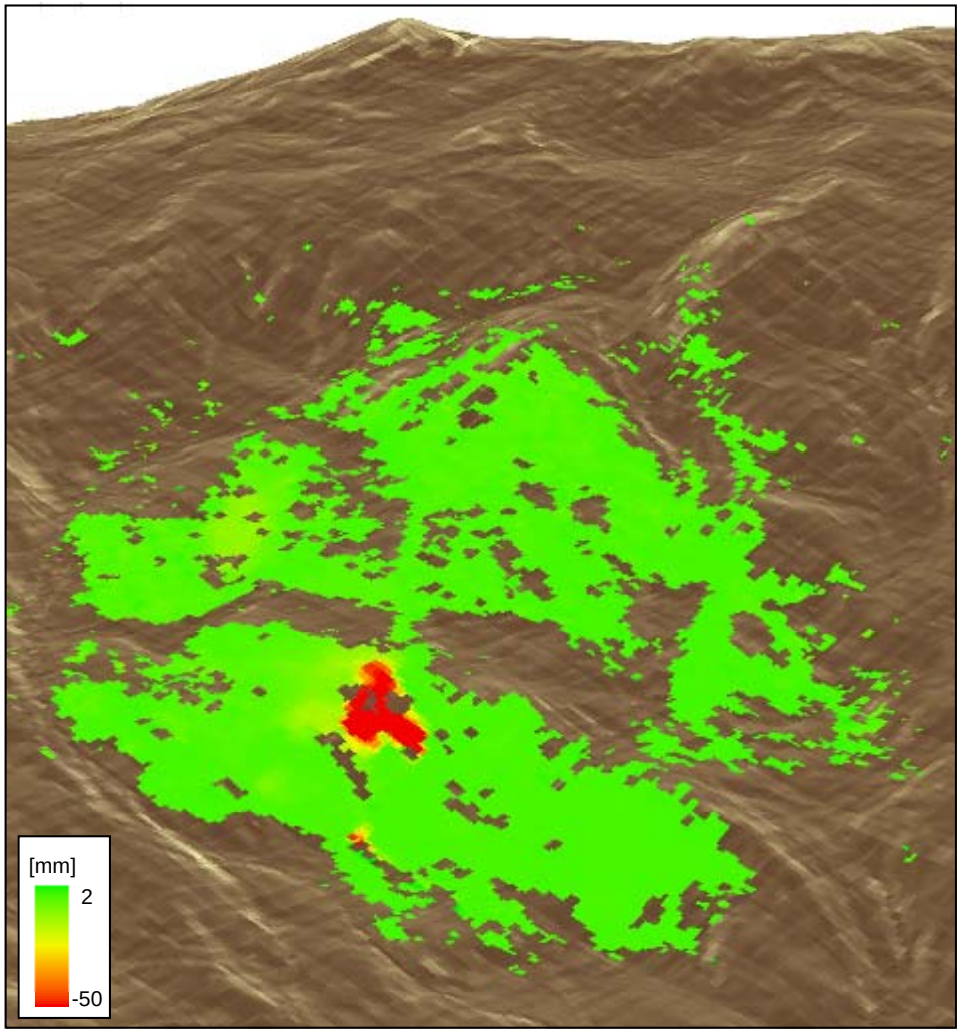
IBIS-L: monitoraggio frane (8 h)

Geocoded Line Of Sight Displacement Map



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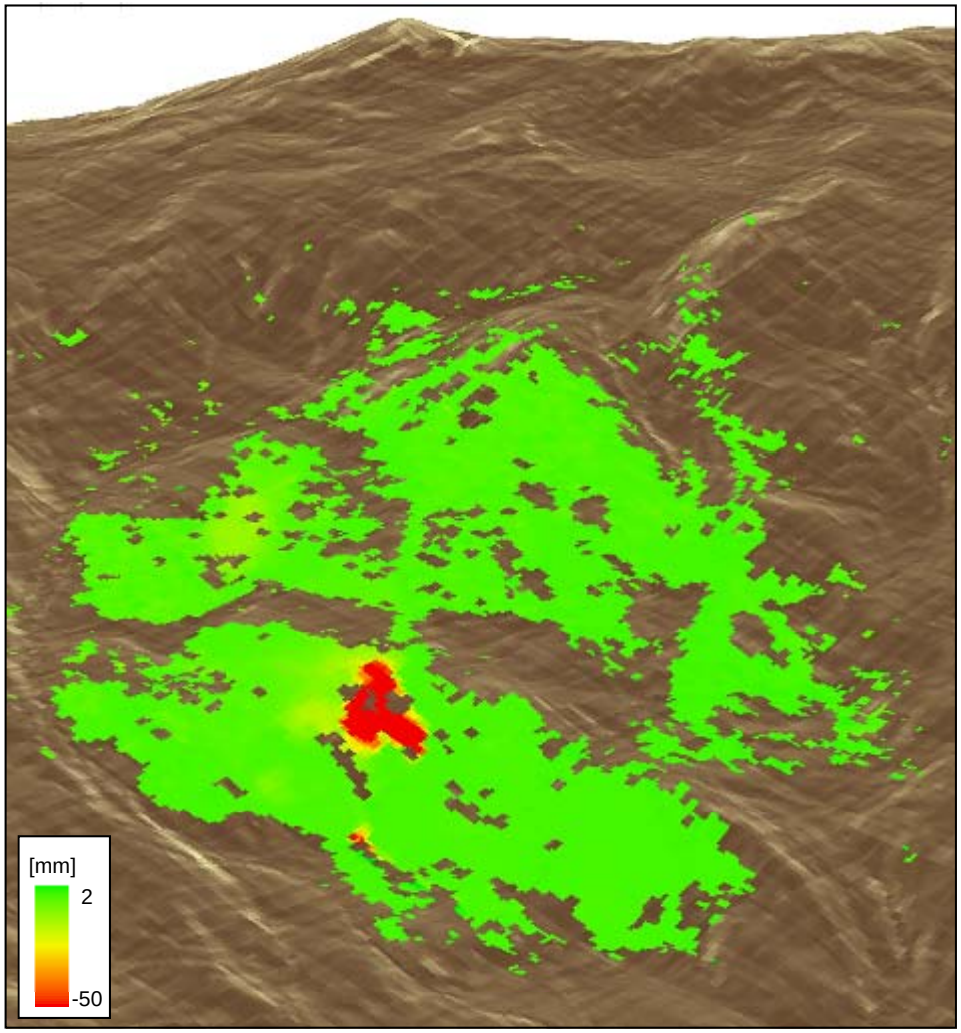
IBIS-L: monitoraggio frane (9 h)

Geocoded Line Of Sight Displacement Map



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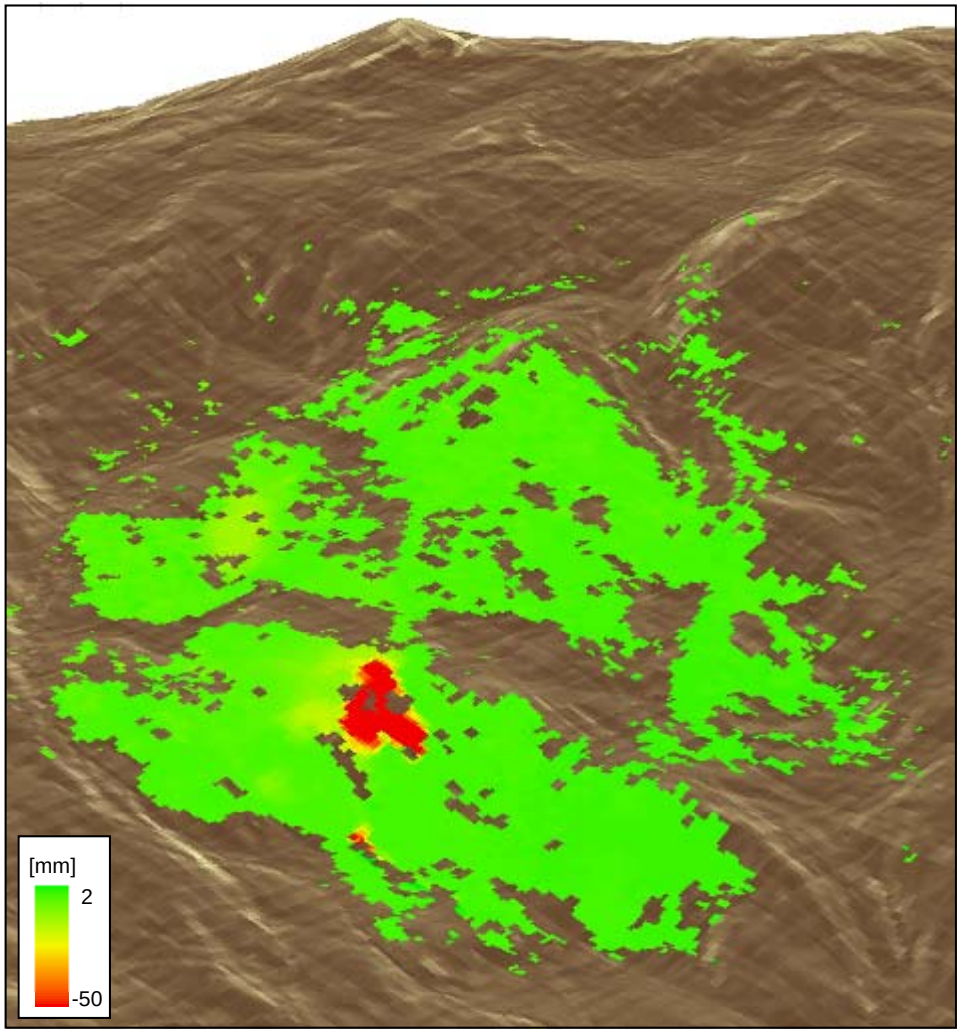
IBIS-L: monitoraggio frane (10 h)

Geocoded Line Of Sight Displacement Map



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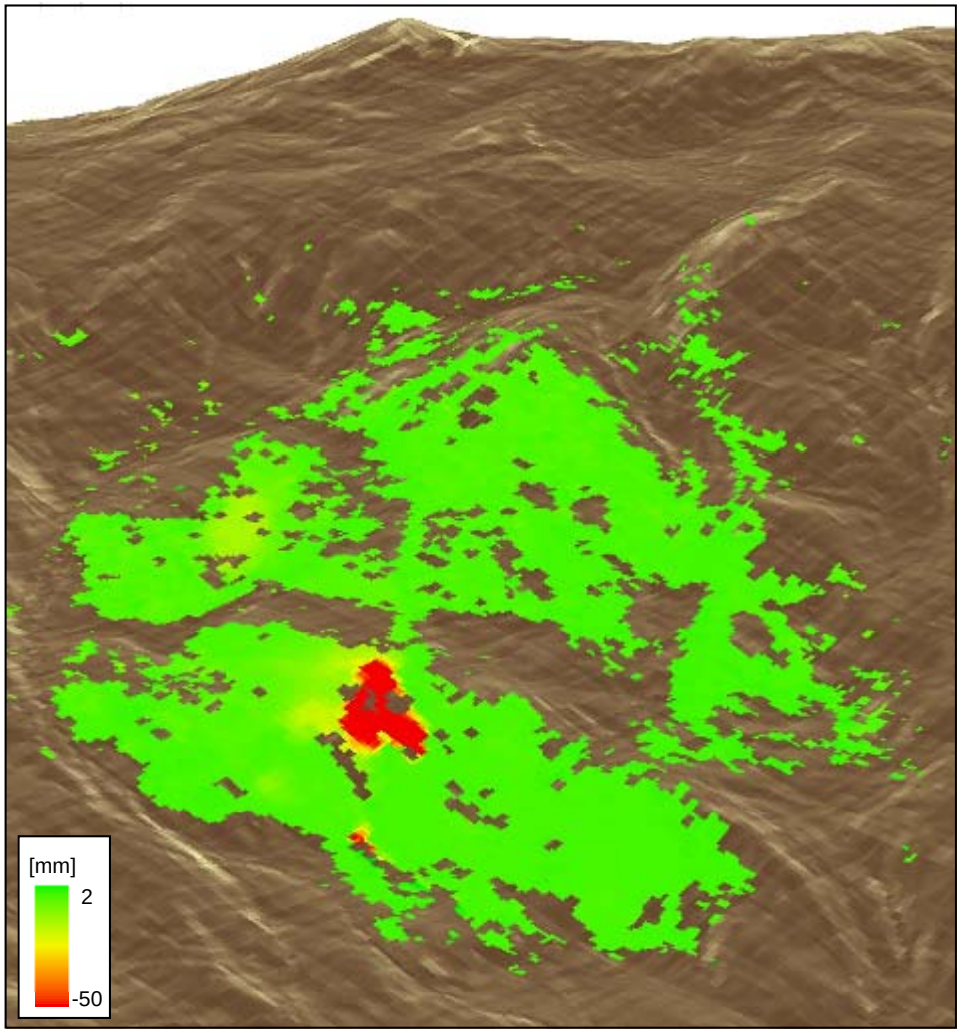
IBIS-L: monitoraggio frane (11 h)

Geocoded Line Of Sight Displacement Map



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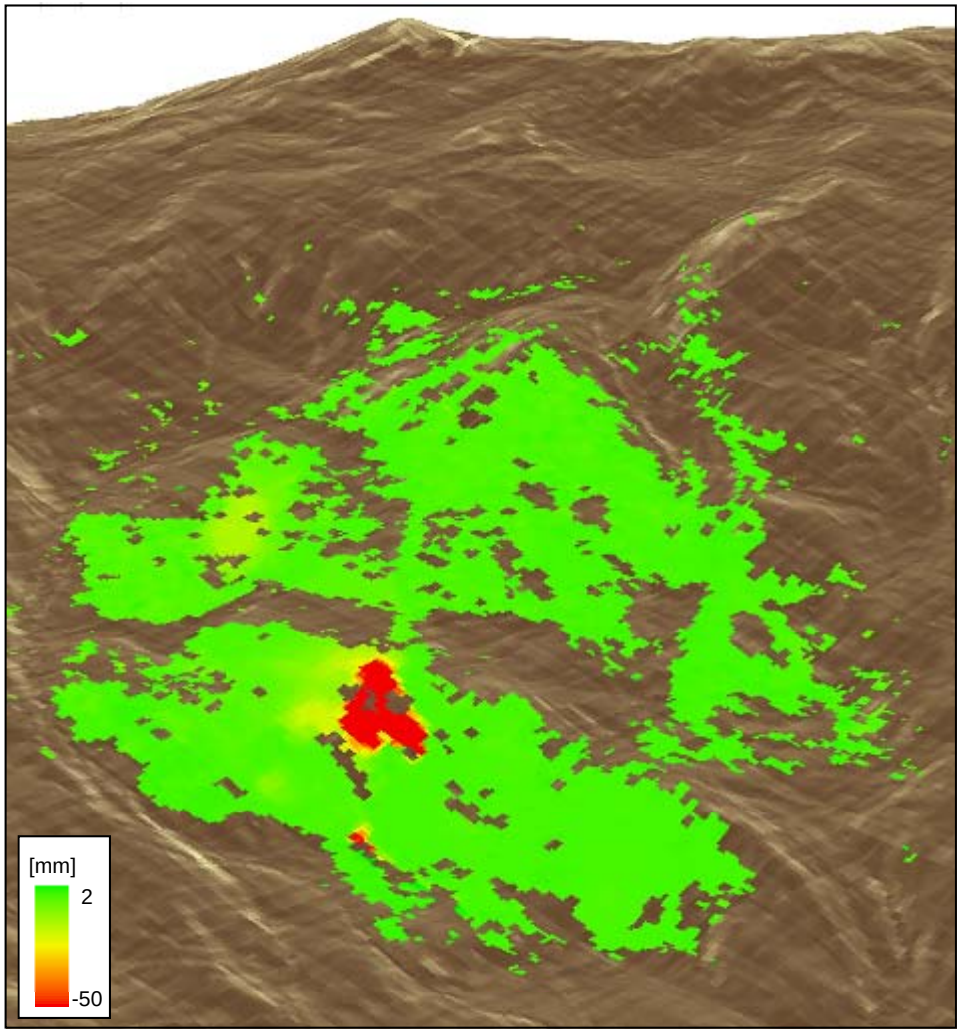
IBIS-L: monitoraggio frane (12 h)

Geocoded Line Of Sight Displacement Map



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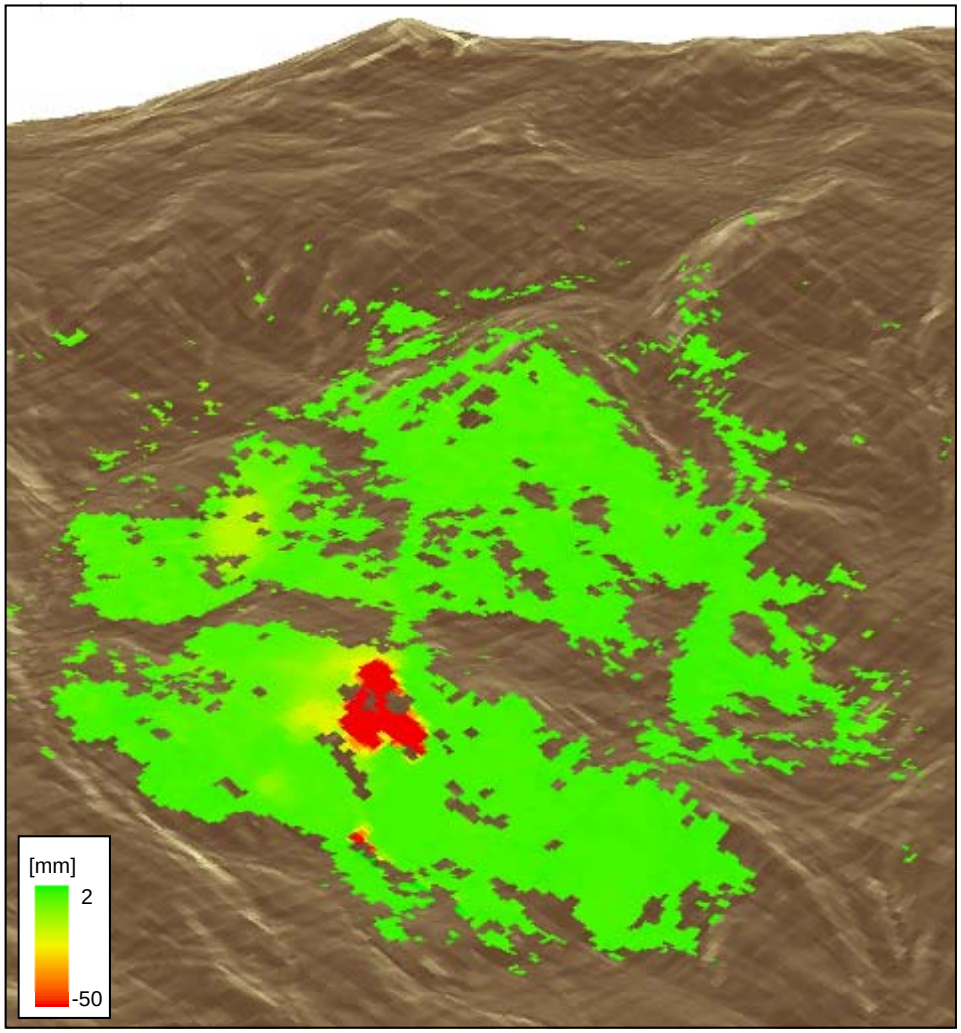
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio frane (13 h)

Geocoded Line Of Sight Displacement Map



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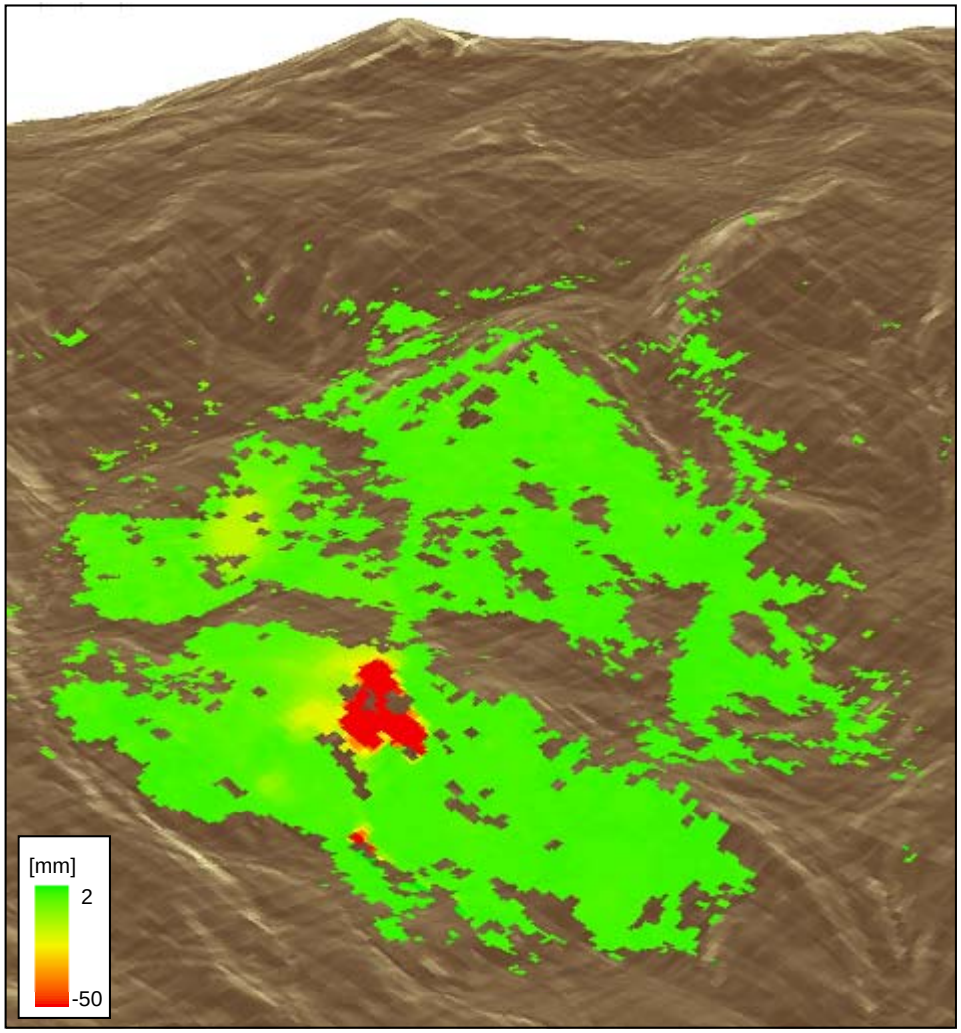
IBIS-L: monitoraggio frane (14 h)

Geocoded Line Of Sight Displacement Map



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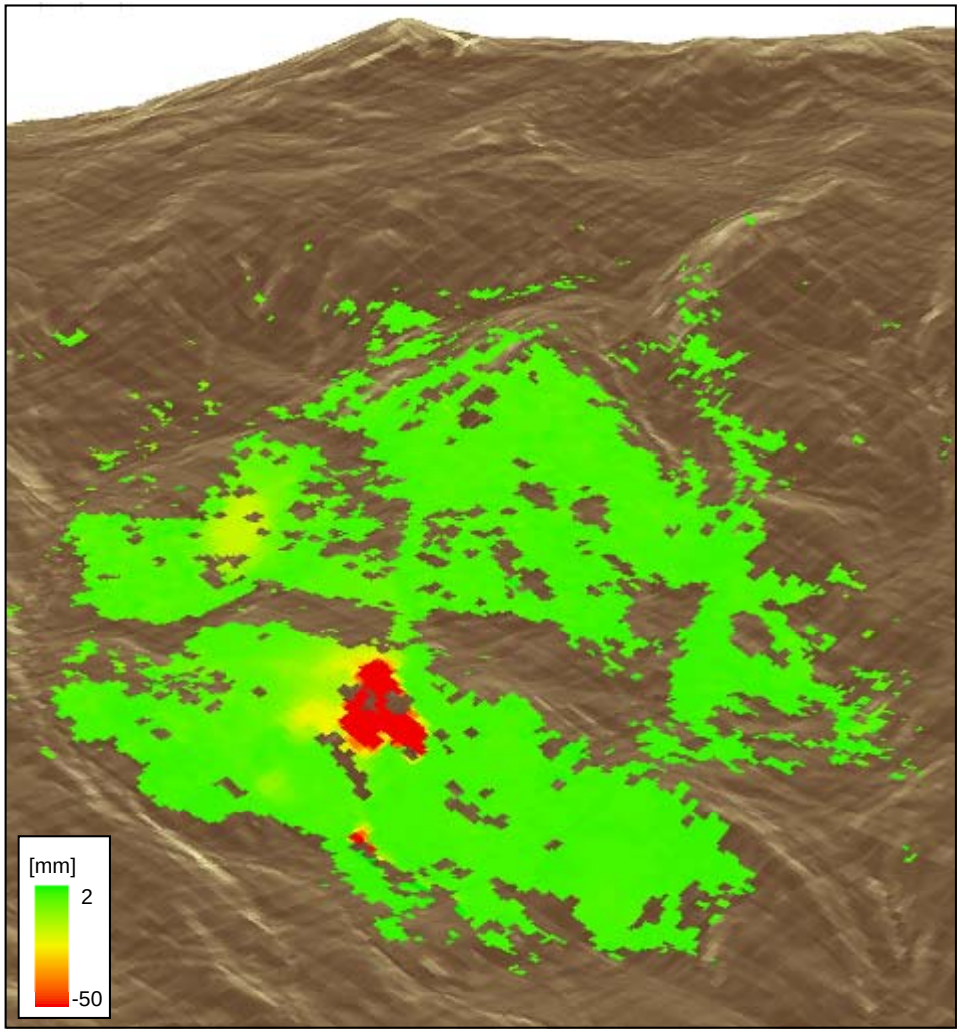
IBIS-L: monitoraggio frane (15 h)

Geocoded Line Of Sight Displacement Map



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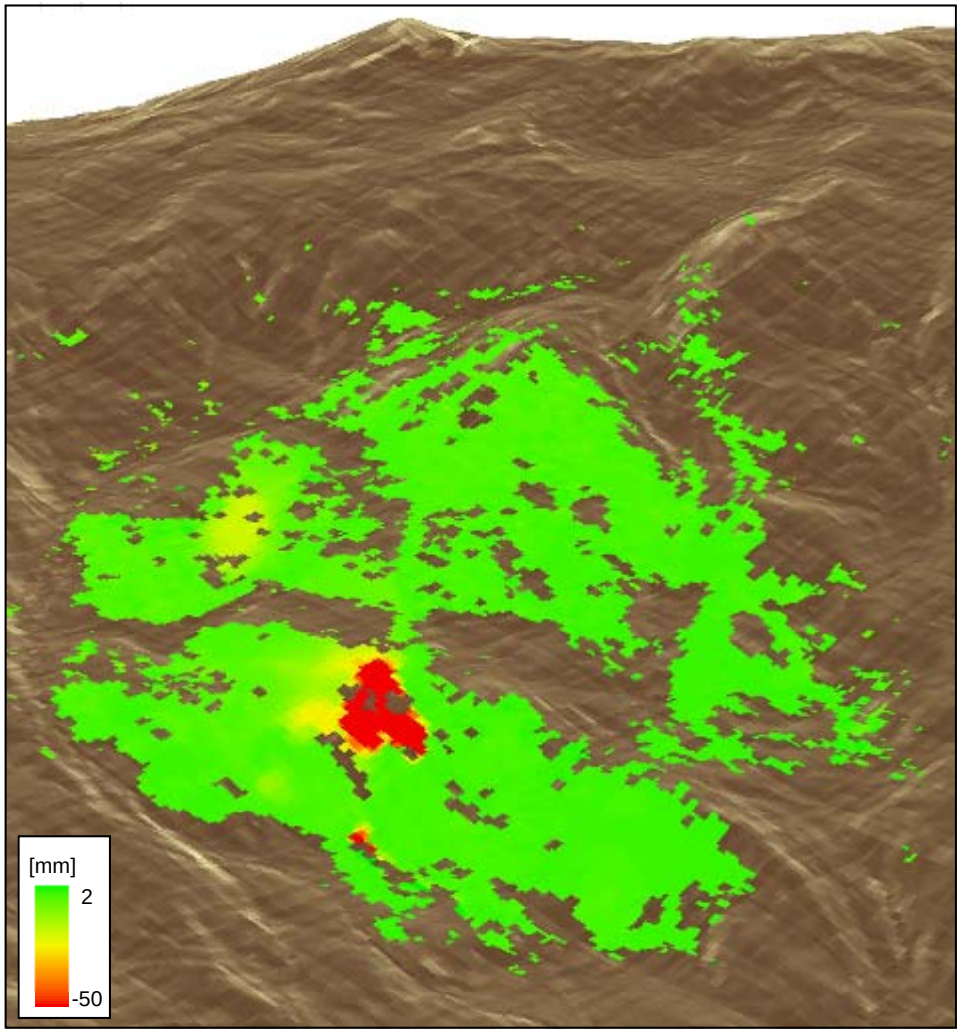
IBIS-L: monitoraggio frane (16 h)

Geocoded Line Of Sight Displacement Map



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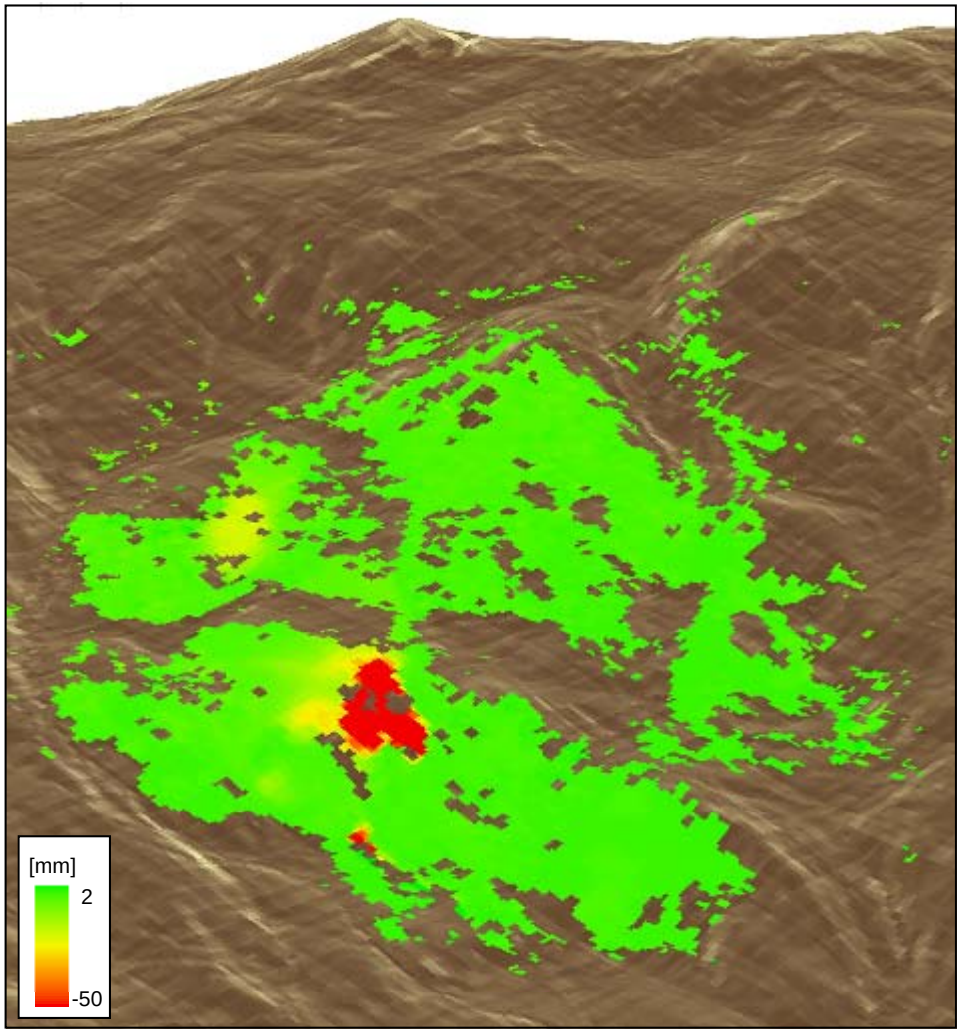
IBIS-L: monitoraggio frane (17 h)

Geocoded Line Of Sight Displacement Map



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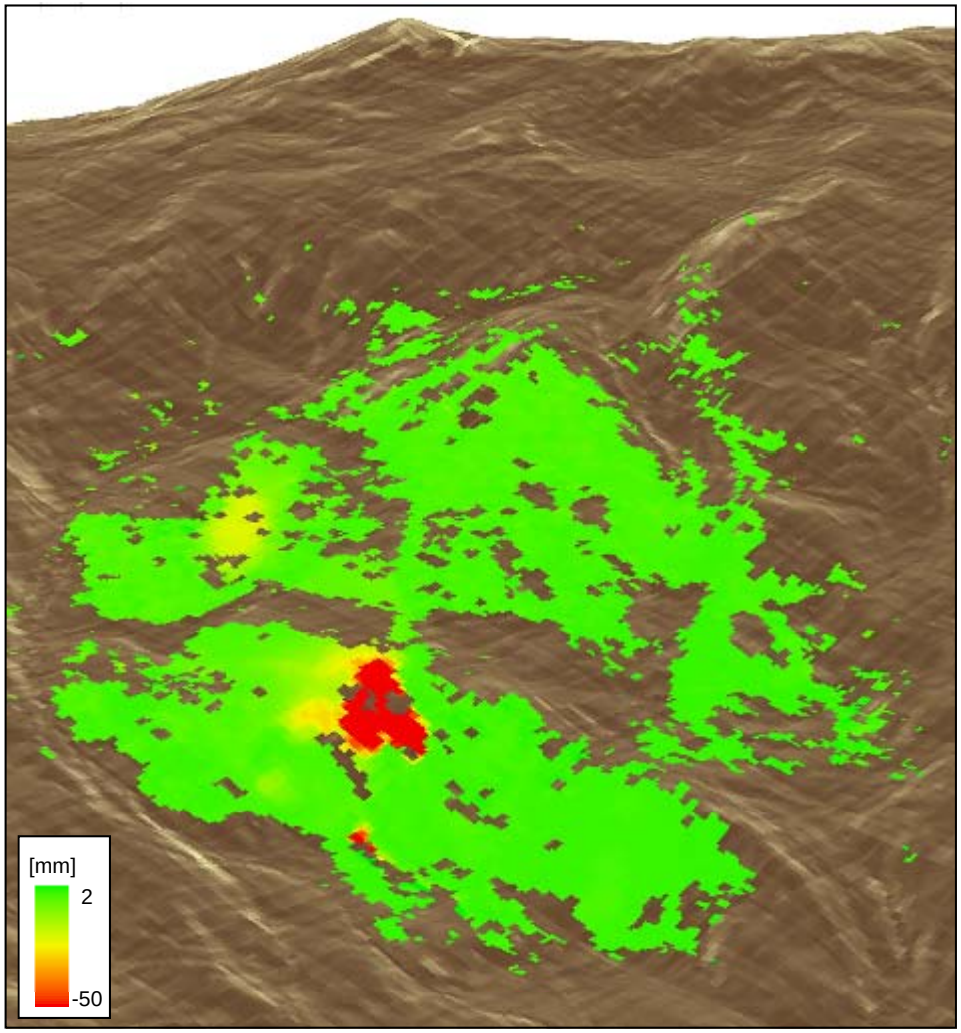
IBIS-L: monitoraggio frane (18 h)

Geocoded Line Of Sight Displacement Map



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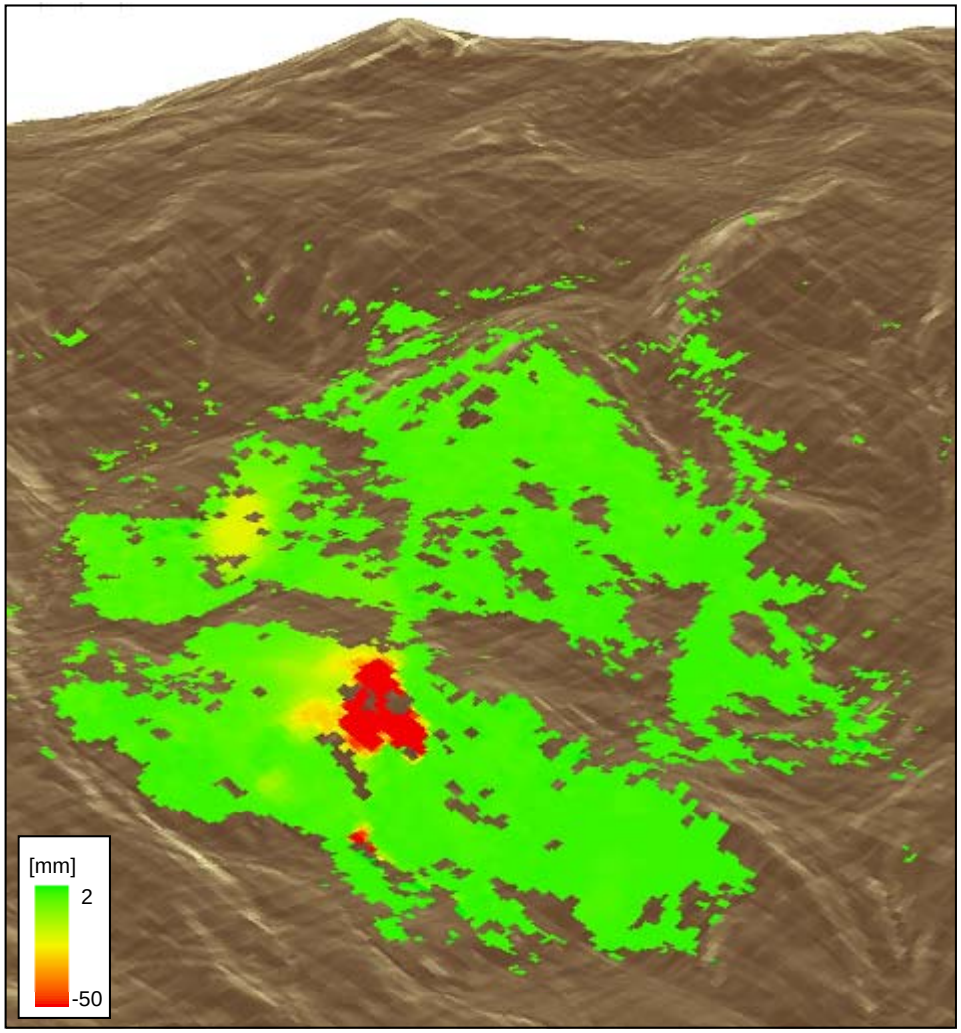
IBIS-L: monitoraggio frane (19 h)

Geocoded Line Of Sight Displacement Map



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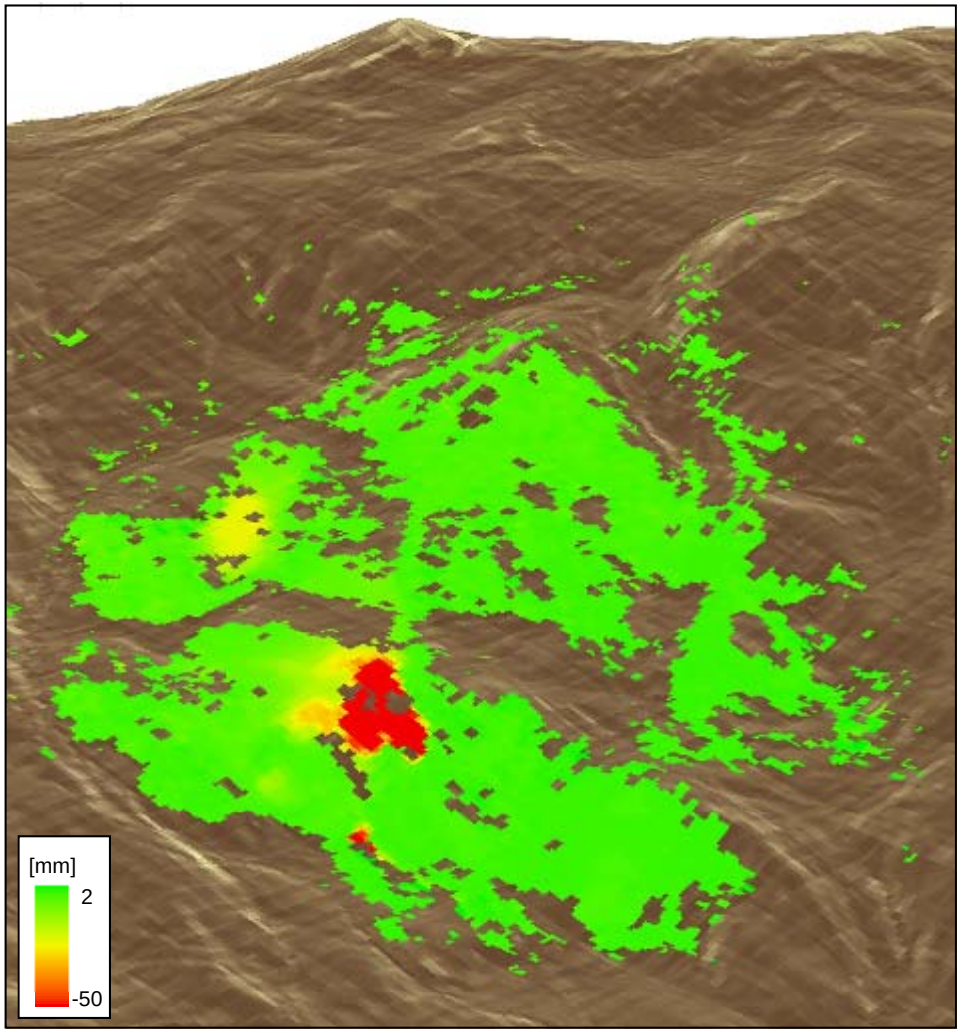
IBIS-L: monitoraggio frane (20 h)

Geocoded Line Of Sight Displacement Map



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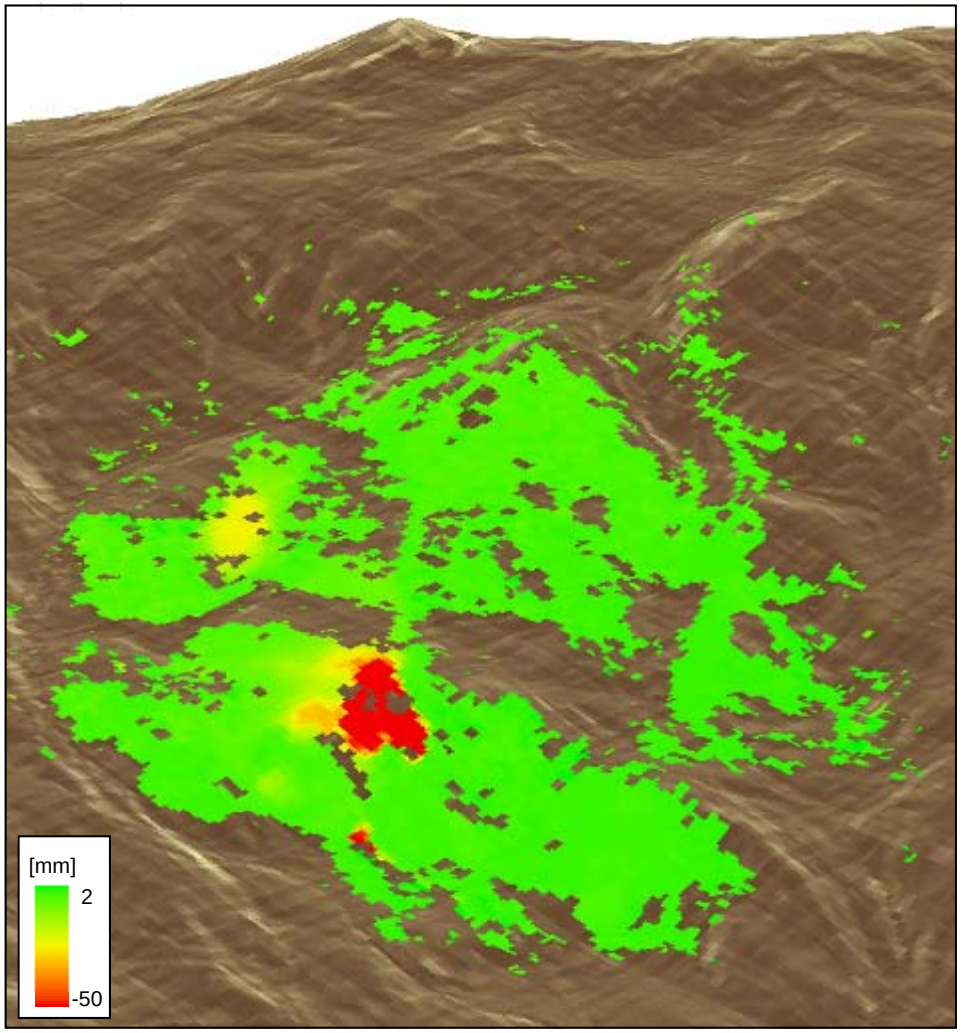
IBIS-L: monitoraggio frane (21 h)

Geocoded Line Of Sight Displacement Map



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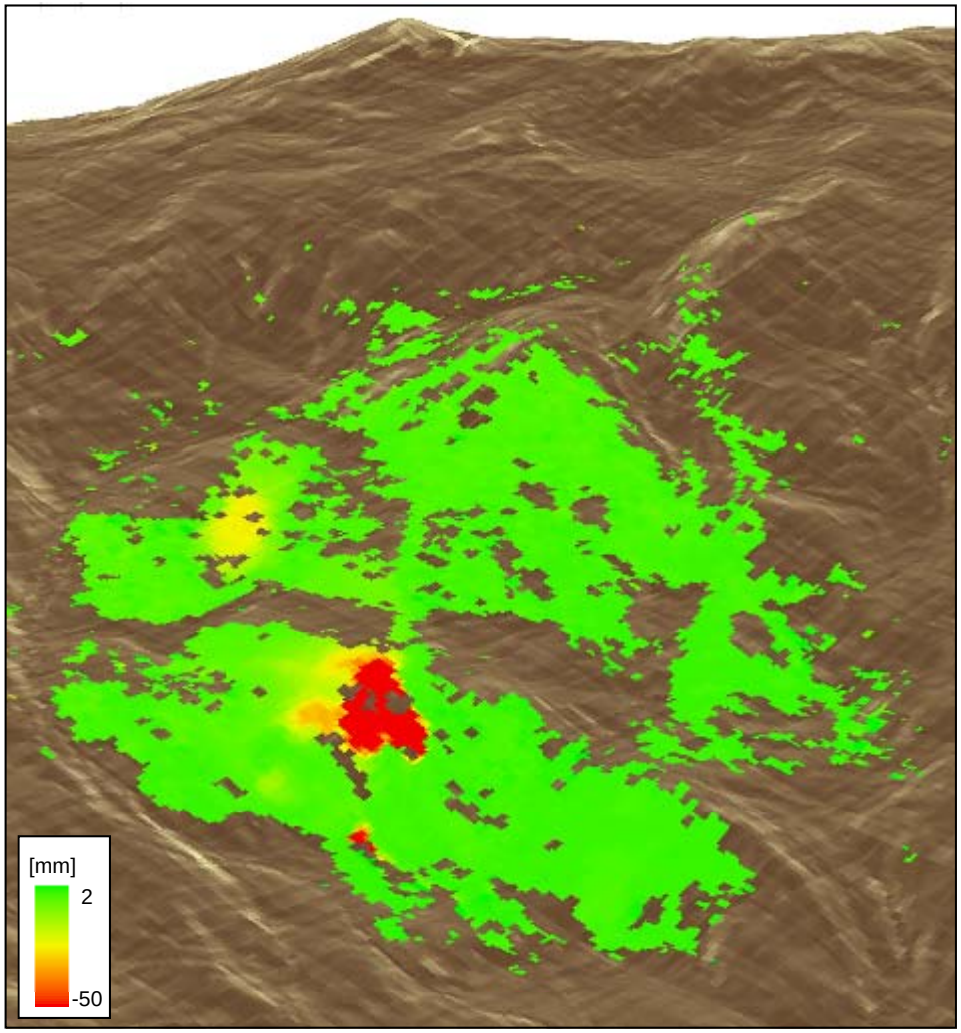
IBIS-L: monitoraggio frane (22 h)

Geocoded Line Of Sight Displacement Map



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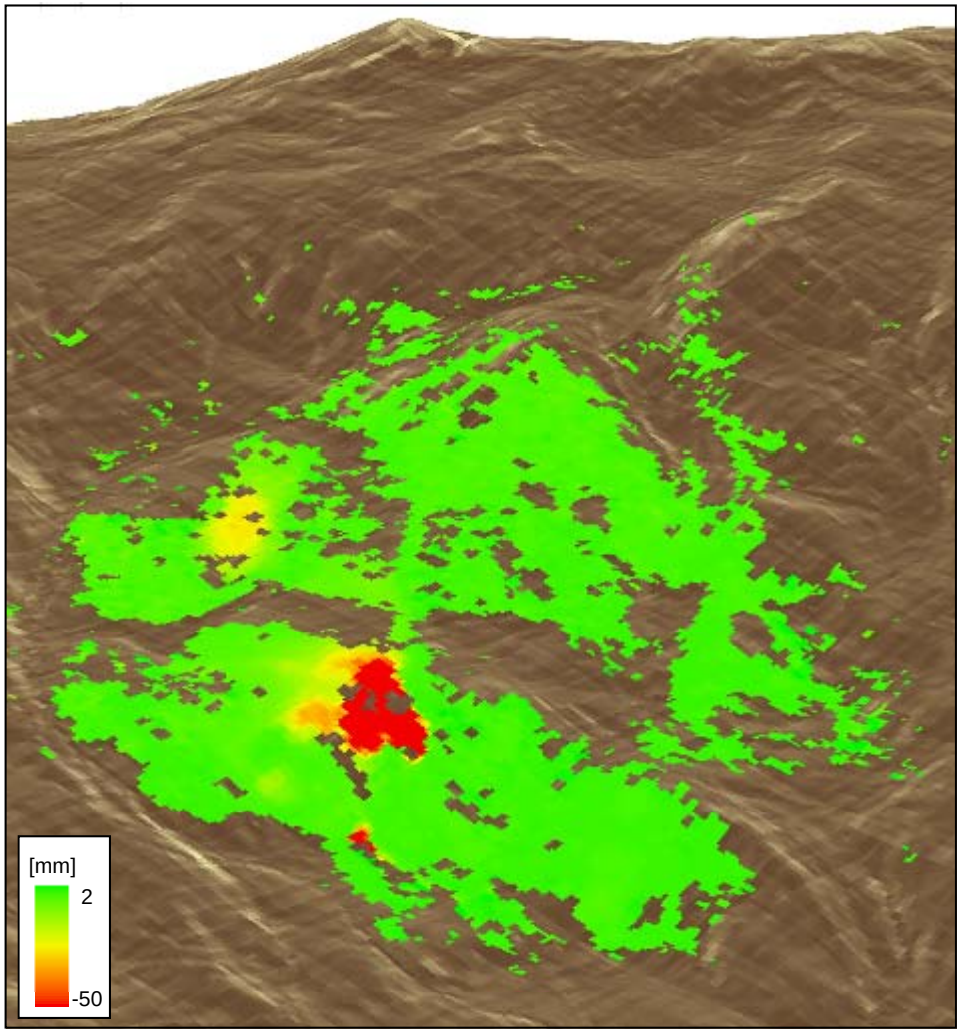
IBIS-L: monitoraggio frane (23 h)

Geocoded Line Of Sight Displacement Map



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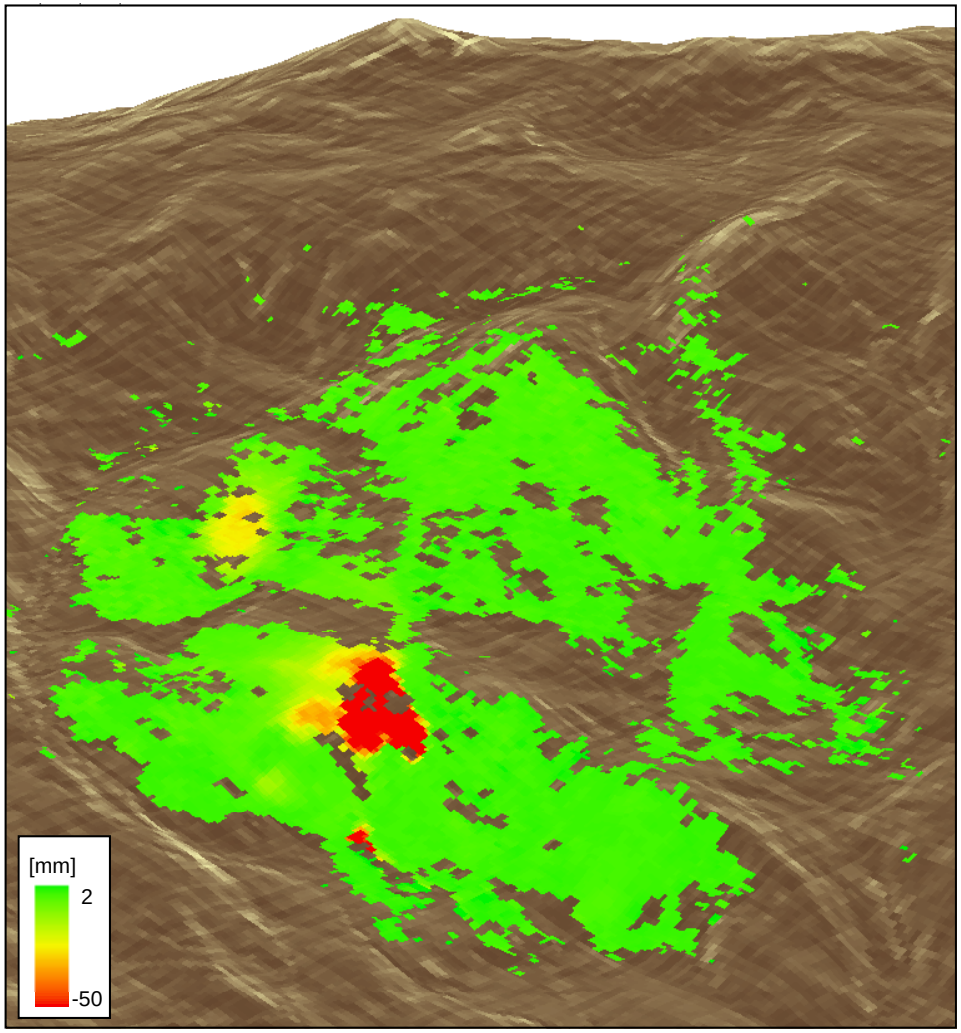
IBIS-L: monitoraggio frane (24 h)

Geocoded Line Of Sight Displacement Map



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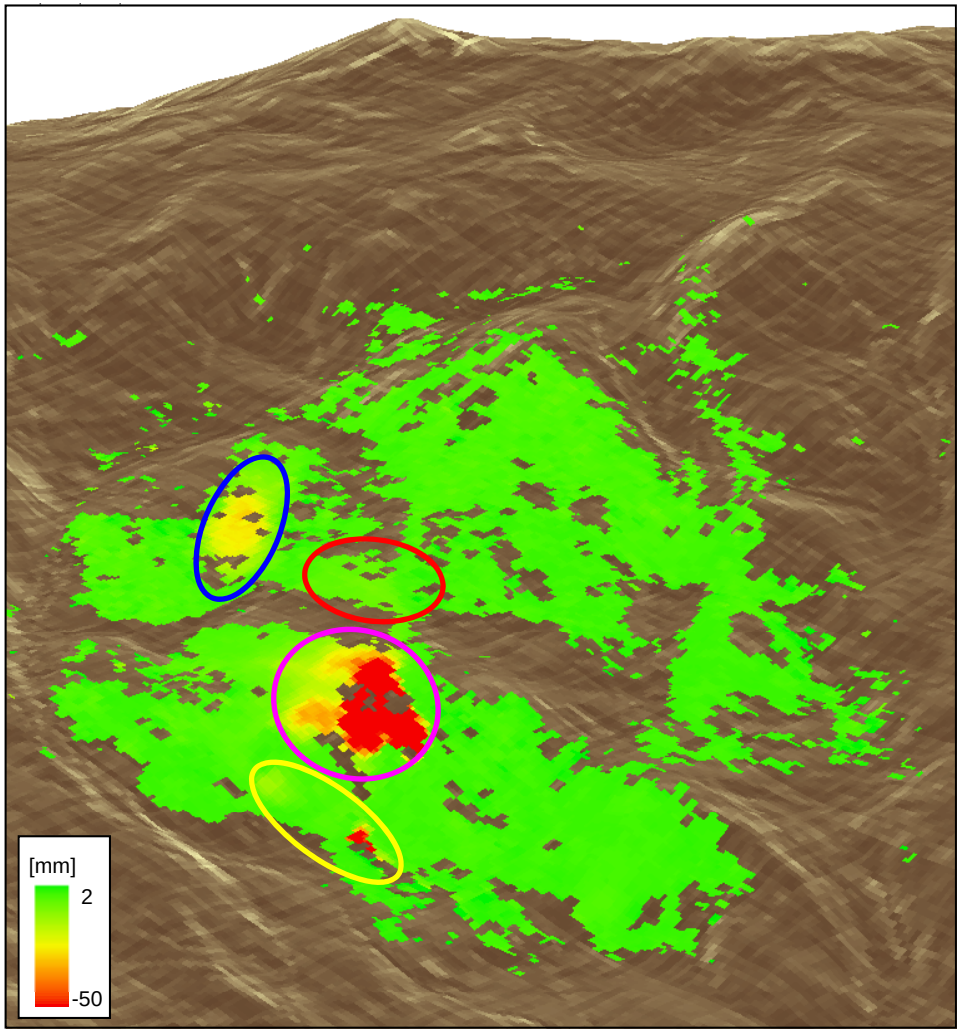
IBIS-L: monitoraggio frane

Zona A	
Zona B	
Zona C	
Zona D	

Geocoded Line Of Sight Displacement Map



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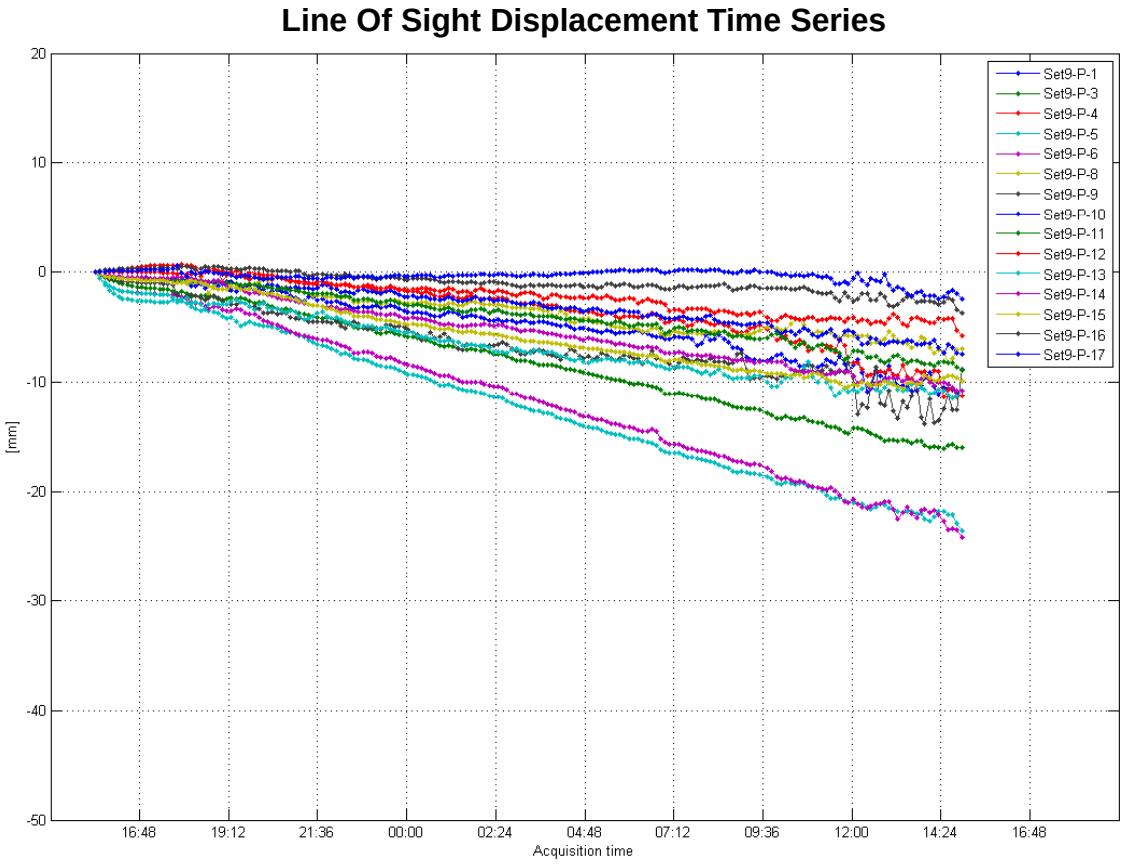
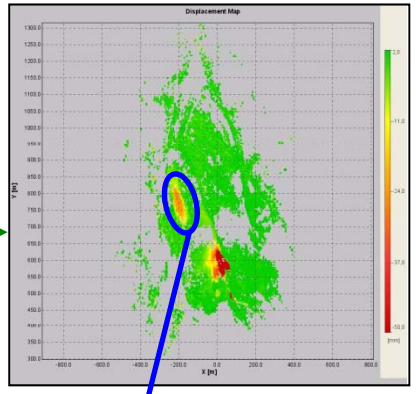
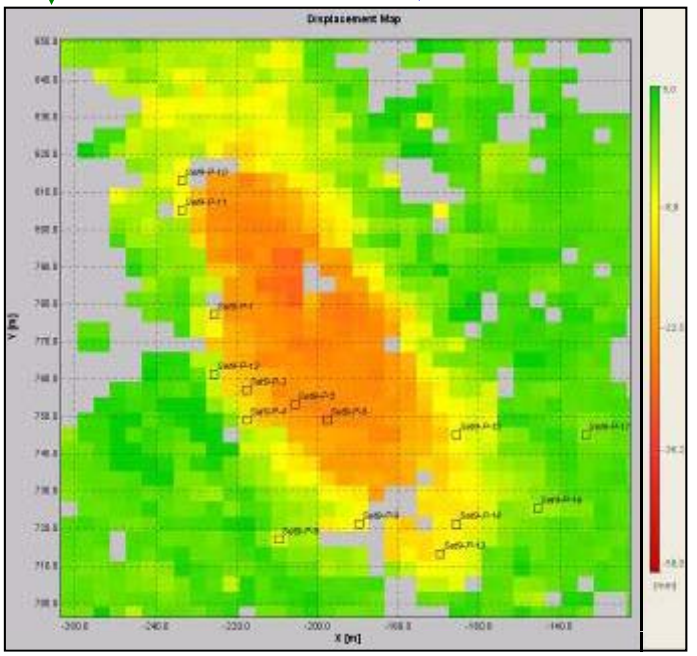
IBIS-L: monitoraggio frane

ZONA A - movimento di alcuni punti di misura selezionati



Mappe di spostamento cumulato dopo 24 ore





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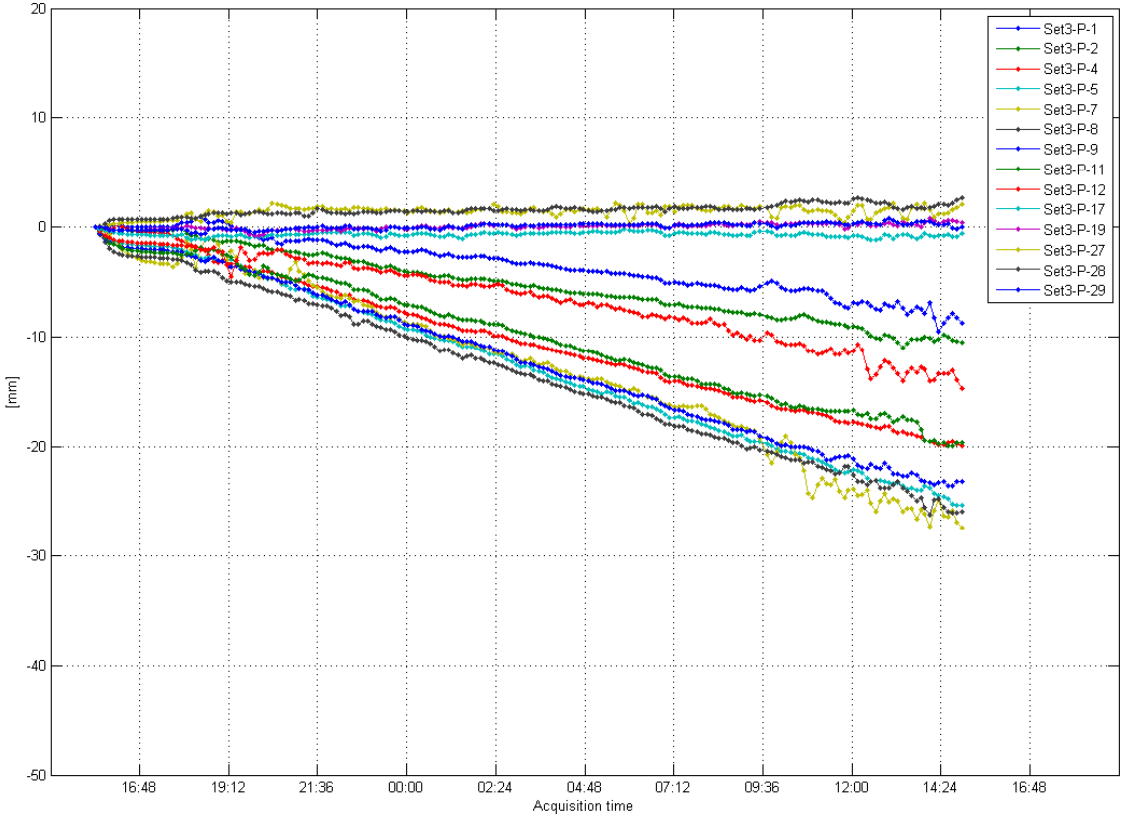
IDS INGEGNERIA DEI SISTEMI

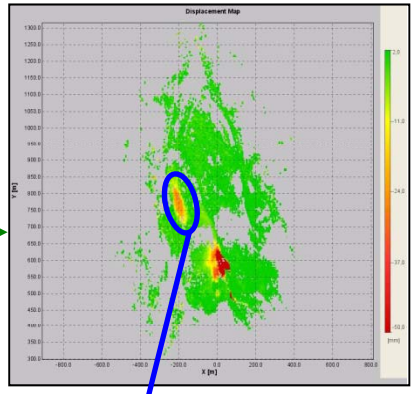
IBIS-L: monitoraggio frane

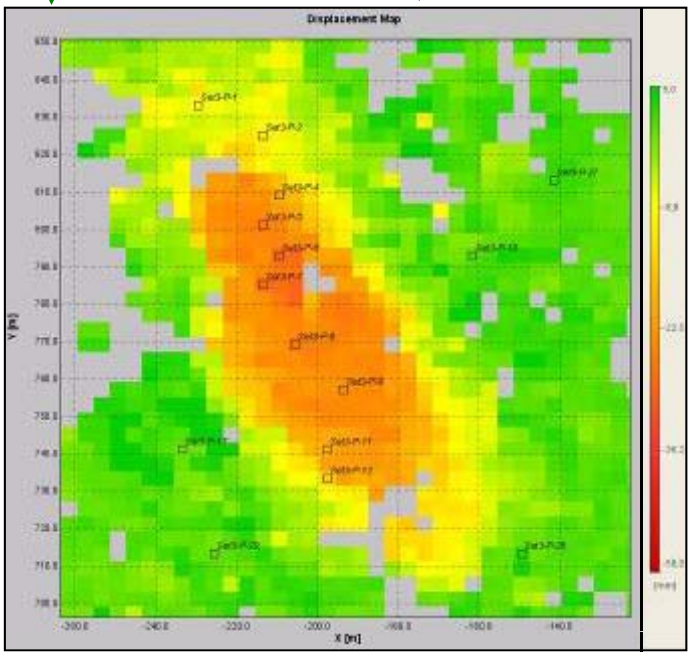
ZONE A - displacement of a few points

Line Of Sight Displacement Time Series



Mappe di spostamento cumulato dopo 24 ore





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IDS INGEGNERIA DEI SISTEMI

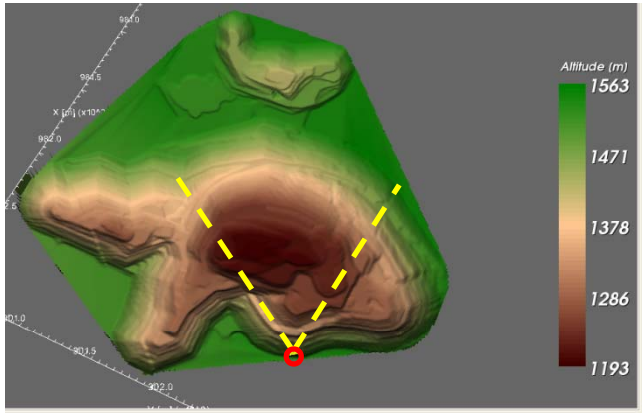
IBIS-M: stabilità dei fronti di scavo

Following a 80,000 ton slip occurred in late 2009 and the consequent closure of operations, an IBIS-M unit was deployed in January 2010 at the Pipeline pit in Cortez, Nevada, owned by Barrick.

The IBIS-M system was aimed at providing early warnings and support for geotechnical evaluation purposes.

After 7 months of rental of the equipment, in July 2010, the IBIS-M unit was purchased by Barrick.

IBIS-M: stabilità dei fronti di scavo



DISTANCE FROM THE SLOPE	[m]	800 – 1500
ANTENNA BEAM WIDTH	[deg]	68
NUMBER OF POINTS	-	90.000
RANGE RESOLUTION	[m]	0.5 (1.64 ft)
CROSS-RANGE RESOLUTION	[mrad]	4.5
SCANNING TIME	[min]	5

IBIS-M: stabilità dei fronti di scavo

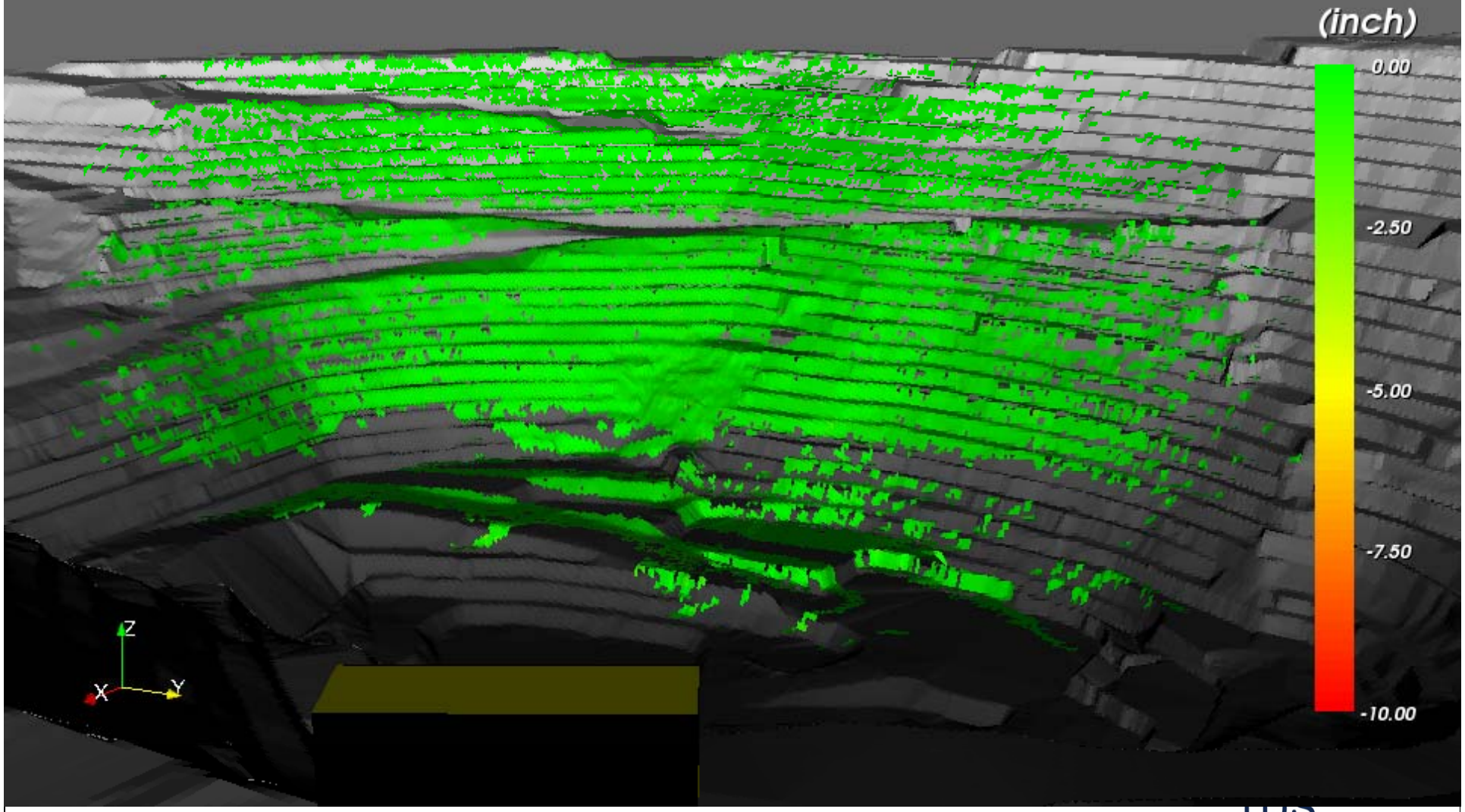
Shelter (pit rim)
IBIS-M basic configuration unit
Fully enclosed (HVAC, WiFi)
Mine grid power supply
Backup power (1 day with genset)
IBIS Controller Software
24/7 functioning

VPN, VNC
connections

IBIS-M: stabilità dei fronti di scavo

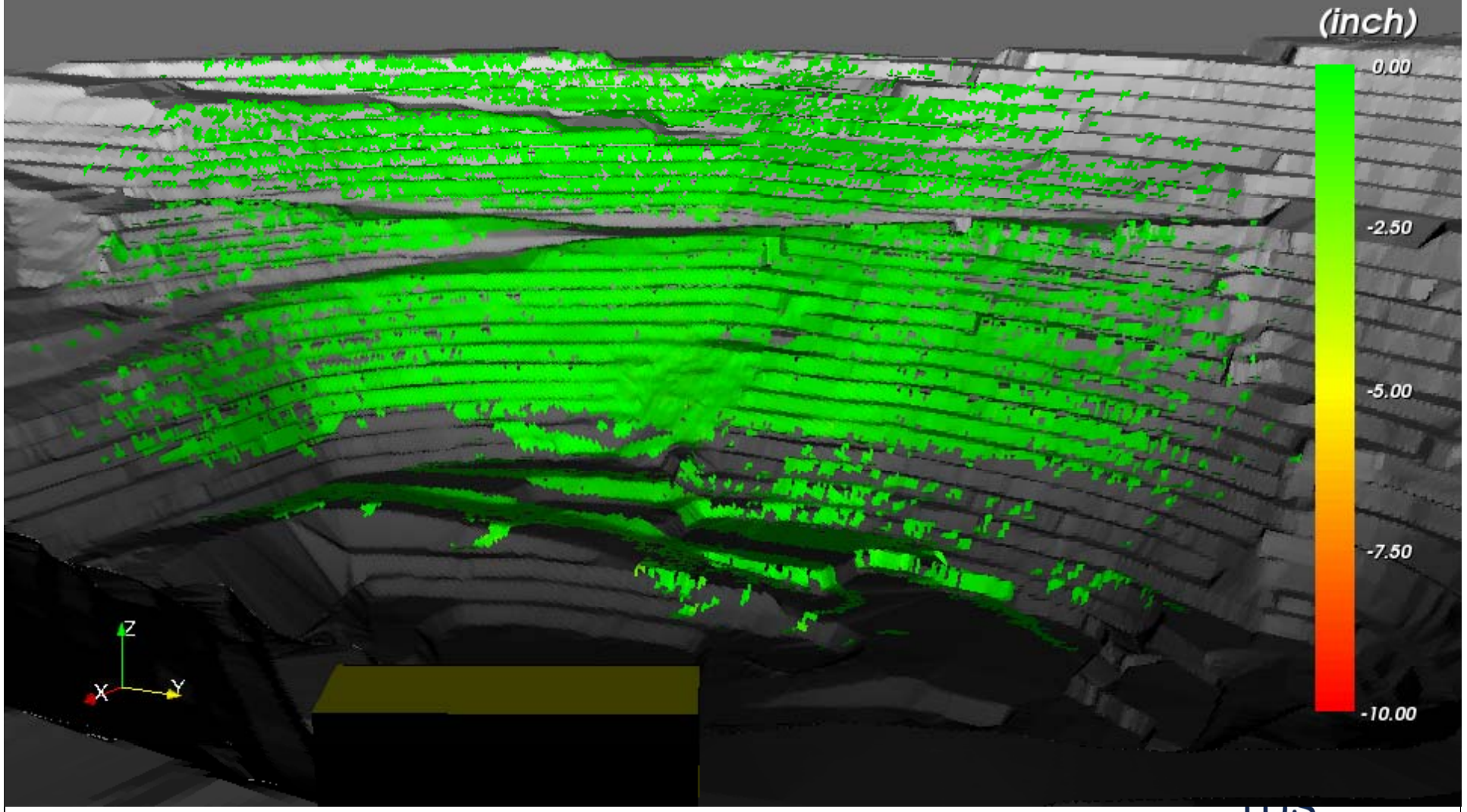
Start Time: 15:33 03/02/10
Stop Time: 14:36 18/02/10

Cumulative displacement from 03/02 to 18/02



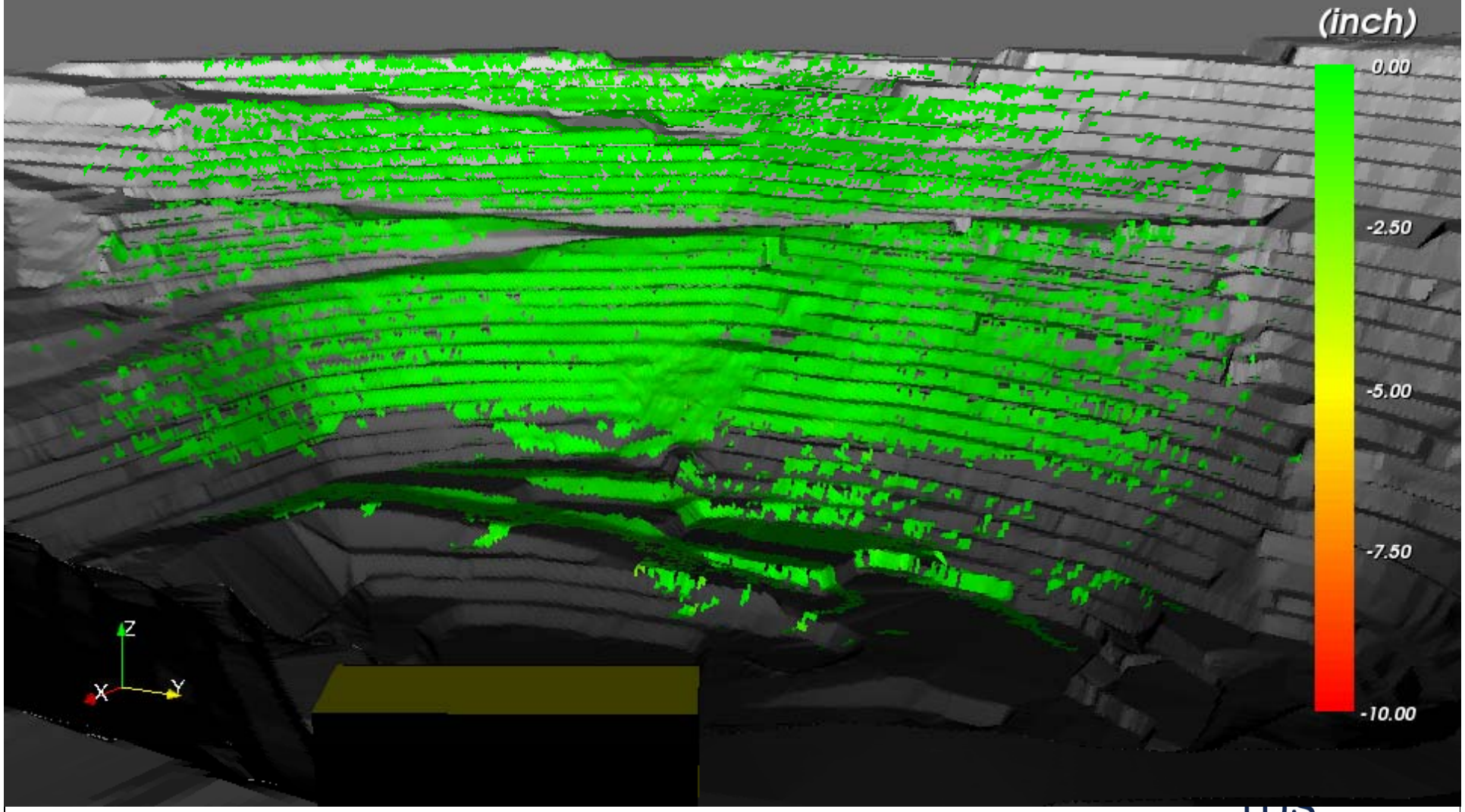
Start Time: 15:33 03/02/10
Stop Time: 10:56 25/02/10

Cumulative displacement from 03/02 to 25/02



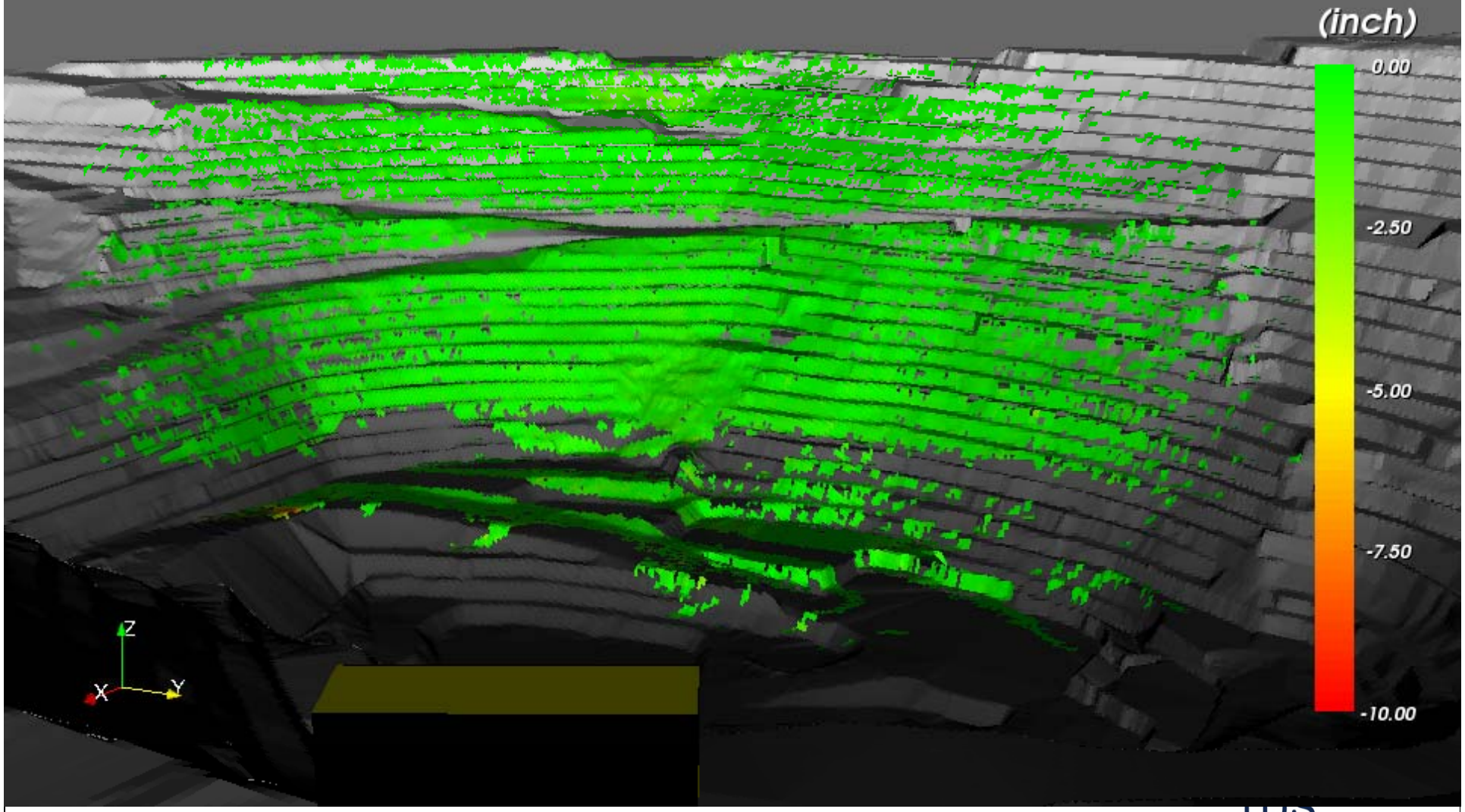
Start Time: 15:33 03/02/10
Stop Time: 17:20 07/03/10

Cumulative displacement from 03/02 to 07/03



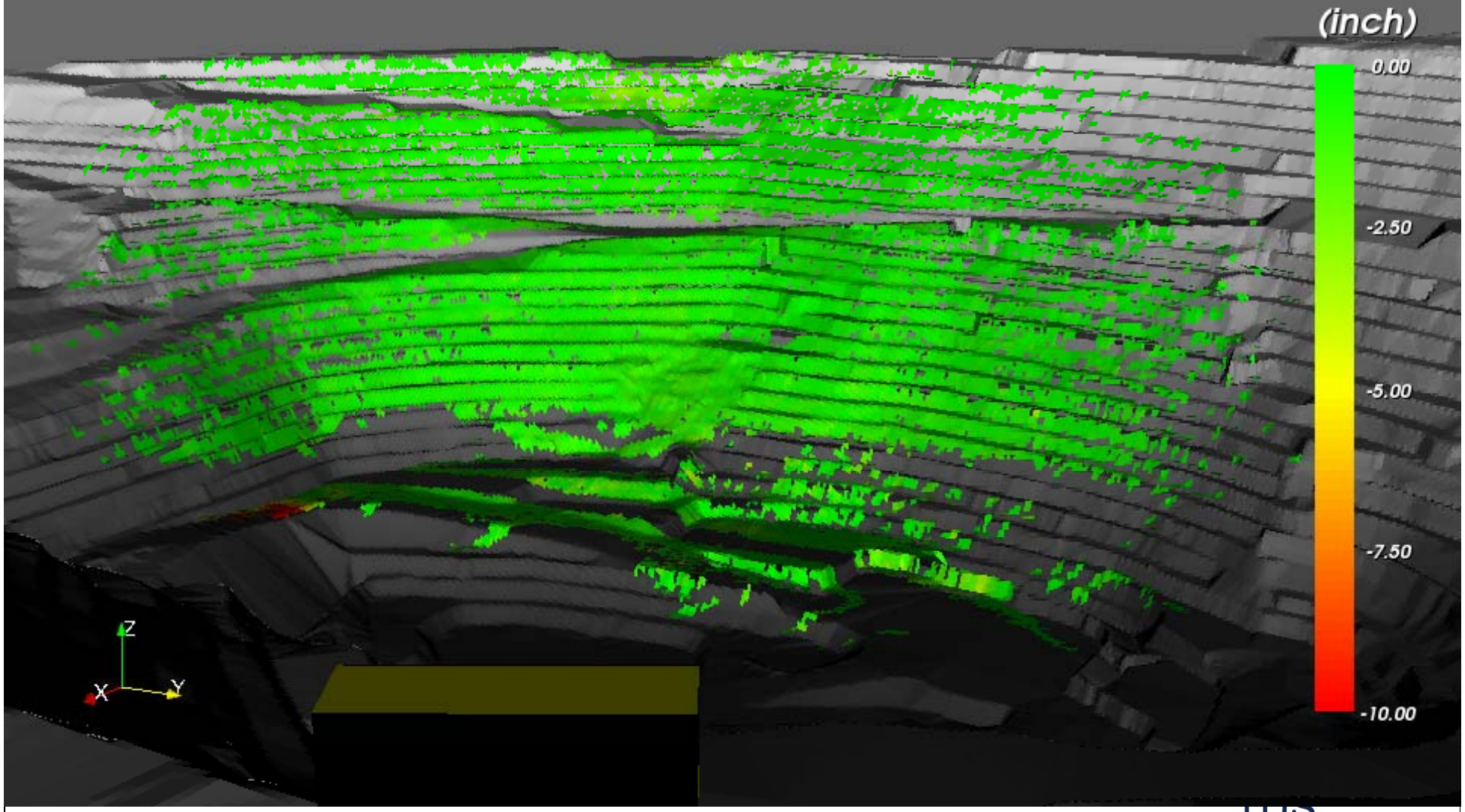
Start Time: 15:33 03/02/10
Stop Time: 18:18 21/03/10

Cumulative displacement from 03/02 to 21/03



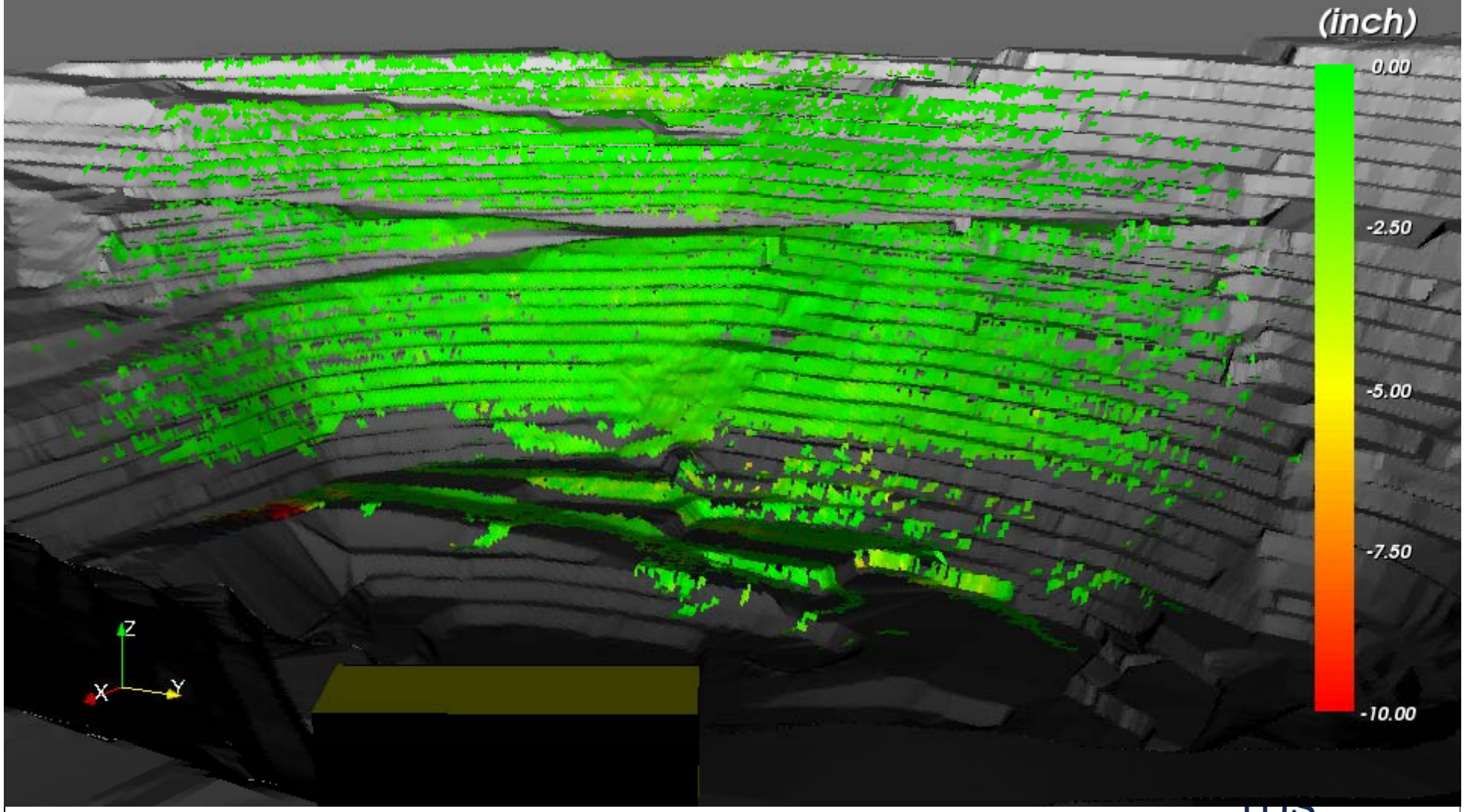
Start Time: 15:33 03/02/10
Stop Time: 16:13 04/04/10

Cumulative displacement from 03/02 to 04/04



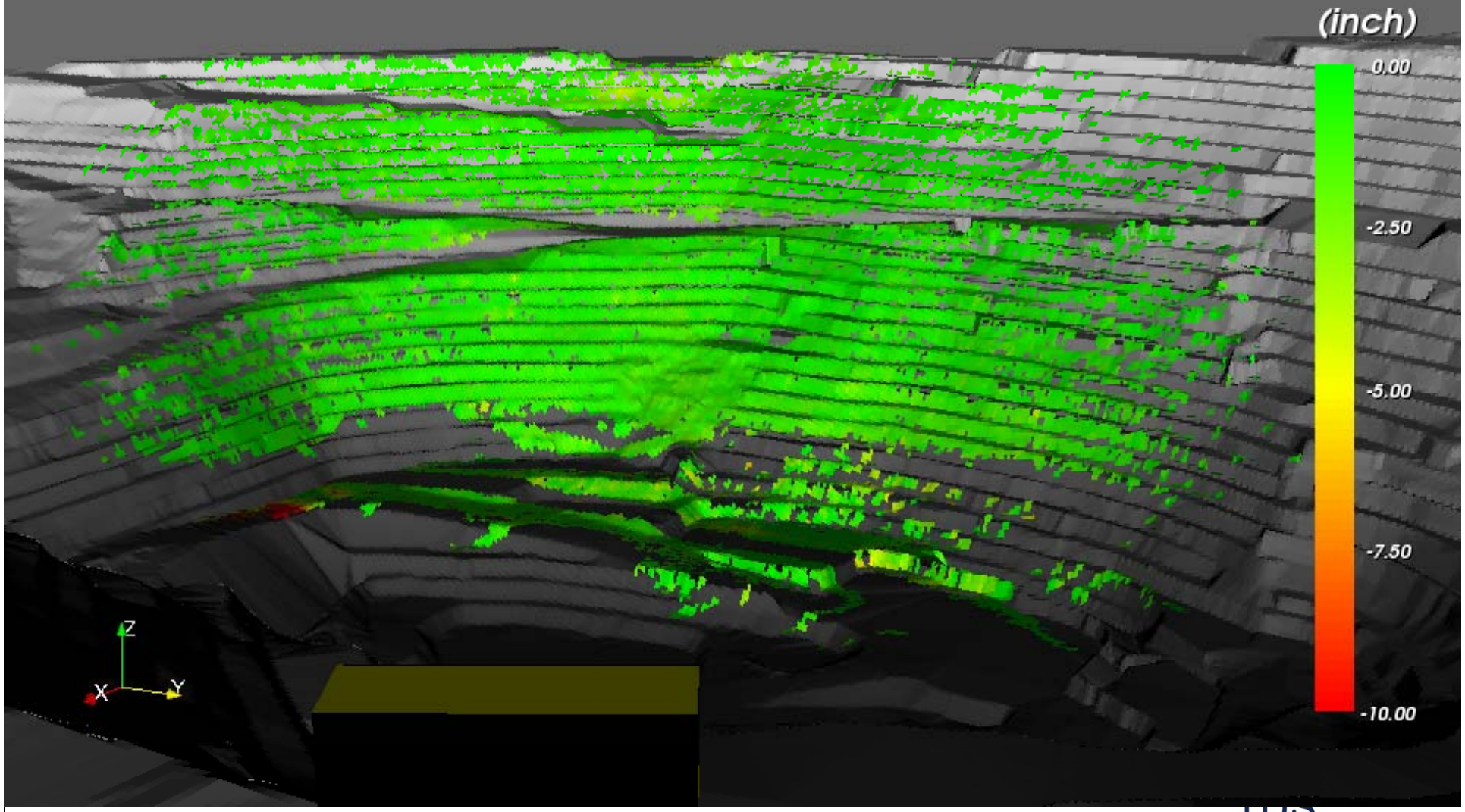
Start Time: 15:33 03/02/10
Stop Time: 12:08 19/04/10

Cumulative displacement from 03/02 to 19/04



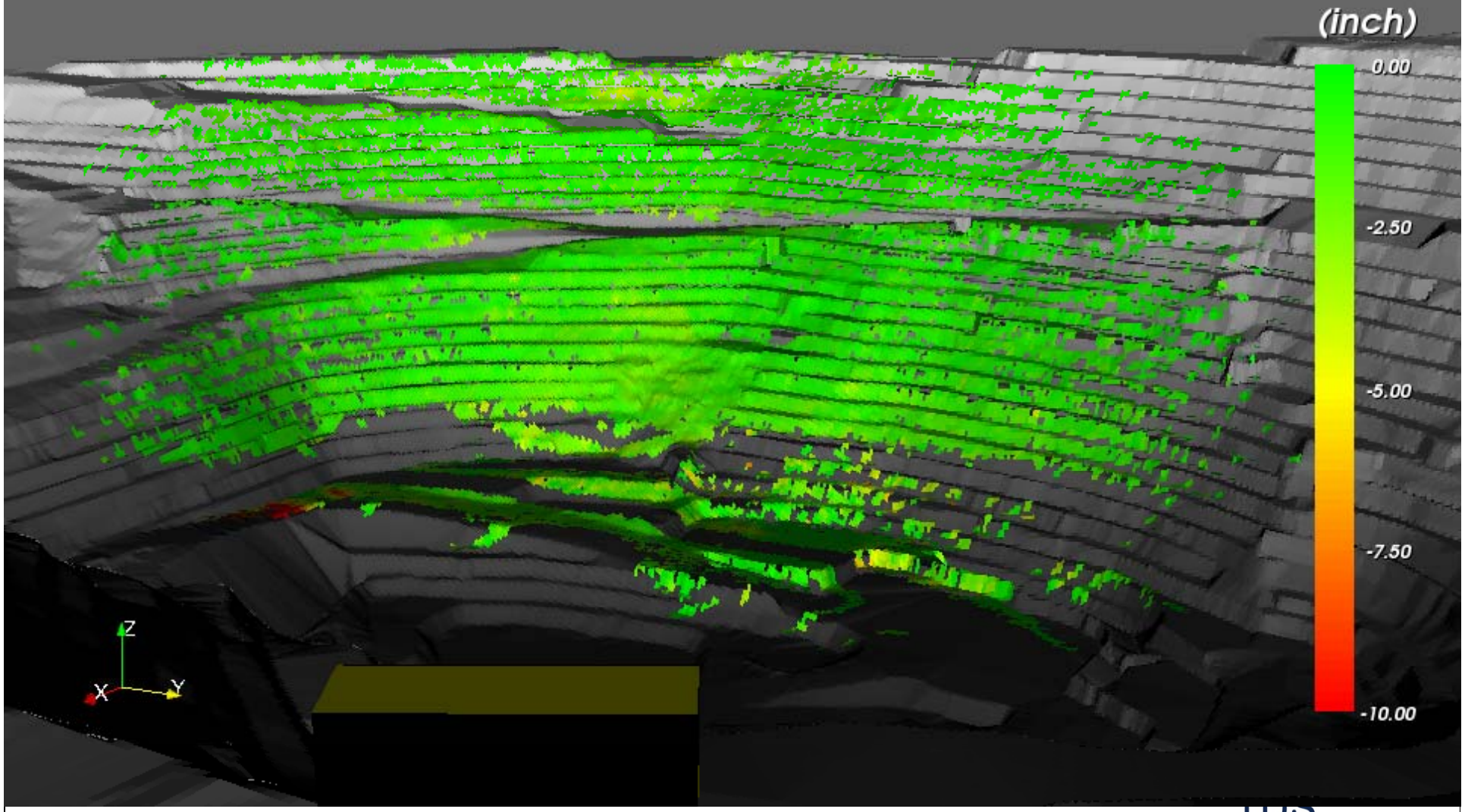
Start Time: 15:33 03/02/10
Stop Time: 16:59 04/05/10

Cumulative displacement from 03/02 to 04/05



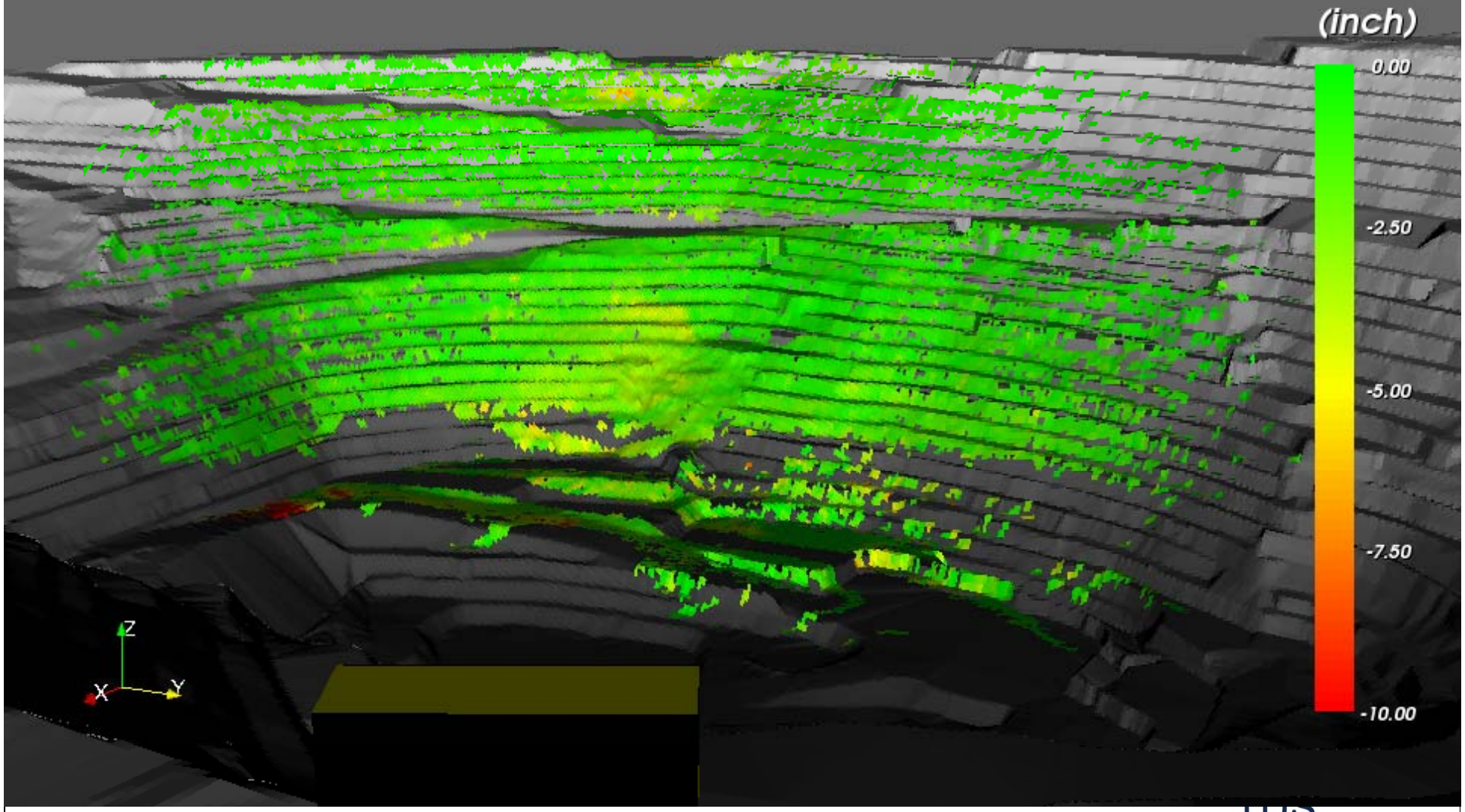
Start Time: 15:33 03/02/10
Stop Time: 18:25 18/05/10

Cumulative displacement from 03/02 to 18/05



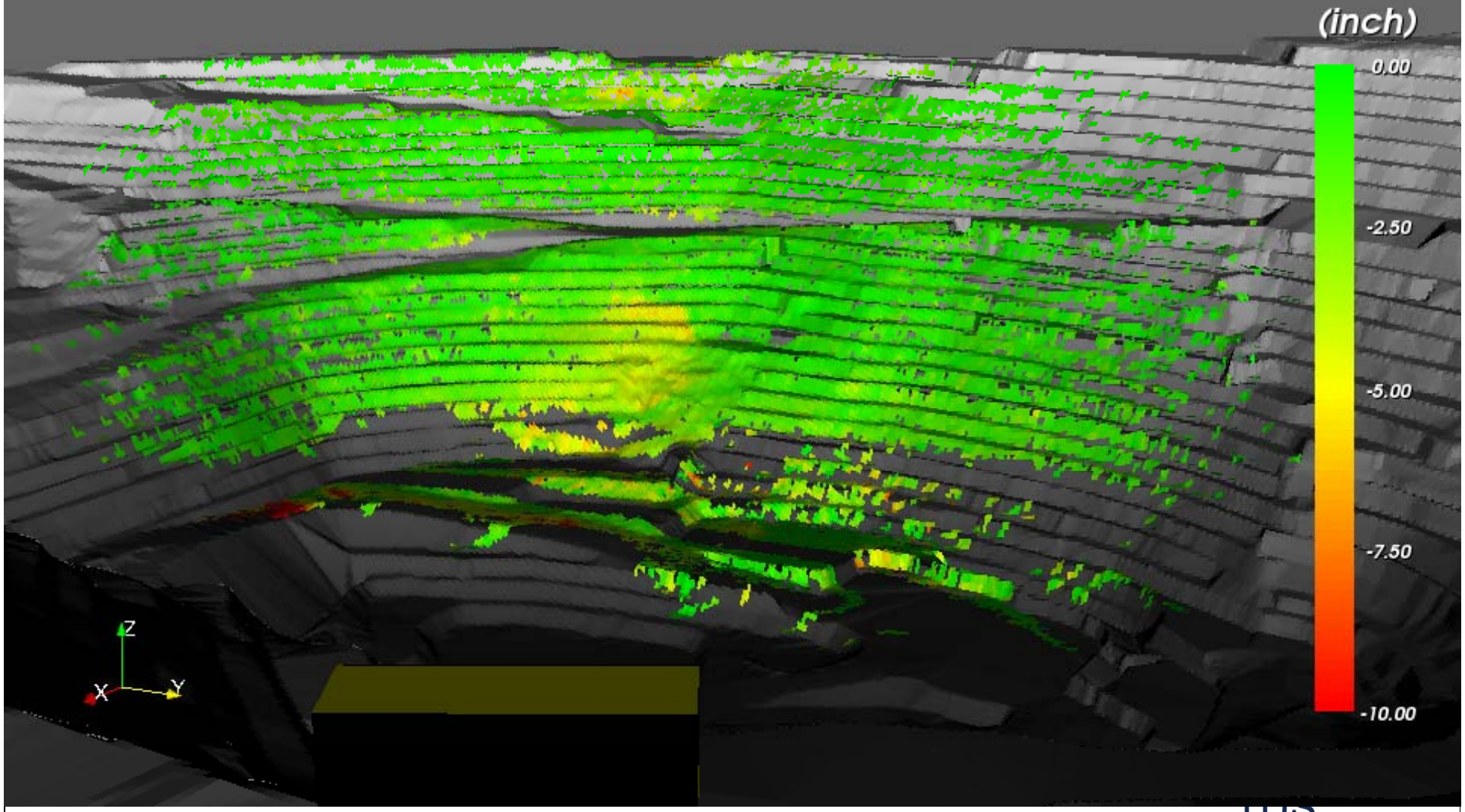
Start Time: 15:33 03/02/10
Stop Time: 12:39 01/06/10

Cumulative displacement from 03/02 to 01/06



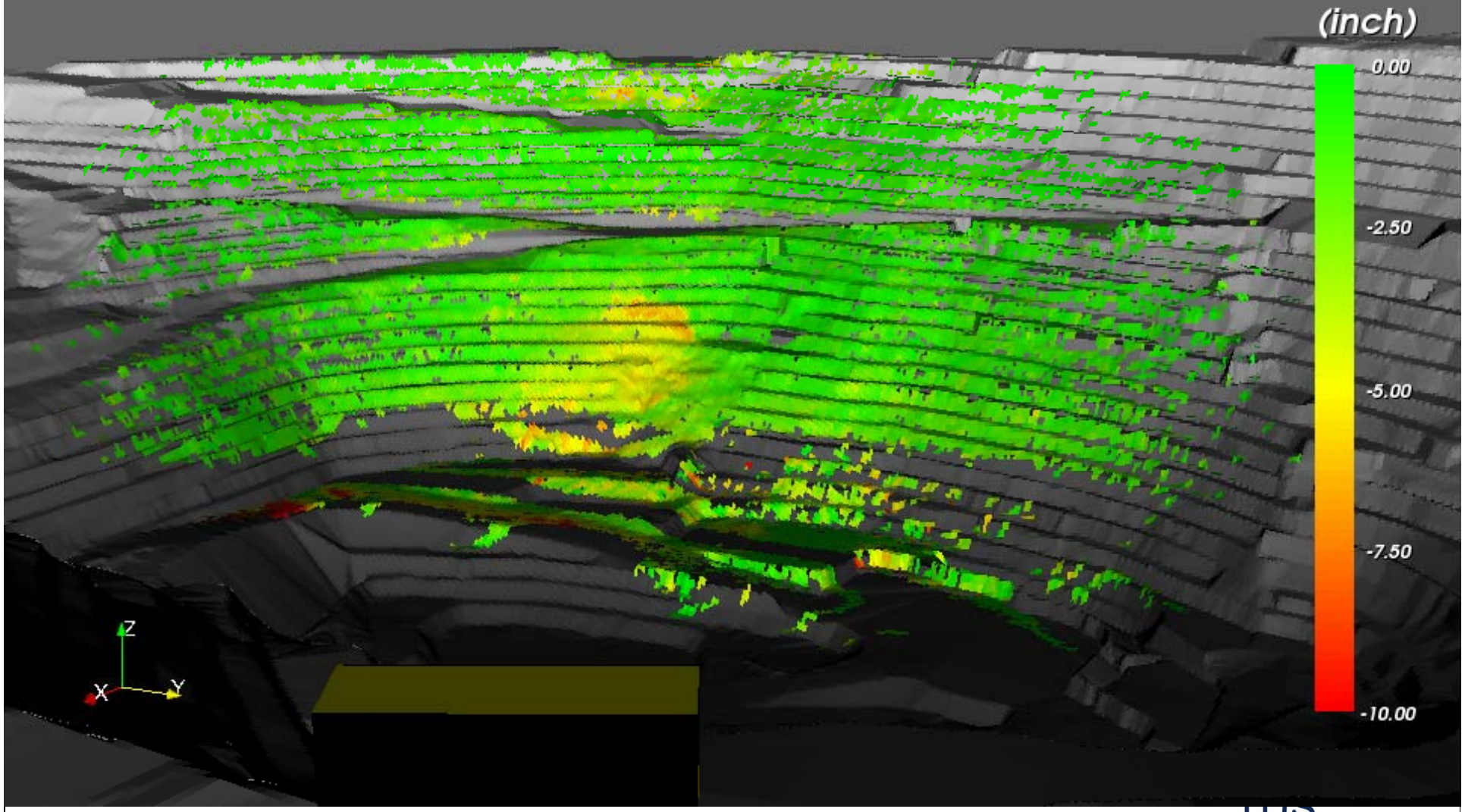
Start Time: 15:33 03/02/10
Stop Time: 16:37 15/06/10

Cumulative displacement from 03/02 to 15/06



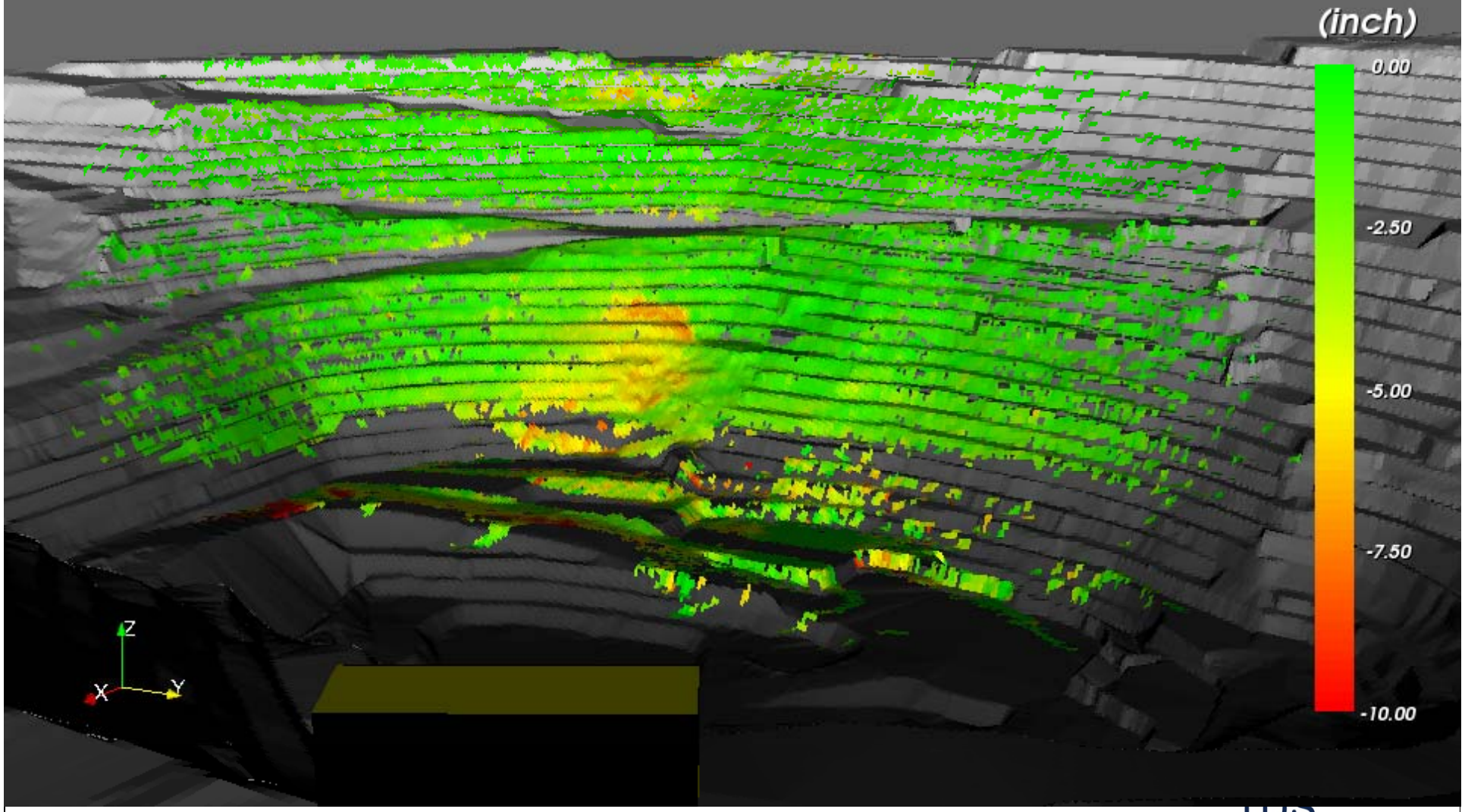
Start Time: 15:33 03/02/10
Stop Time: 13:14 29/06/10

Cumulative displacement from 03/02 to 29/06



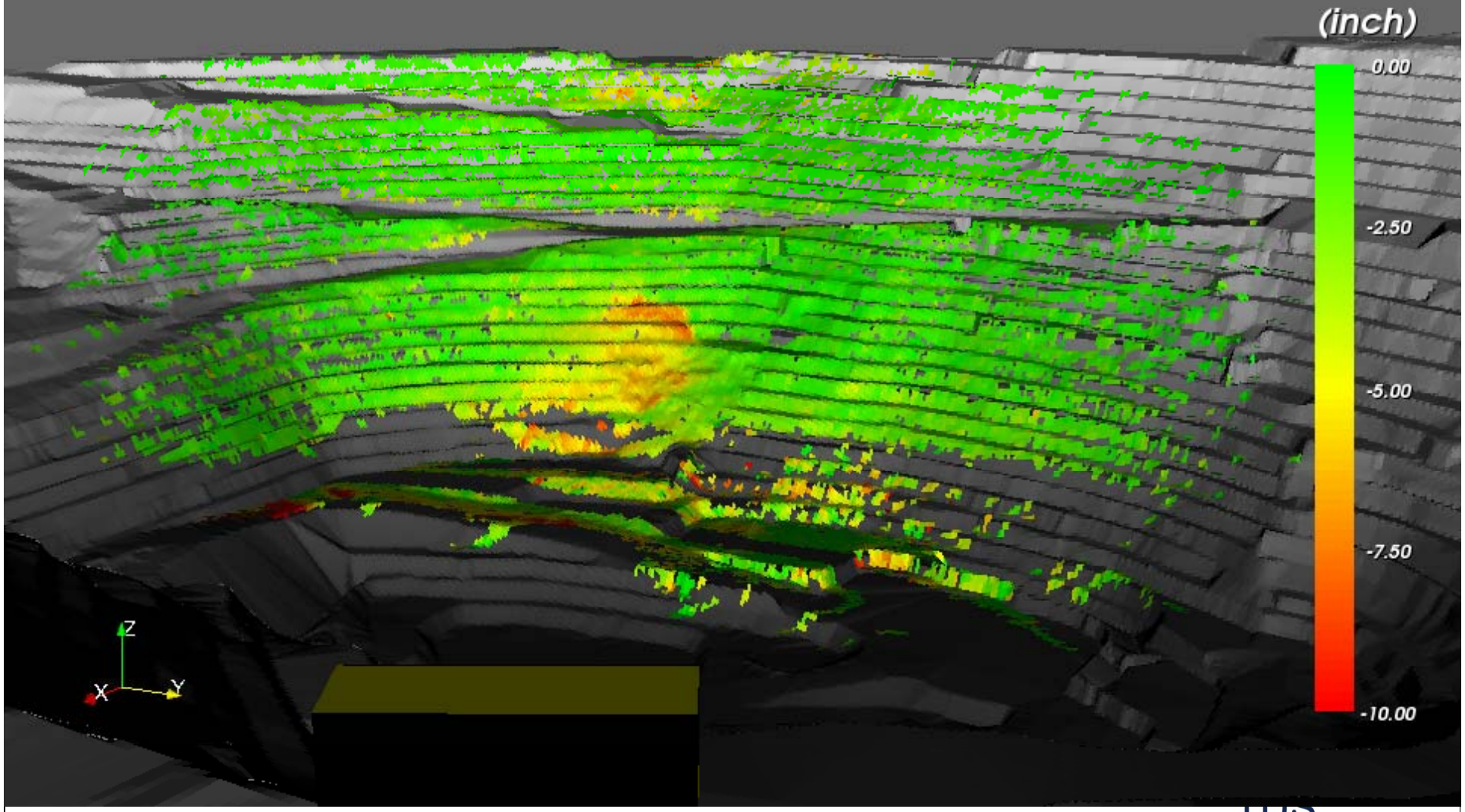
Start Time: 15:33 03/02/10
Stop Time: 13:33 14/07/10

Cumulative displacement from 03/02 to 14/07



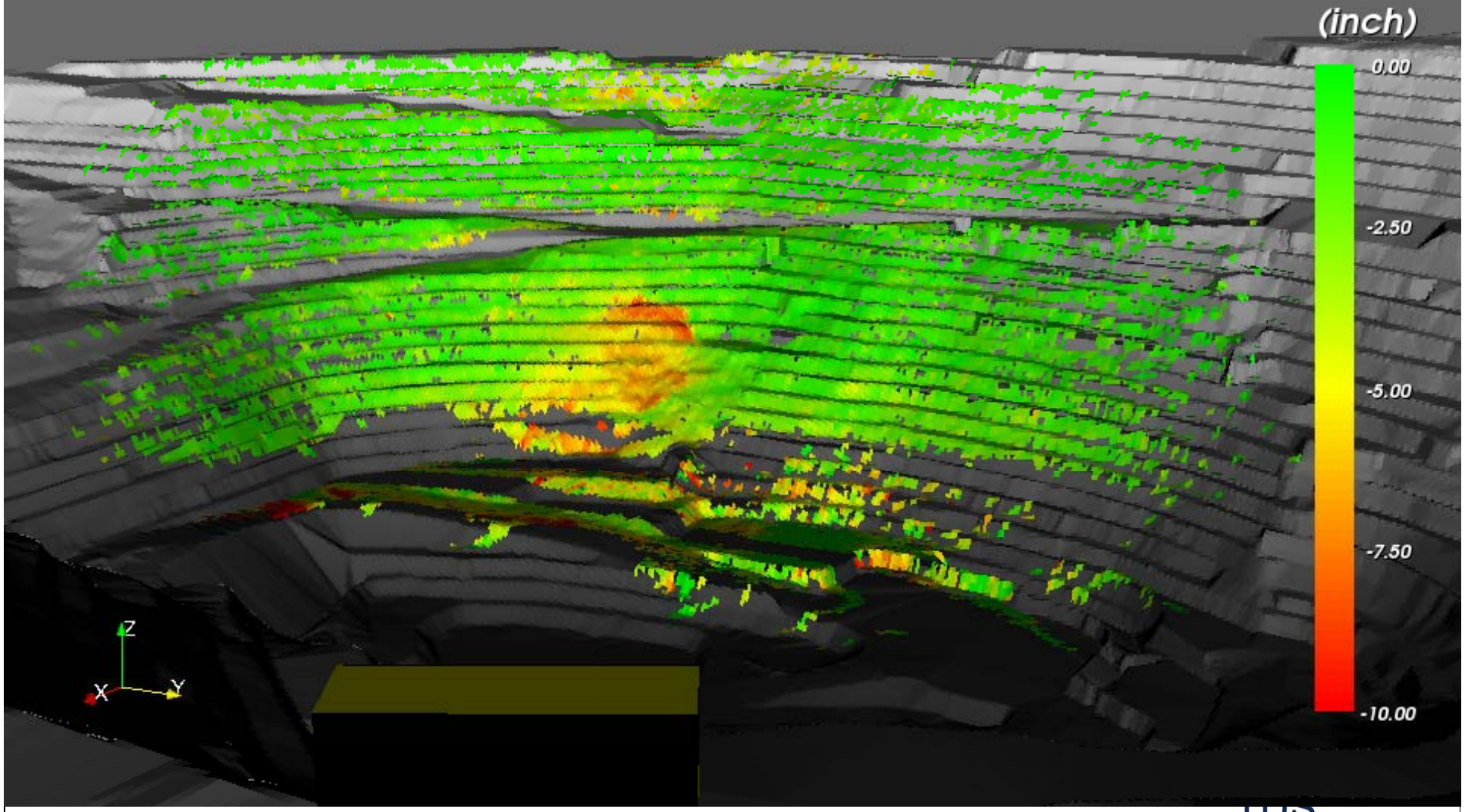
Start Time: 15:33 03/02/10
Stop Time: 13:39 29/07/10

Cumulative displacement from 03/02 to 29/07



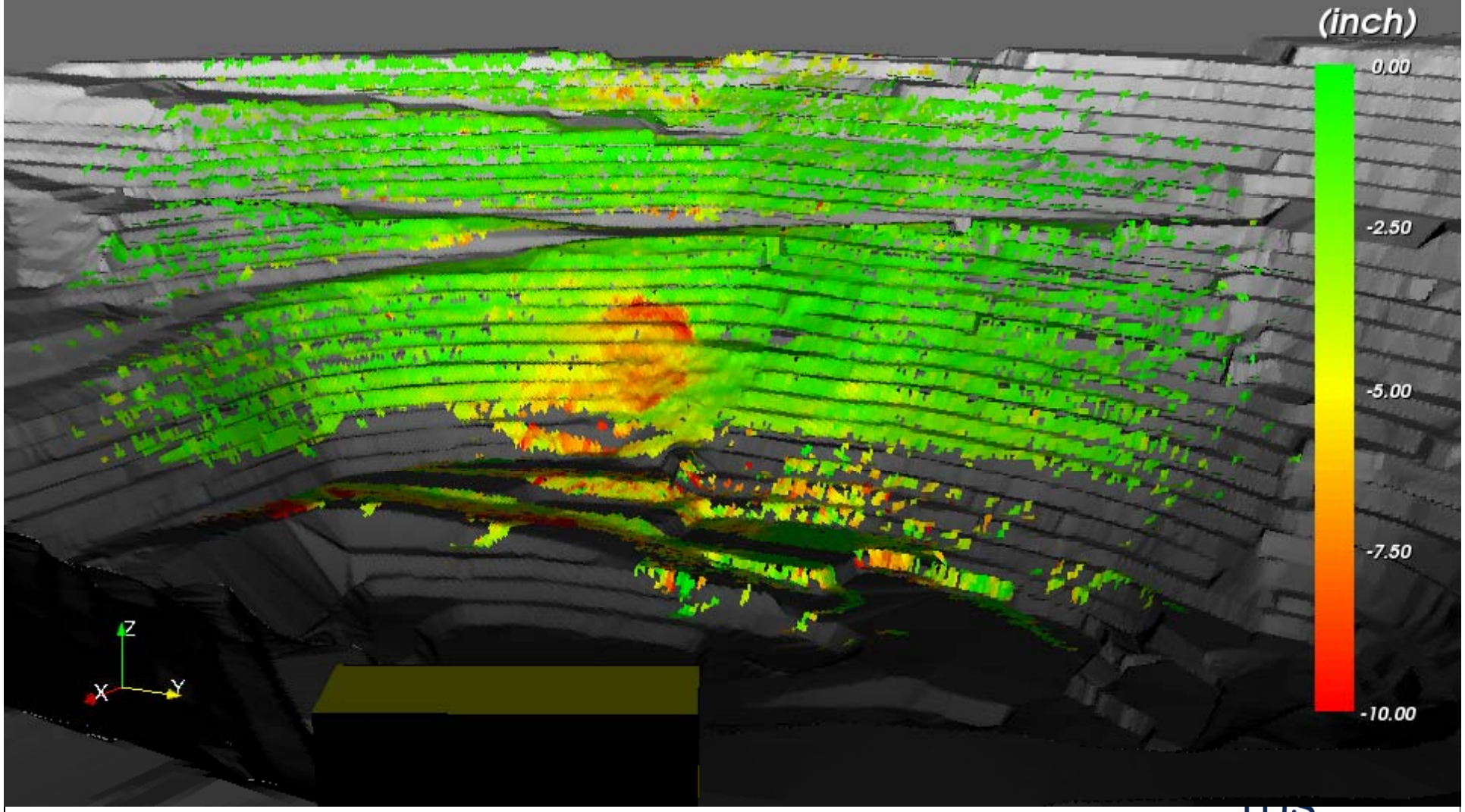
Start Time: 15:33 03/02/10
Stop Time: 13:14 13/08/10

Cumulative displacement from 03/02 to 13/08



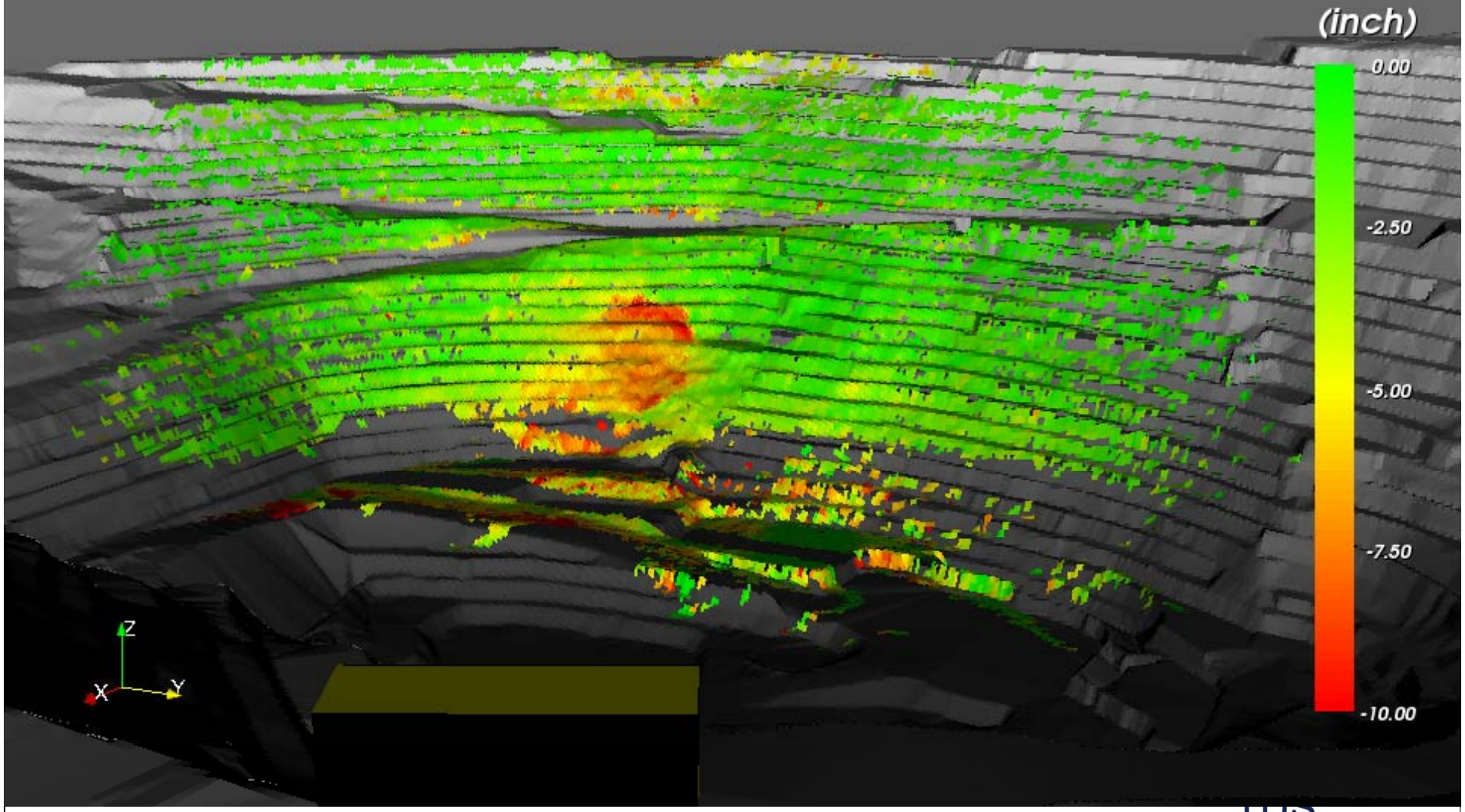
Start Time: 15:33 03/02/10
Stop Time: 15:20 27/08/10

Cumulative displacement from 03/02 to 27/08



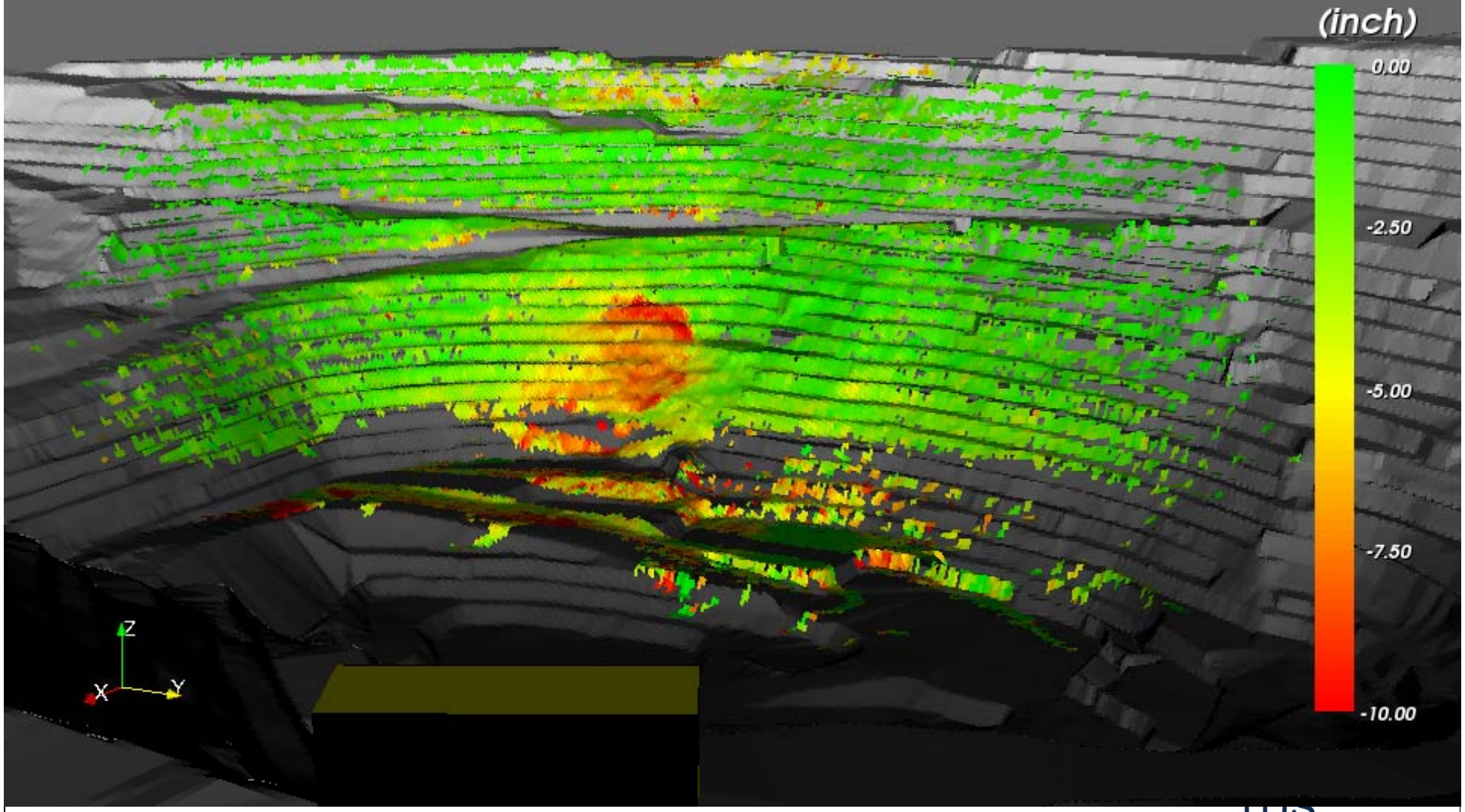
Start Time: 15:33 03/02/10
Stop Time: 10:53 10/09/10

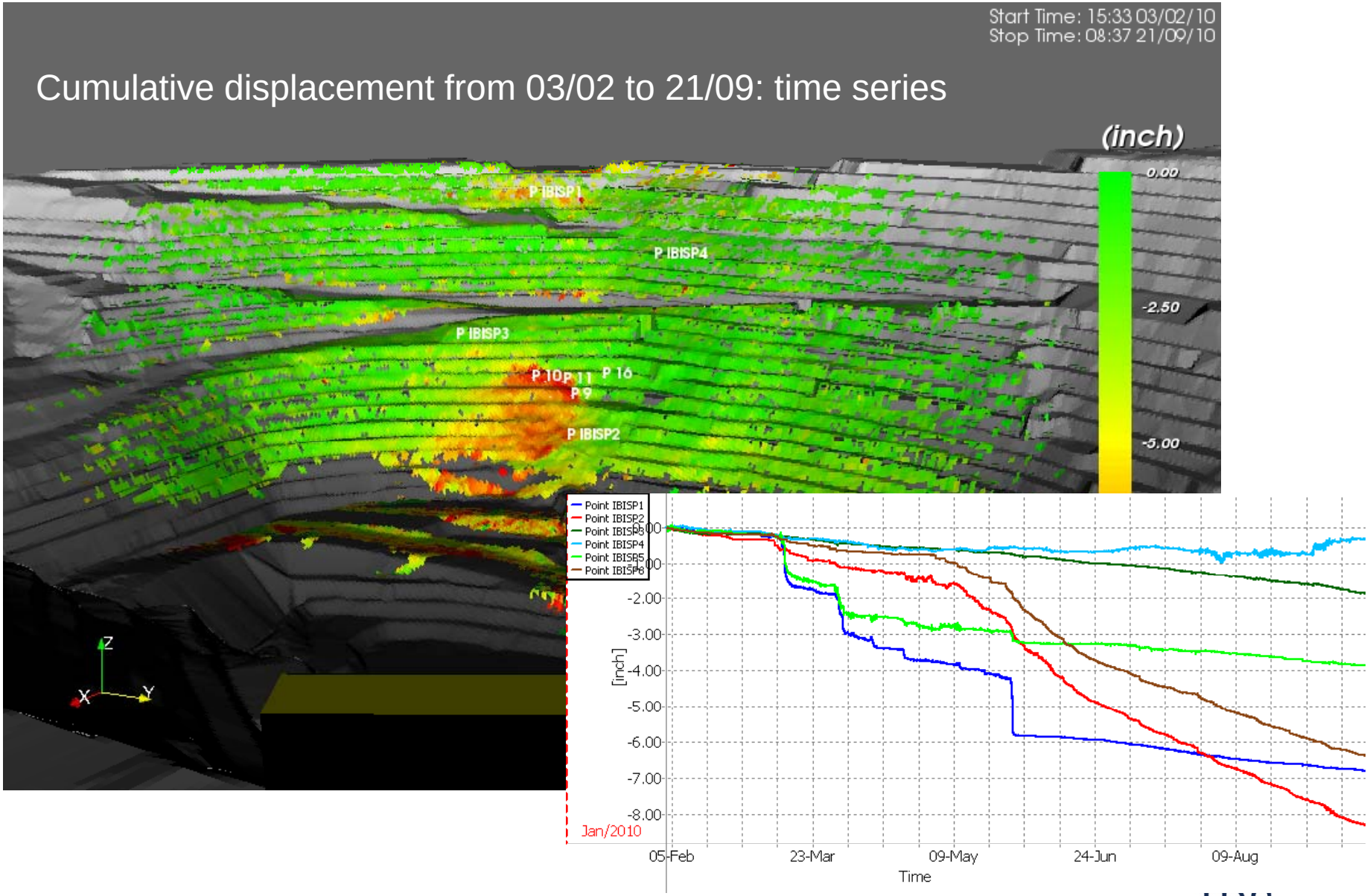
Cumulative displacement from 03/02 to 10/09

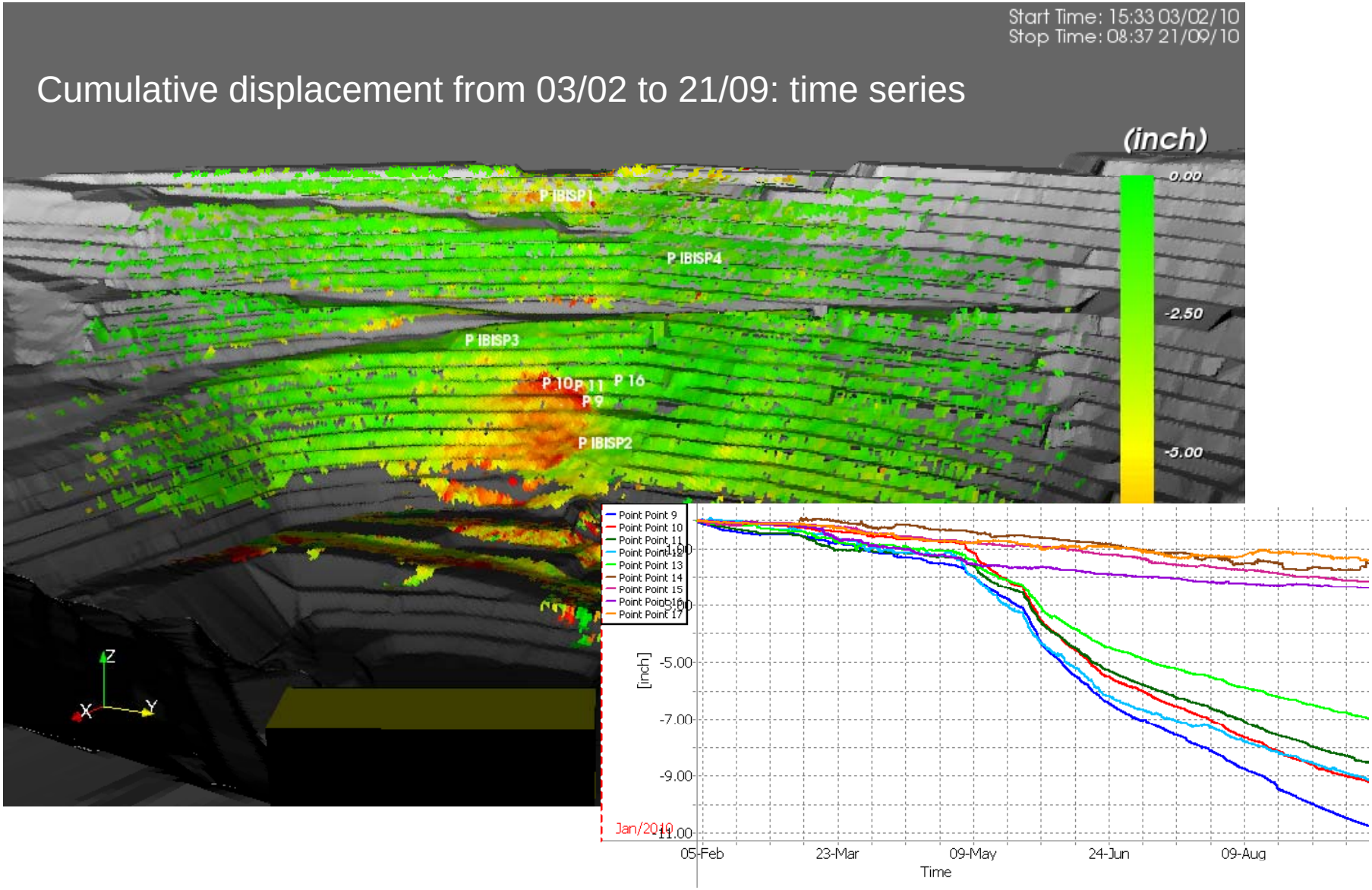


Start Time: 15:33 03/02/10
Stop Time: 08:37 21/09/10

Cumulative displacement from 03/02 to 21/09



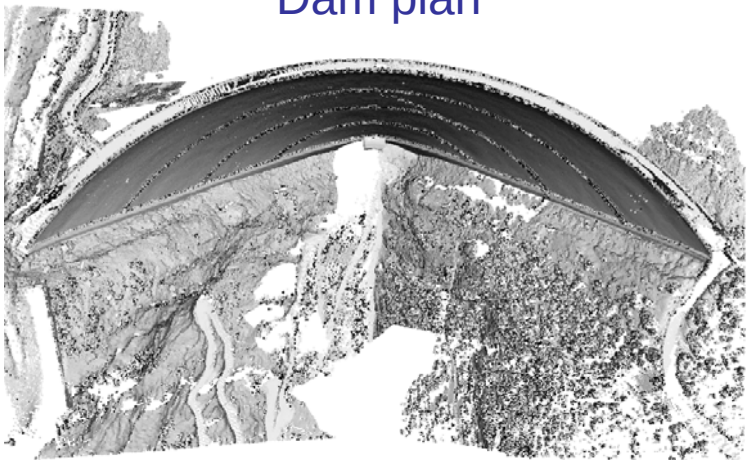

Start Time: 15:33 03/02/10
Stop Time: 08:37 21/09/10
Cumulative displacement from 03/02 to 21/09: time series
(inch)
0.00
-2.50
-5.00
P IBISP1
P IBISP4
P IBISP3
P 10
P 11
P 16
P 9
P IBISP2
Z
X
Y
Point IBISP1
Point IBISP2
Point IBISP3
Point IBISP4
Point IBISP5
Point IBISP6
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
[inch]
Jan/2010
05-Feb
23-Mar
09-May
24-Jun
09-Aug
Time


Start Time: 15:33 03/02/10
Stop Time: 08:37 21/09/10
Cumulative displacement from 03/02 to 21/09: time series
(inch)
0.00
-2.50
-5.00
P IBISP1
P IBISP4
P IBISP3
P 10
P 11
P 16
P 9
P IBISP2
Z
X
Y
Point Point 9
Point Point 10
Point Point 11
Point Point 12
Point Point 13
Point Point 14
Point Point 15
Point Point 16
Point Point 17
[inch]
-1.00
-3.00
-5.00
-7.00
-9.00
-11.00
Jan/2010
05-Feb
23-Mar
09-May
24-Jun
09-Aug
Time

IBIS-L: monitoraggio dighe

Cancano Dam view

Dam plan



Dam characteristics	
Dam Type	Gravity arch
Location	Alpi Retiche - Italy
Dam height (m)	125.5
Crowing length (m)	381

Survey performed with the Surveying Dept. of Milan Polytechnic

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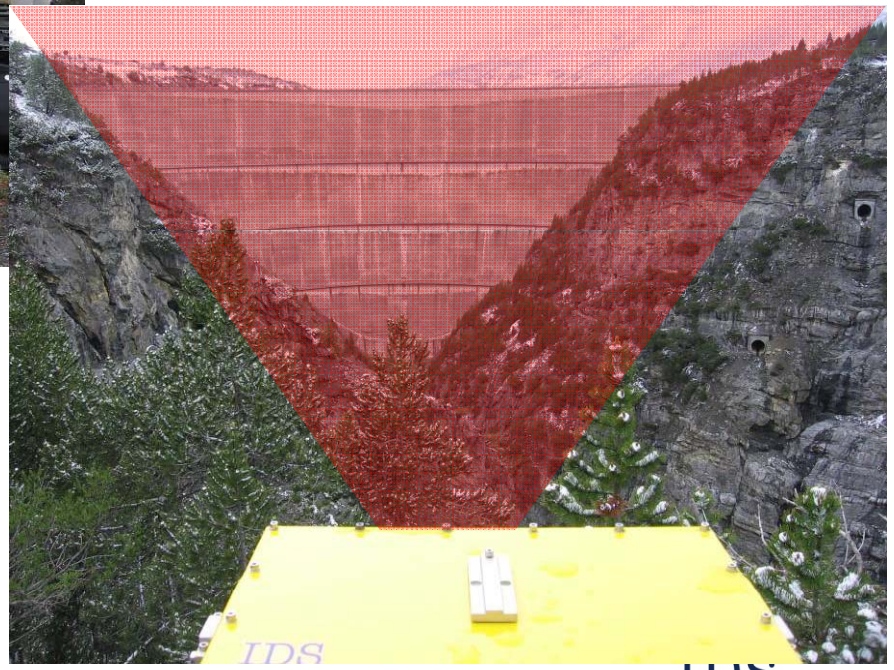
IBIS-L: monitoraggio dighe



IBIS-L configuration

- Dam-sensor distance: 400m
- Range resolution: 0.5m
- Angle resolution: 4.7mrad
- Sampling interval: ca. 9 minutes

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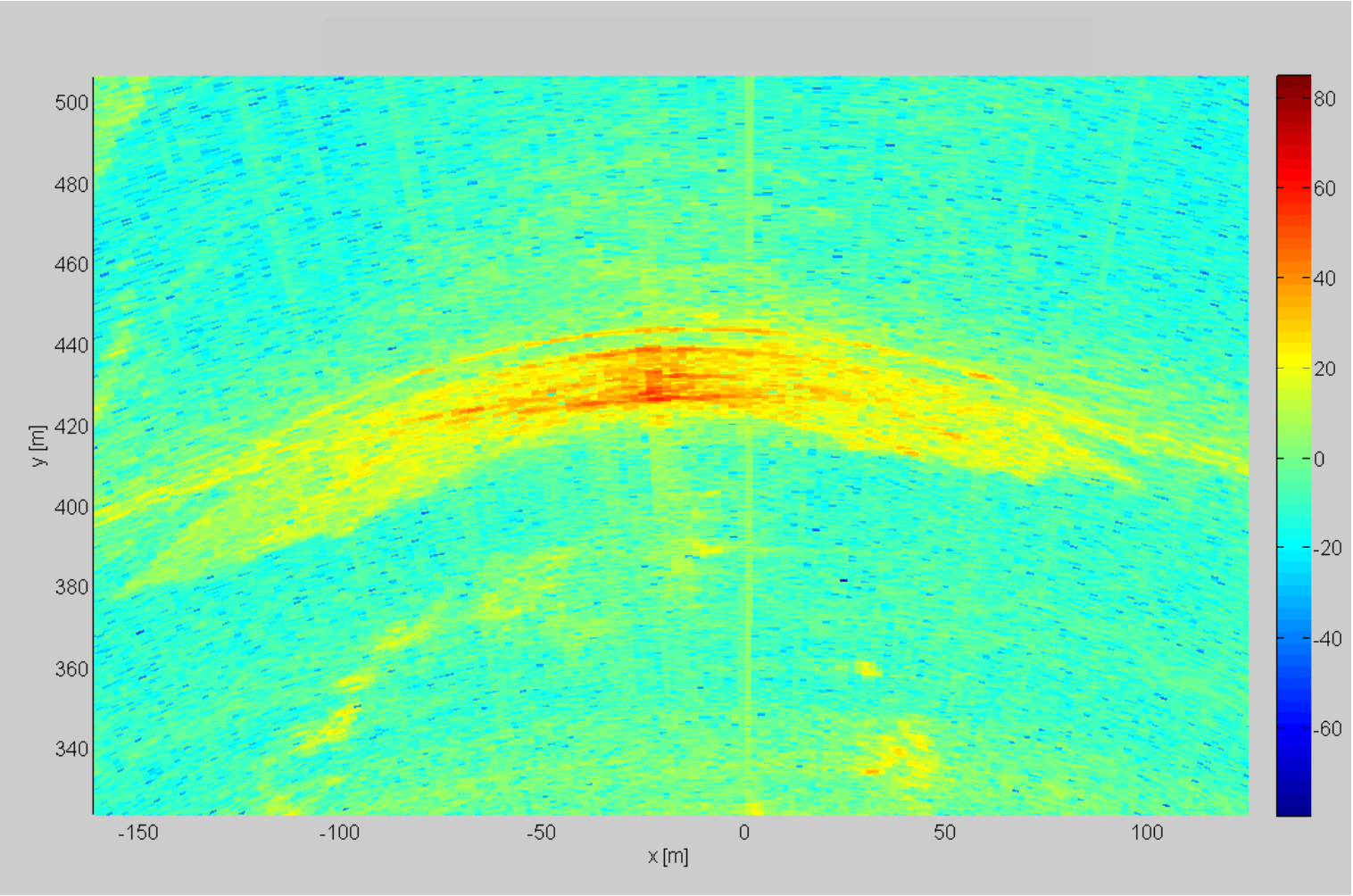
IBIS-L: monitoraggio dighe

Zoom on dam area



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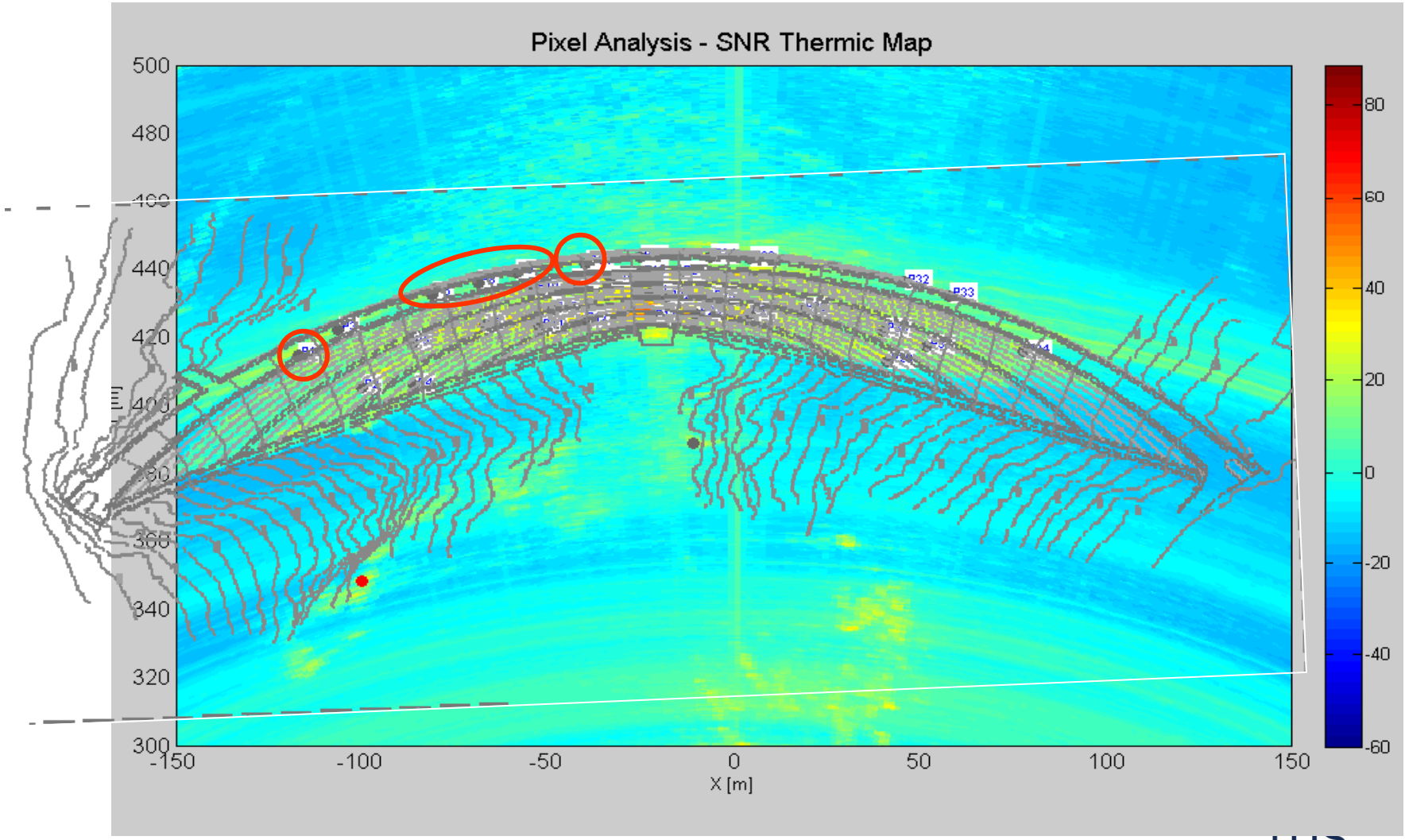
IBIS-L: monitoraggio dighe

Dam Power map projected over plan



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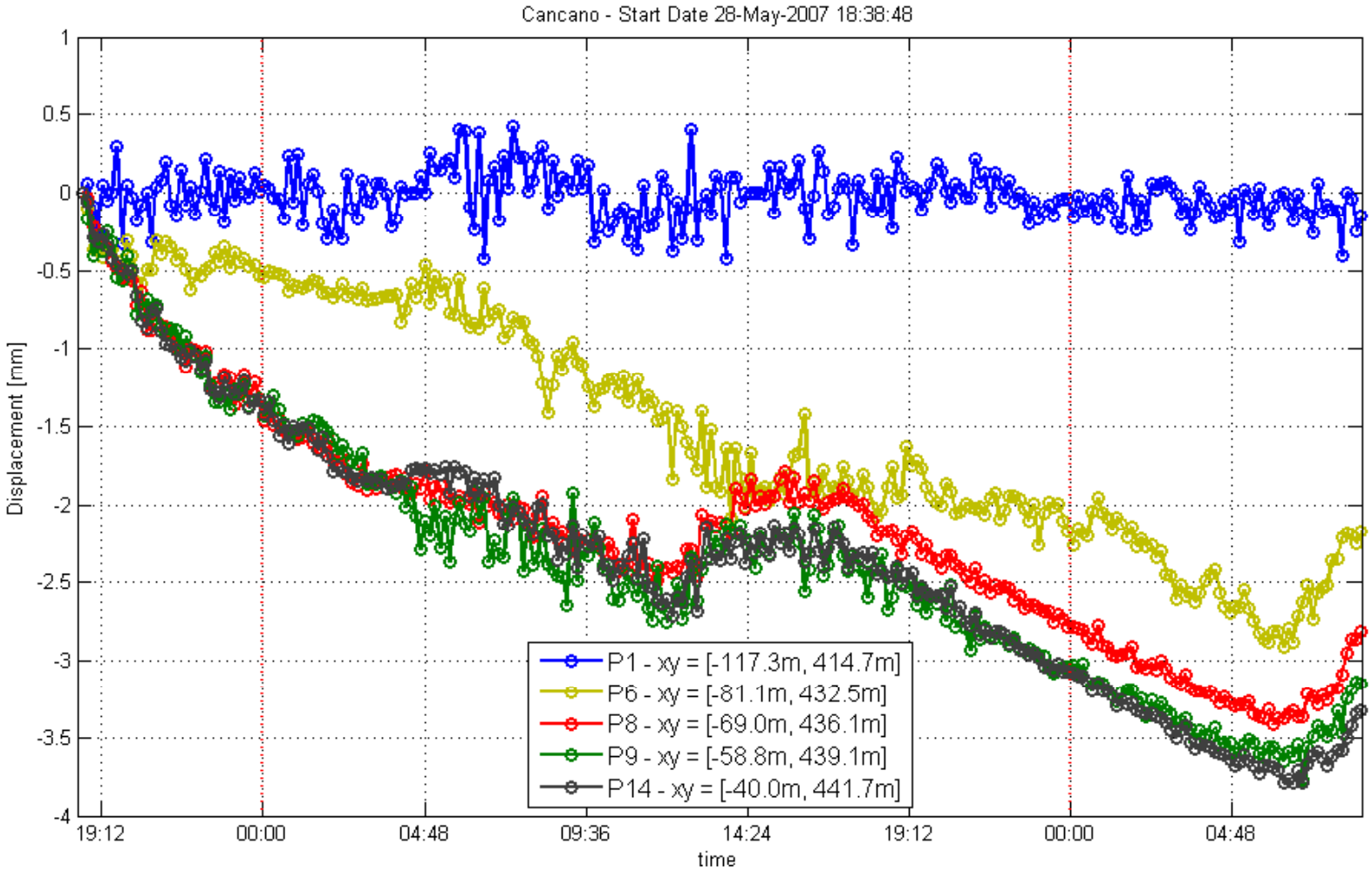
IBIS-L: monitoraggio dighe

Selected pixel L.O.S. displacement – 5 pixel belonging to the dam crown



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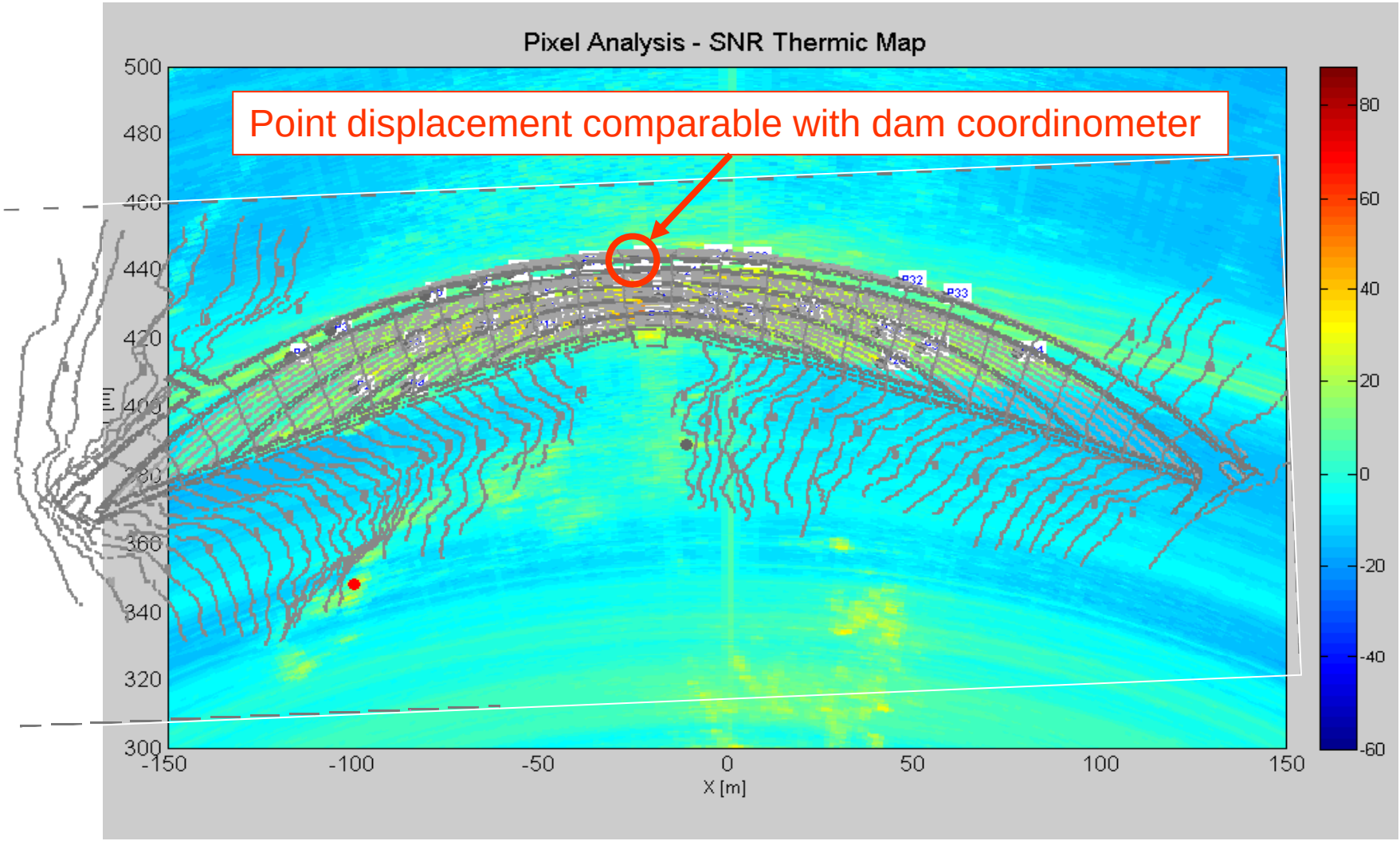
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio dighe



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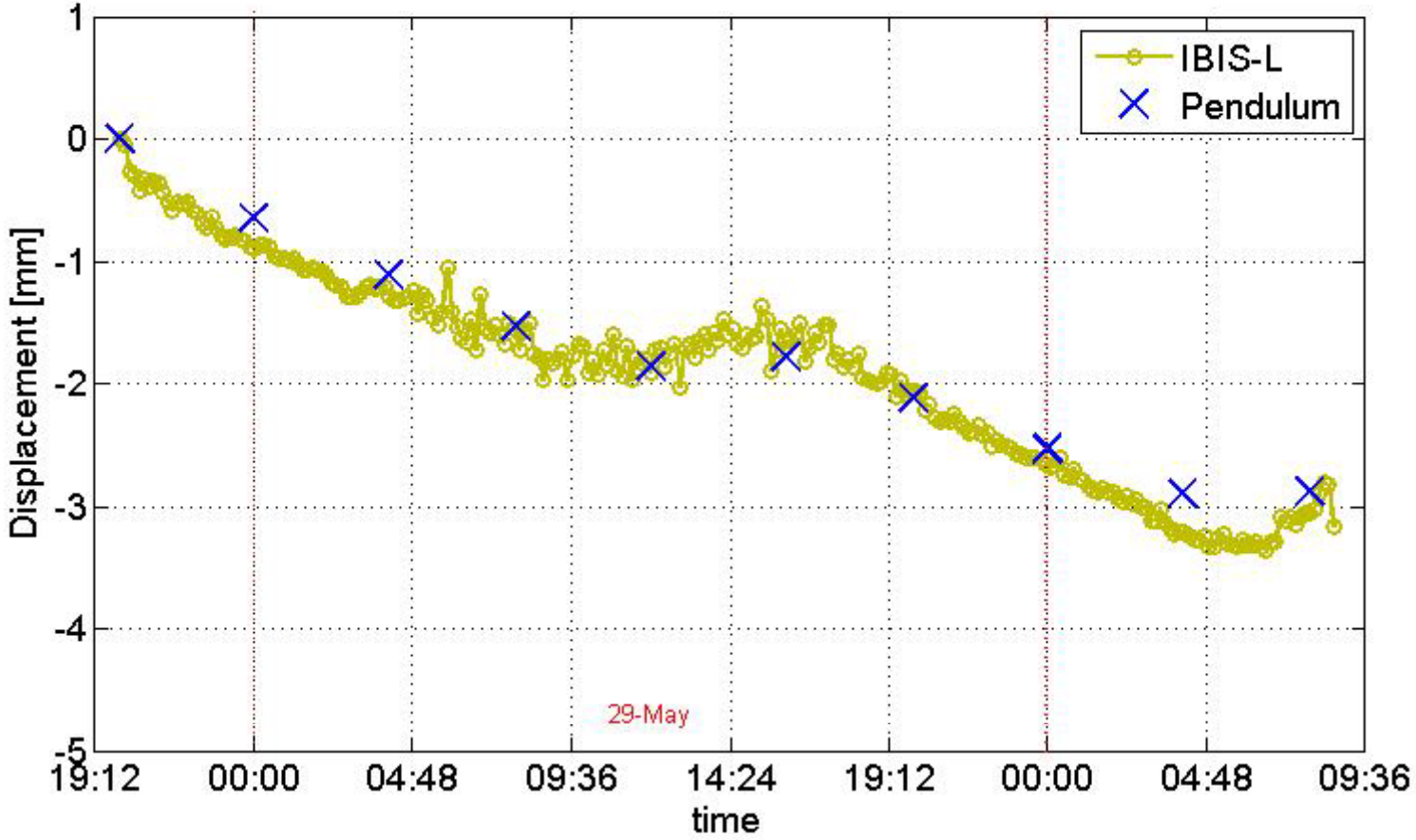
IDS INGEGNERIA DEI SISTEMI

IBIS-L: monitoraggio dighe

Crowining point displacement comparison between IBIS-L and coordinometer measure



IBIS-L sampling interval: 9min
Pendulum sampling interval: 4hours

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IDS INGEGNERIA DEI SISTEMI

IBIS-S: collaudi statici di ponti

Viaducts crossing Forlanini Avenue (Milan, Italy)

Bridge beams are good reflecting points

Static monitoring of a new bridge:

Determination of displacement of the bridge during a static load test

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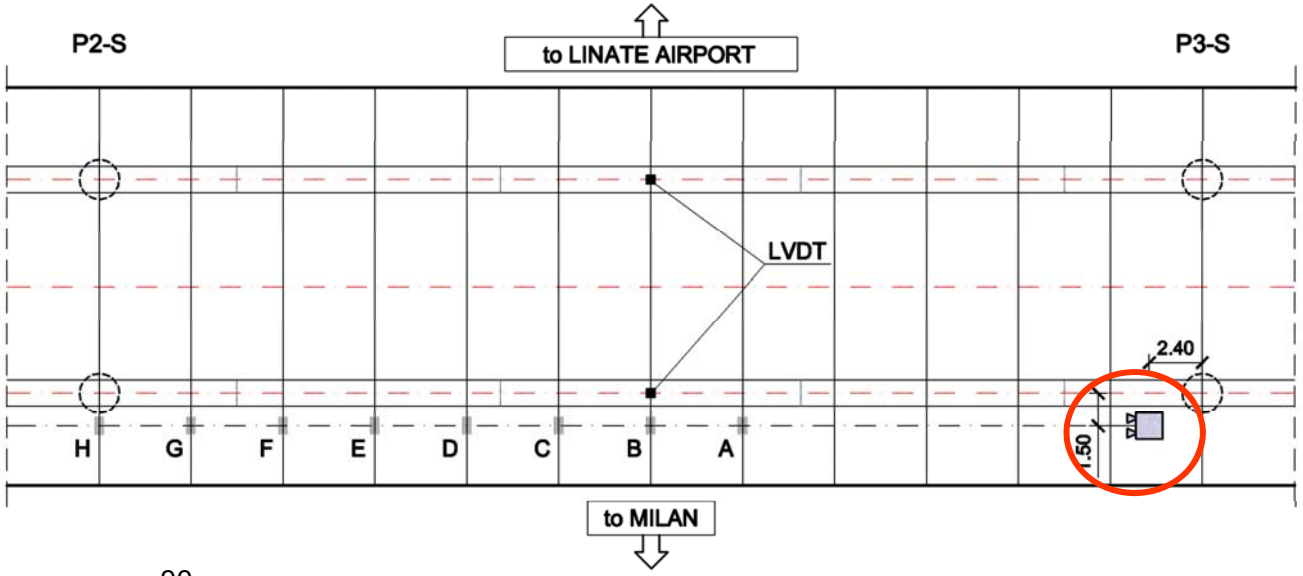
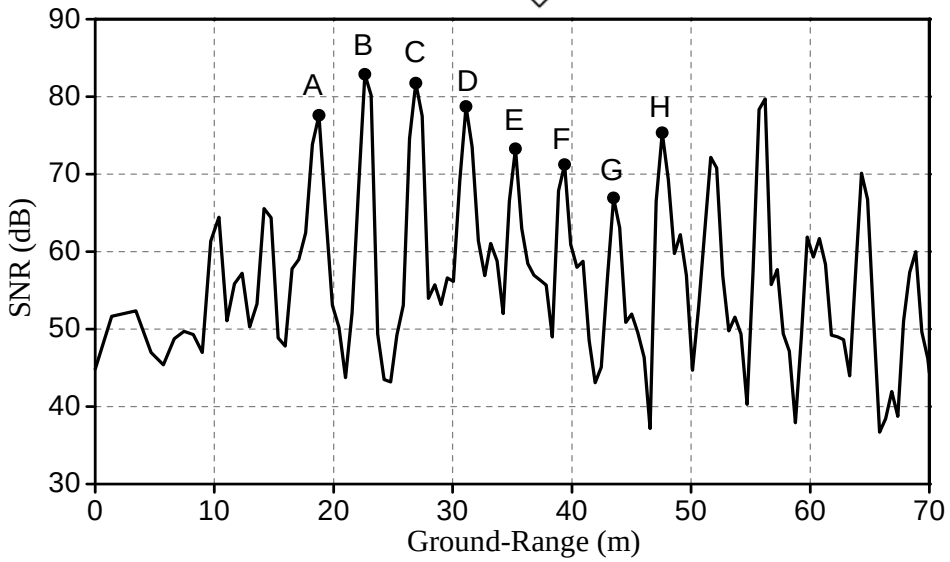
IBIS-S: collaudi statici di ponti





IBIS-S installation

Range profile of P2-S – P3-S span

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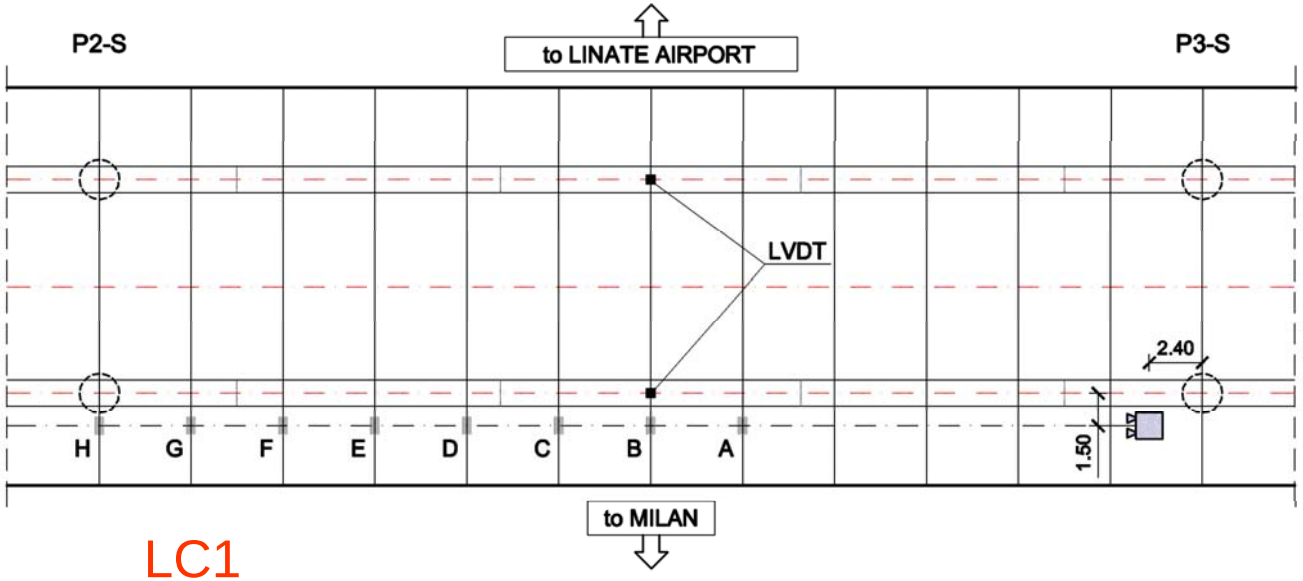
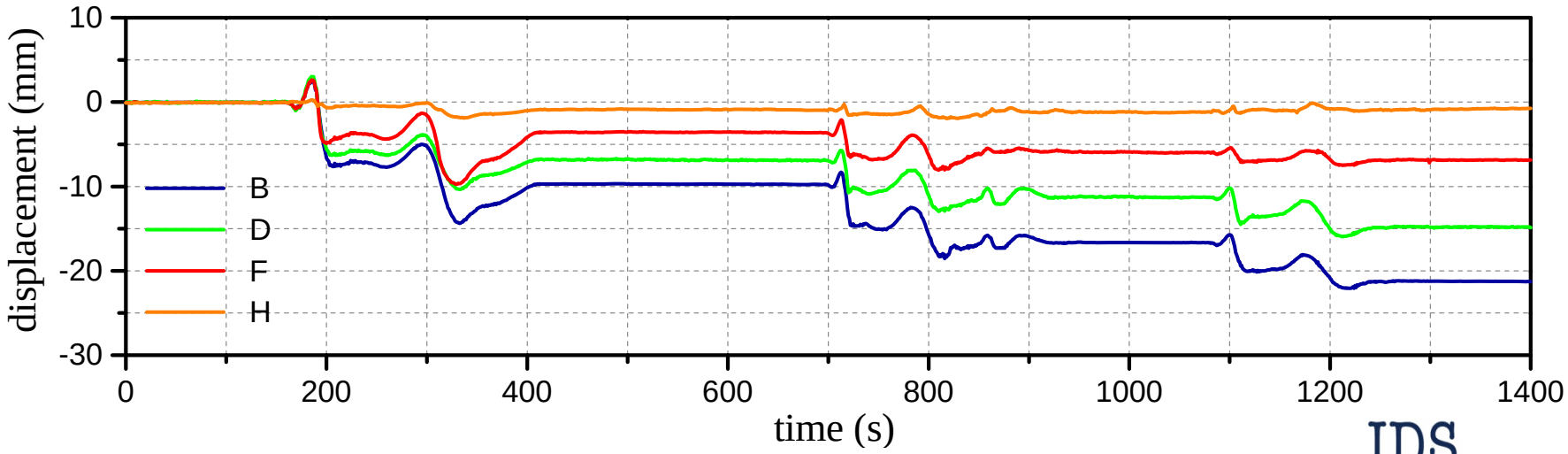
IBIS-S: collaudi statici di ponti



LC1

LVDT



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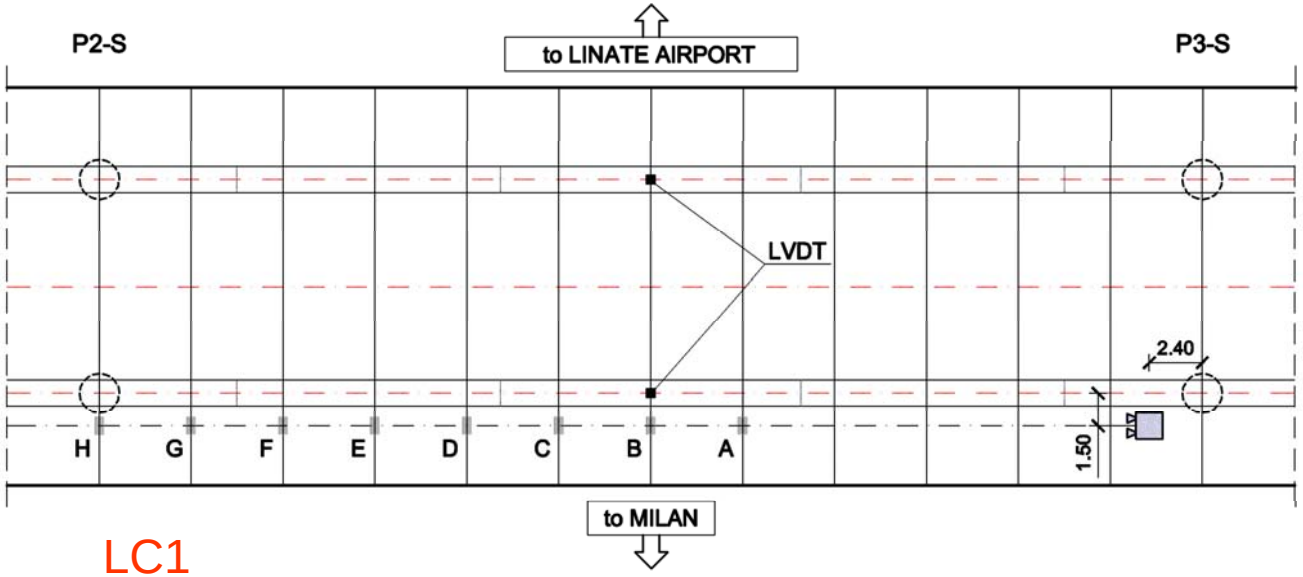
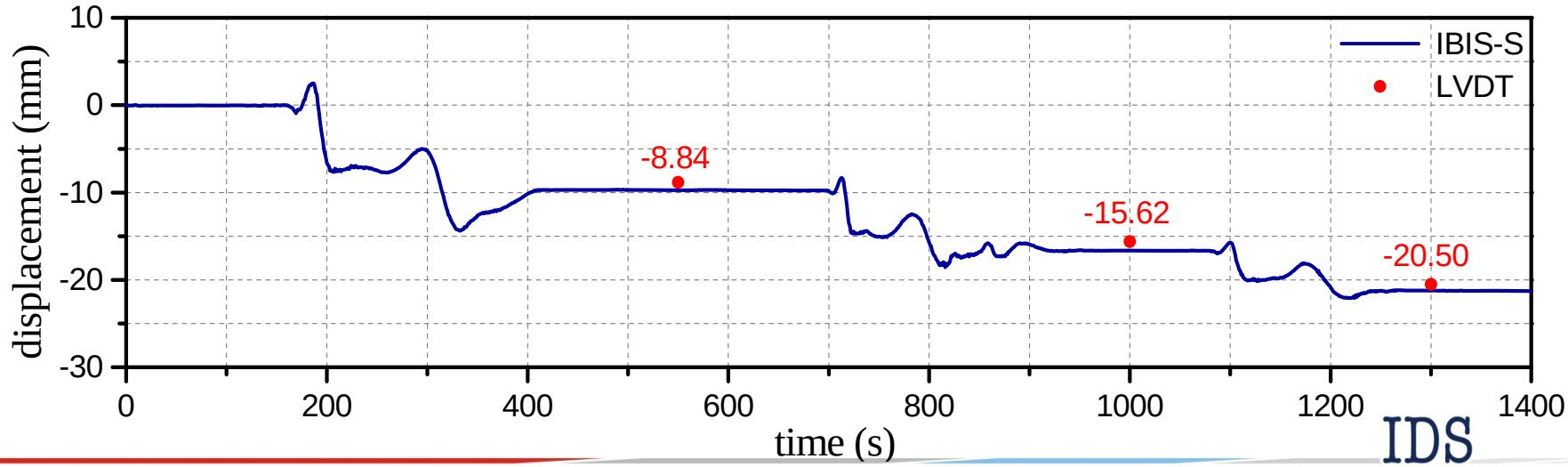
IBIS-S: collaudi statici di ponti



LC1

LVDT



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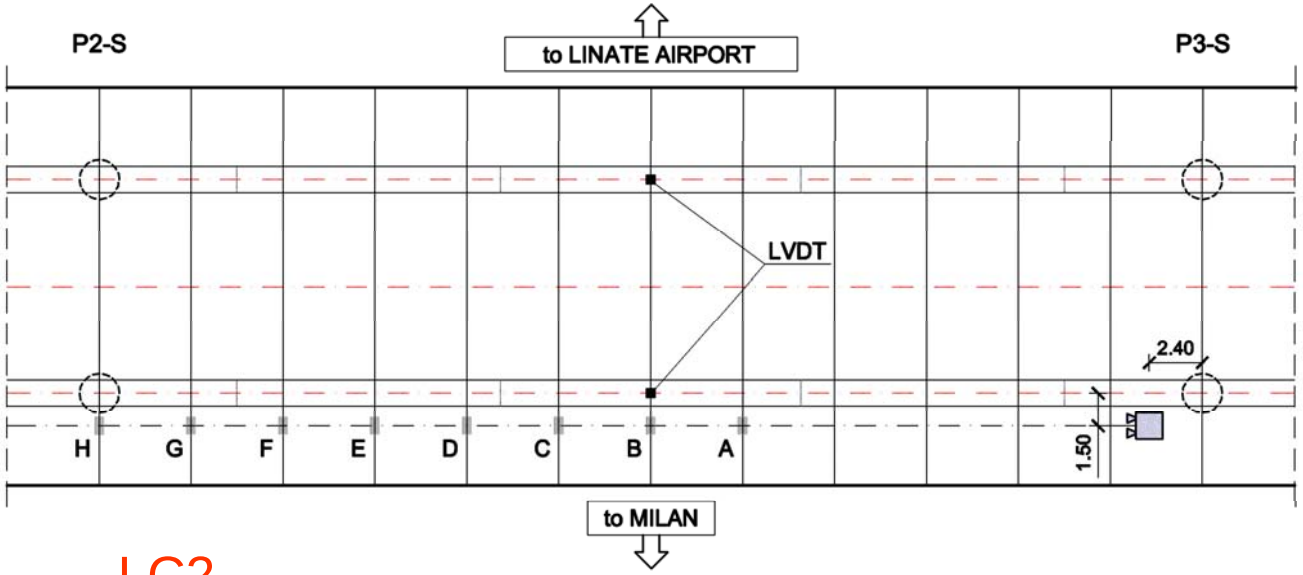
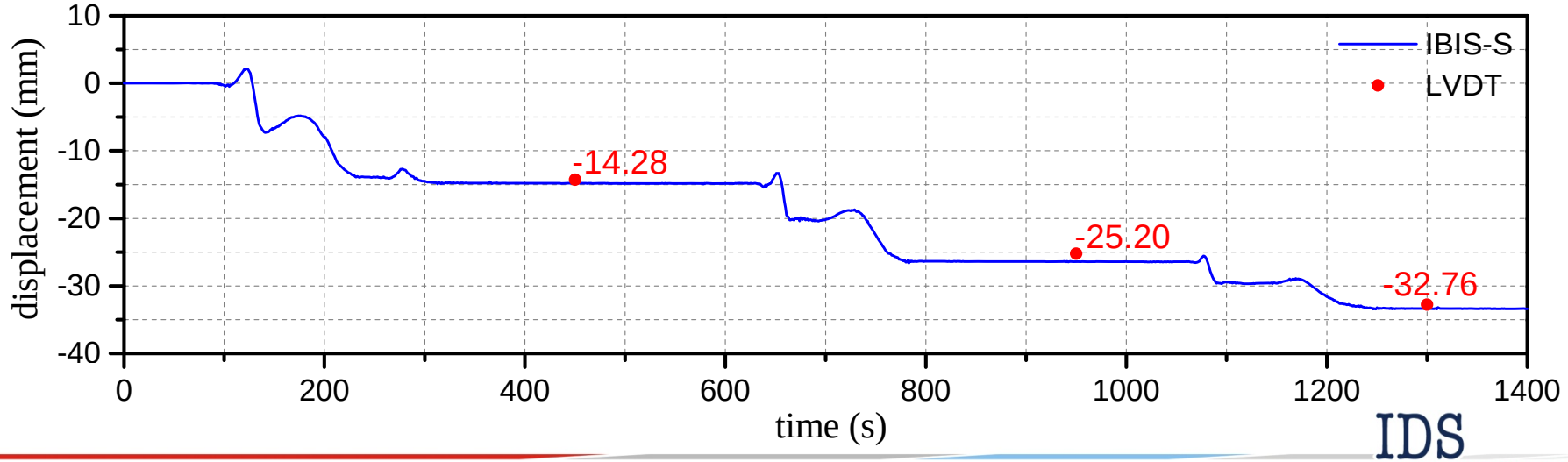
IDS INGEGNERIA DEI SISTEMI

IBIS-S: collaudi statici di ponti



LC2

LVDT



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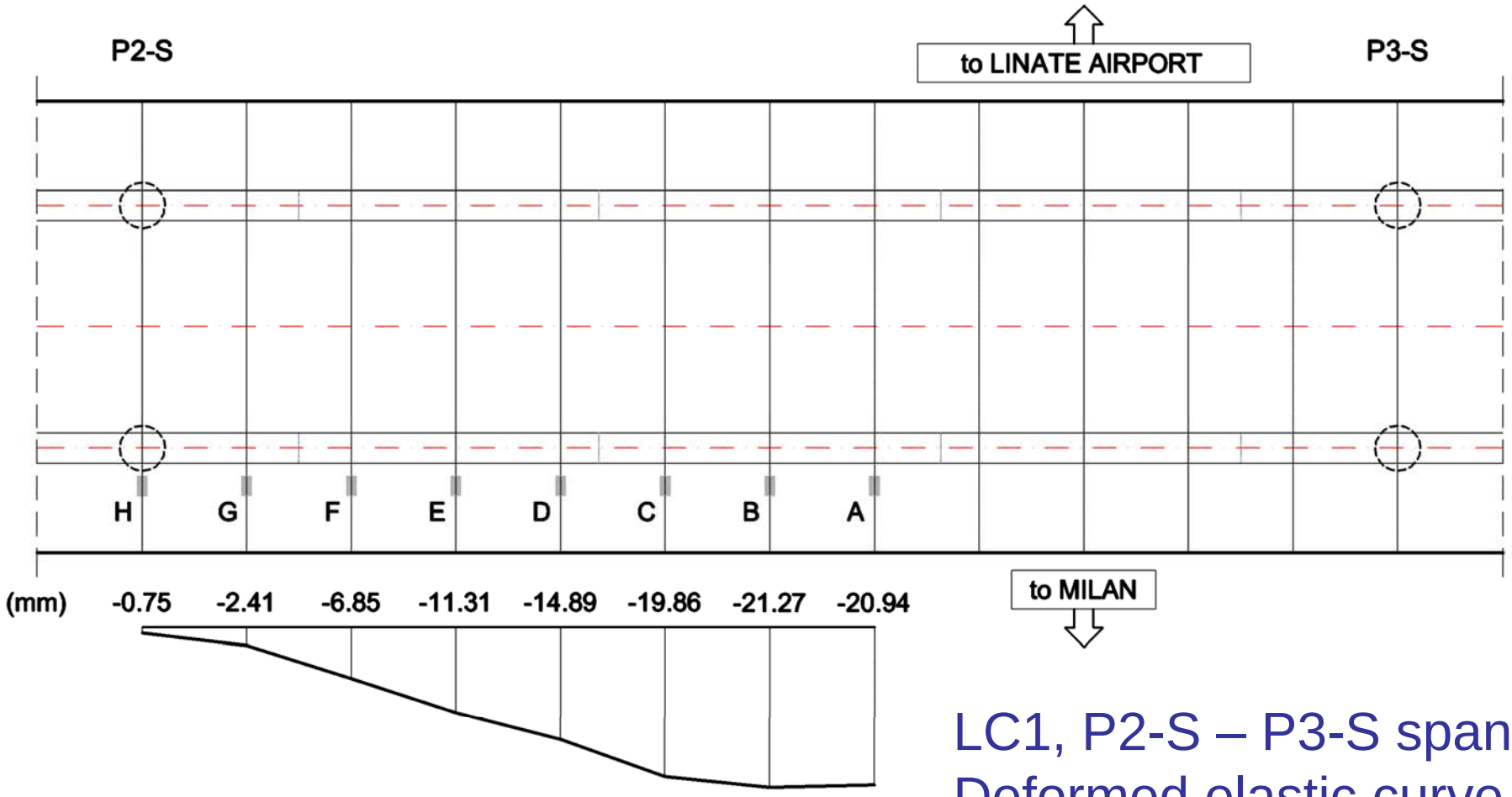
IBIS-S: collaudi statici di ponti



LC1, P2-S – P3-S span: Deformed elastic curve provided by IBIS-S

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NUOVE TECNOLOGIE RADAR

COLLAUDO. MONITORAGGIO E INDAGINI NON INVASIVE PER MANUFATTI

POLITECNICO DI MILANO

IDS INGEGNERIA DEI SISTEMI S.p.A.

Vibration Measurement by Radar Techniques: a Review

Carmelo Gentile

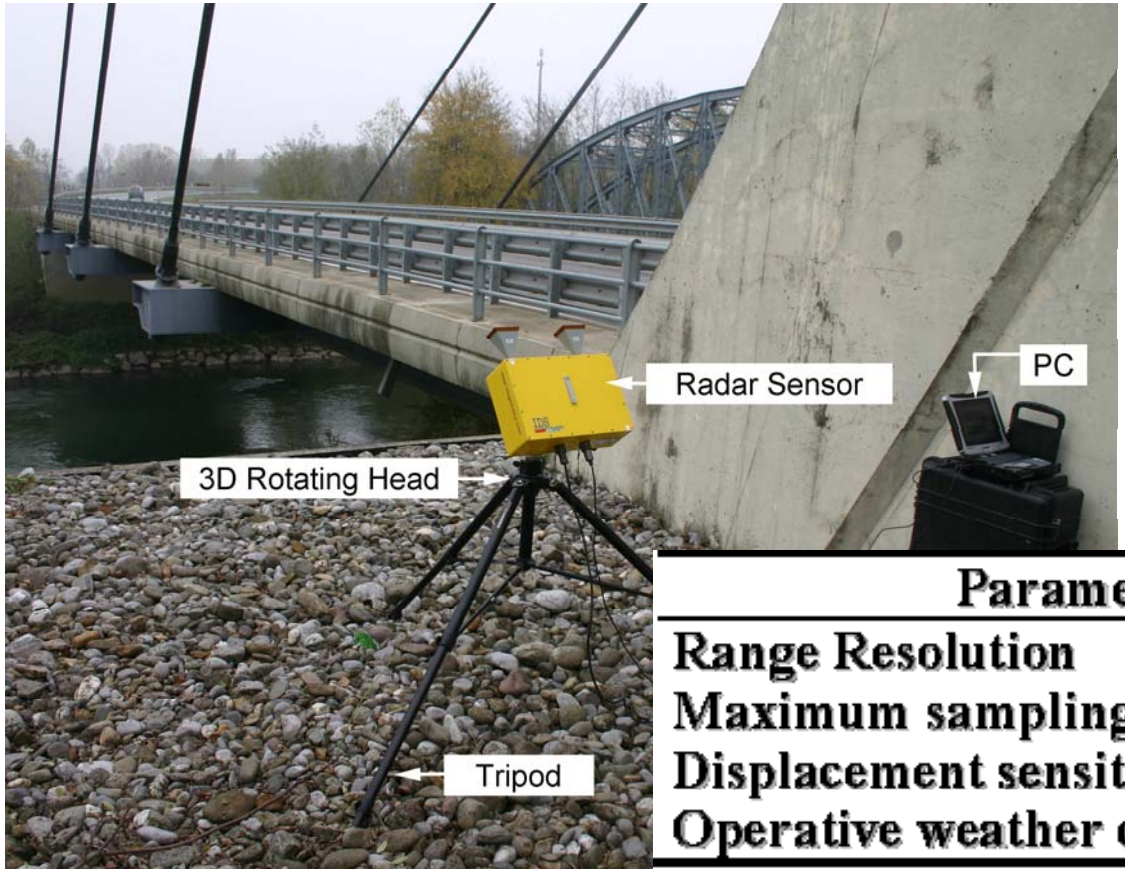
Politecnico di Milano, Dept. of Structural Engineering

OUTLINE

- **The Radar-based measurement technique**
  - Technical characteristics of the radar sensor
  - Background of radar techniques
  - Potential issues
- **Laboratory test**
- **On-site test**
- **Dynamic test (AVT) of a r.c. bridge**
- **Dynamic (AVT) of a steel-composite bridge**
- **Dynamic measurement on stay cables**
  - Cable-stayed bridge over the Oglio river
  - Cable-stayed bridge over the Adda river
  - Cable-stayed bridge in Porto Marghera
- **Dynamic test of Muge guyed mast**

Description of the radar sensor

Industrially engineered microwave interferometer, designed for the non contact measurement of displacement time-histories on civil engineering structures



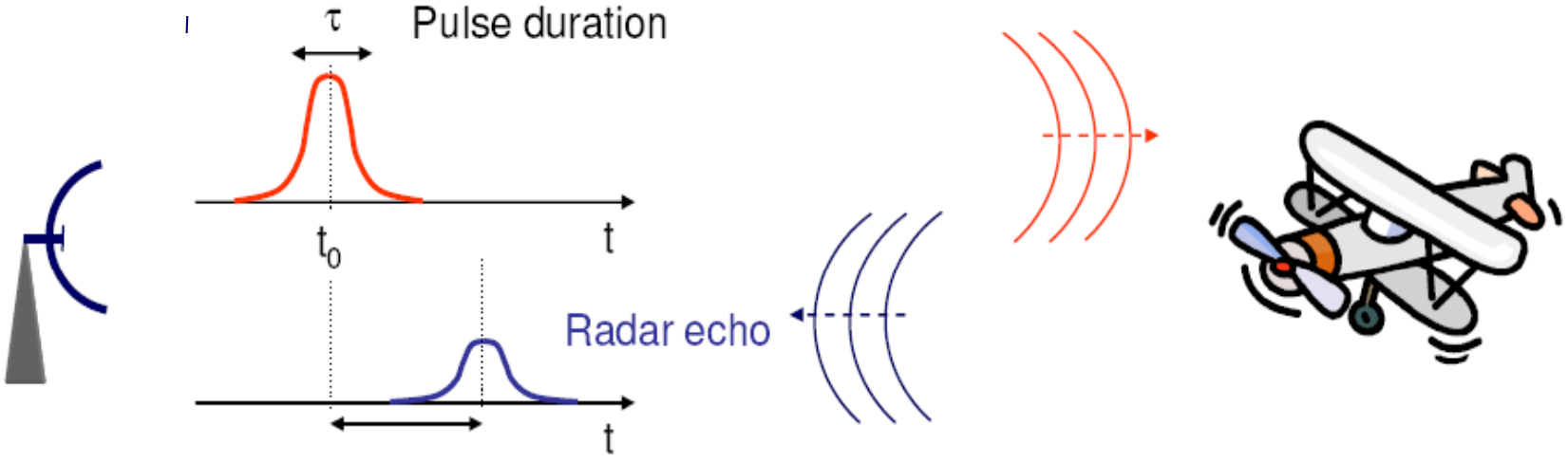
IBIS-S:
Image By Interferometric Survey of Structures

Parameter	
Range Resolution	0.50 m
Maximum sampling frequency	200.00 Hz
Displacement sensitivity	0.02 mn
Operative weather condition	All

Background of radar techniques (1)

RADAR = RAdio Detection And Ranging

The most peculiar and important characteristic of a conventional radar is its ability to determine the range (i.e. the distance) by measuring the time for the radar signal to propagate to the target and back

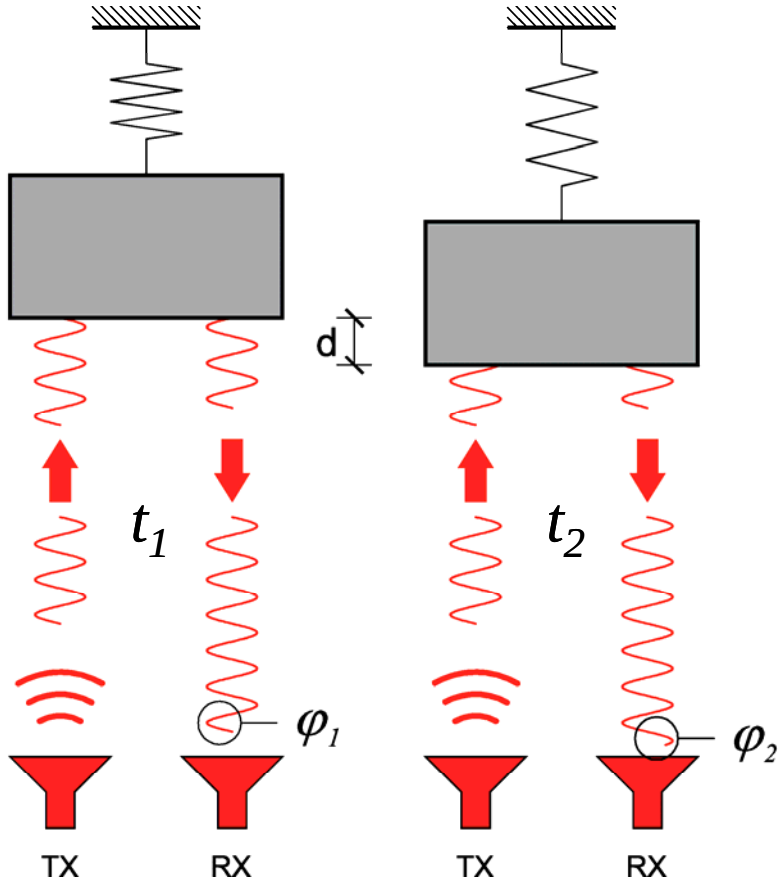


T_0 → $R_0 = \frac{c \cdot T_0}{2}$

Background of radar techniques (2)

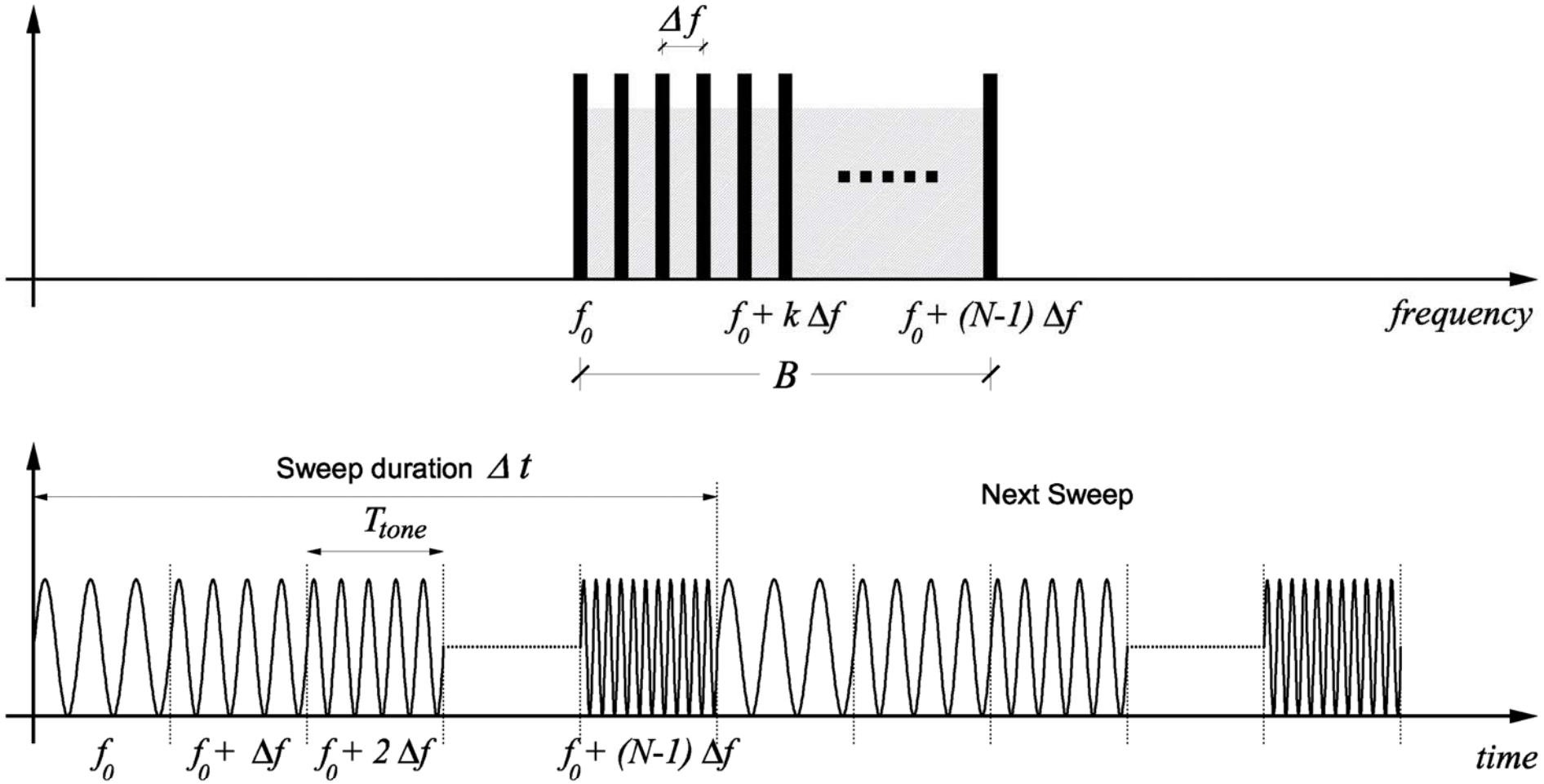
MICROWAVE INTERFEROMETRY

$$d = -\frac{\lambda}{4\pi}(\varphi_2 - \varphi_1)$$



Background of radar techniques (3)

STEPPED FREQUENCY CONTINUOUS WAVEFORM



Background of radar techniques (4)

Main ideas of the microwave-based measurement of deflections:

a) to employ a radar to take coherent and consecutive ***images*** of the investigated structure, with each image being a distance map of the intensity of radar echoes coming from the reflecting targets detected on the structure;

b) to compute the displacement of each target from the phase difference between two consecutive images (the phase difference is proportional to the displacement)

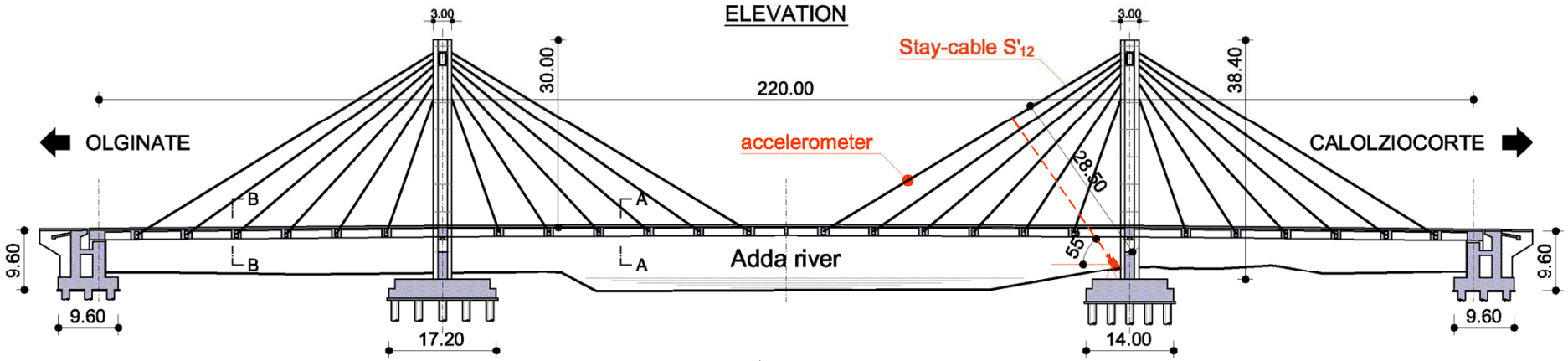
Main information simultaneously provided by the radar technique:

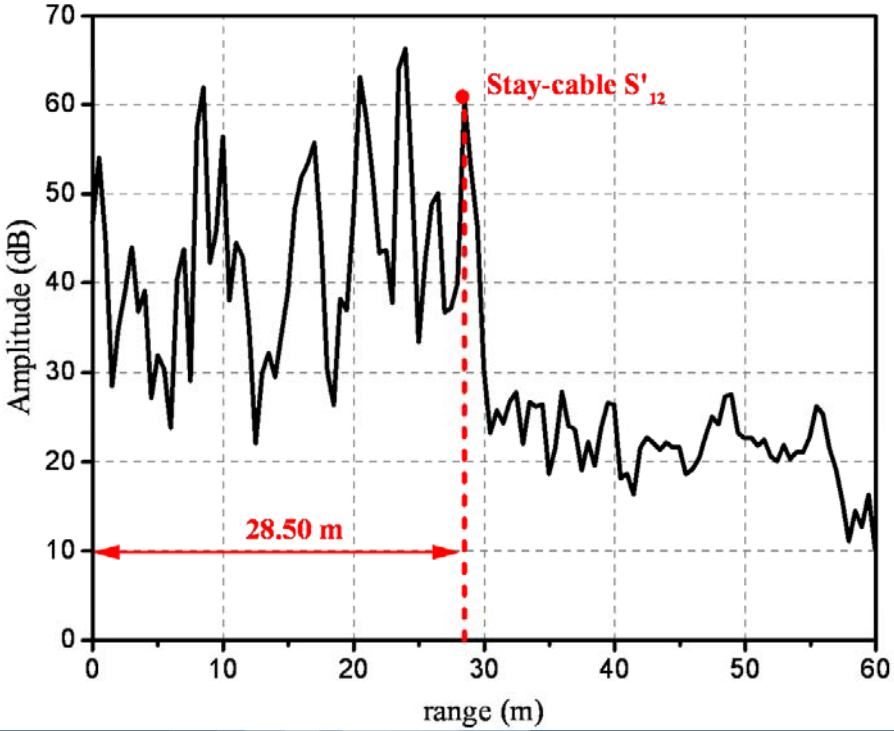
Position and displacement of the target points, placed at different distances from the radar, that are characterized by a good electromagnetic reflectivity

Potential issues:

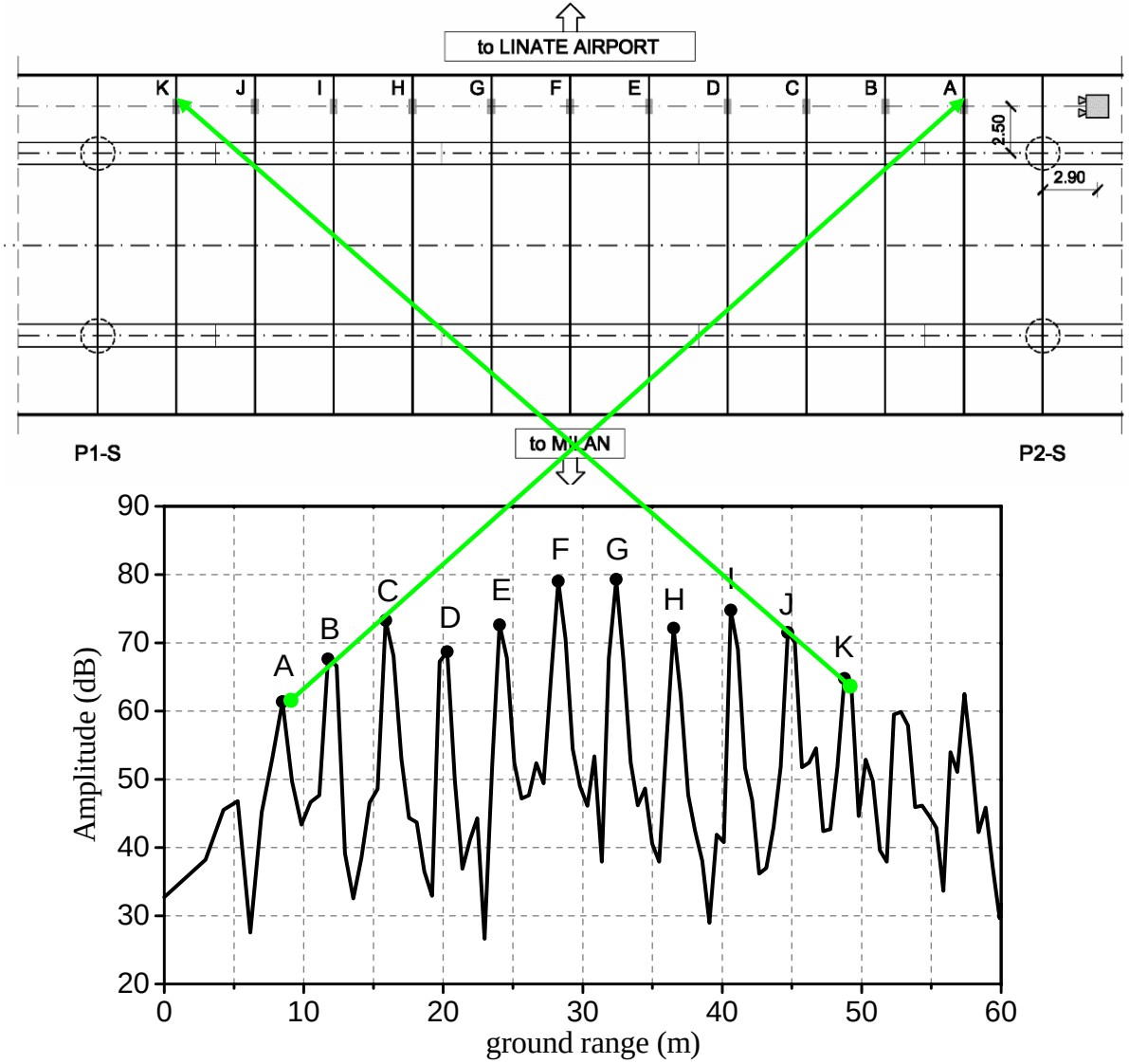
1D imaging, Displacement in line-of-sight only

Background of radar techniques (5)

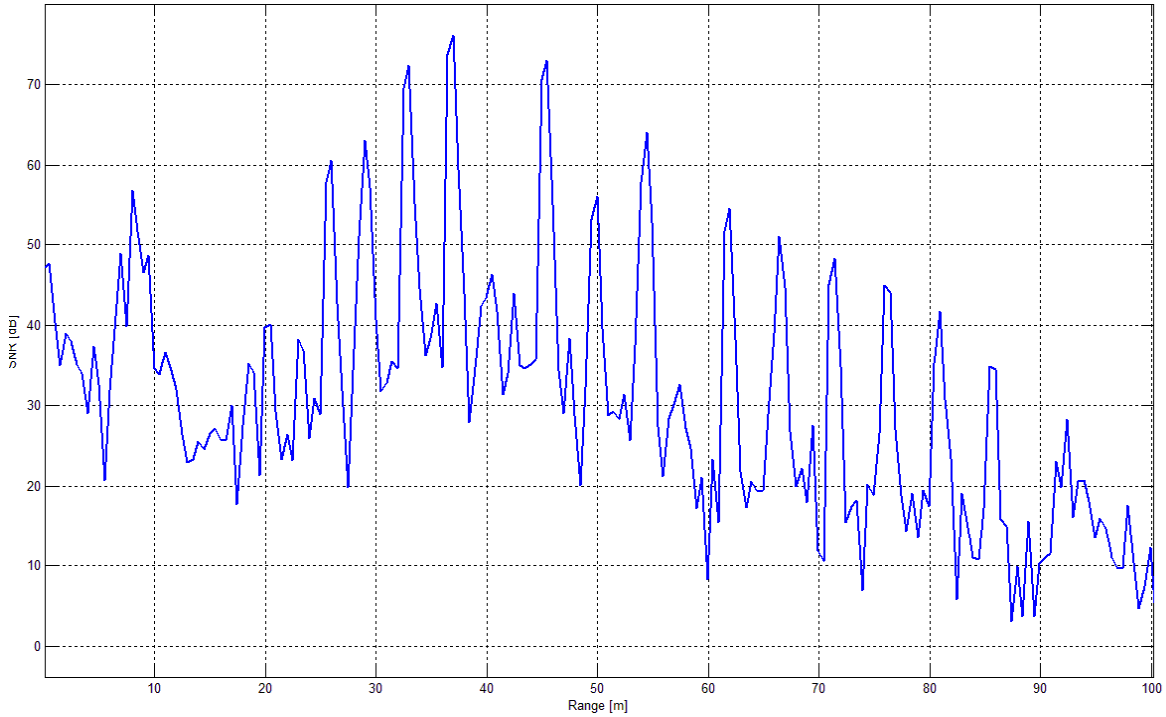




Background of radar techniques (6)



Background of radar techniques (7)



Potential issues (1)

Stepped Frequency – Continuous Wave

⇓⇓⇓

SF-CW radar cannot distinguish two targets having the same distance from the equipment

⇓⇓⇓

Careful positioning of the sensor

Potential issues (2)

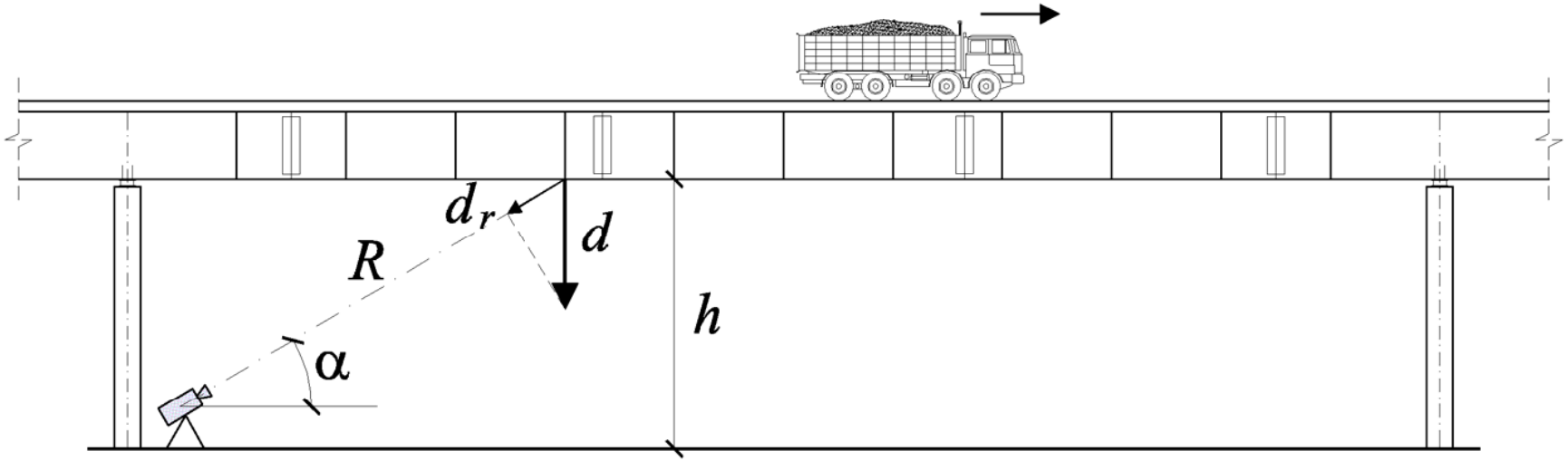
Interferometry

⇓ ⇓ ⇓

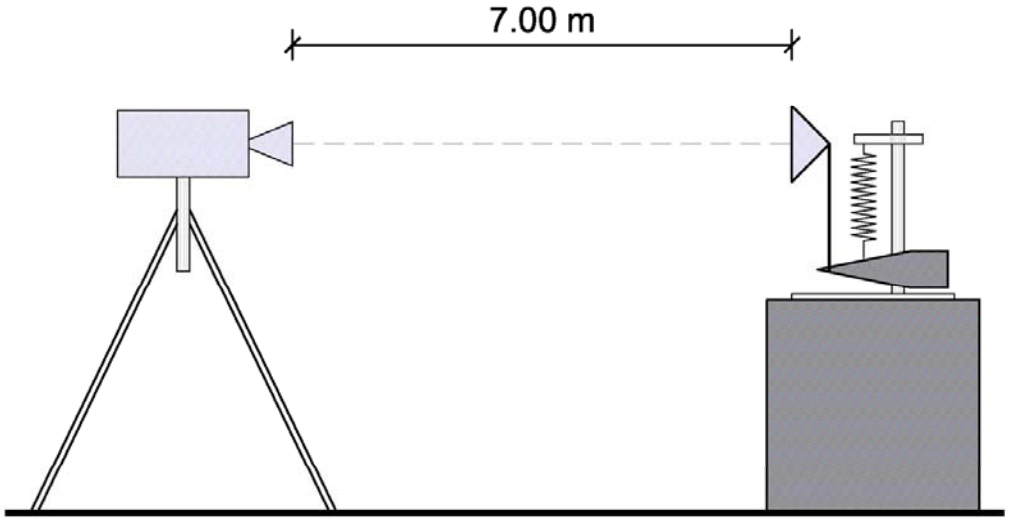
Interferometry provides the radial displacement

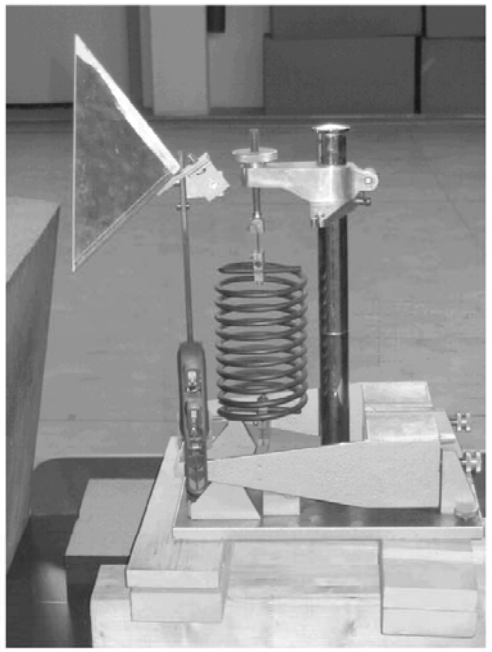
⇓ ⇓ ⇓

The evaluation of actual displacements requires the knowledge of the direction of motion

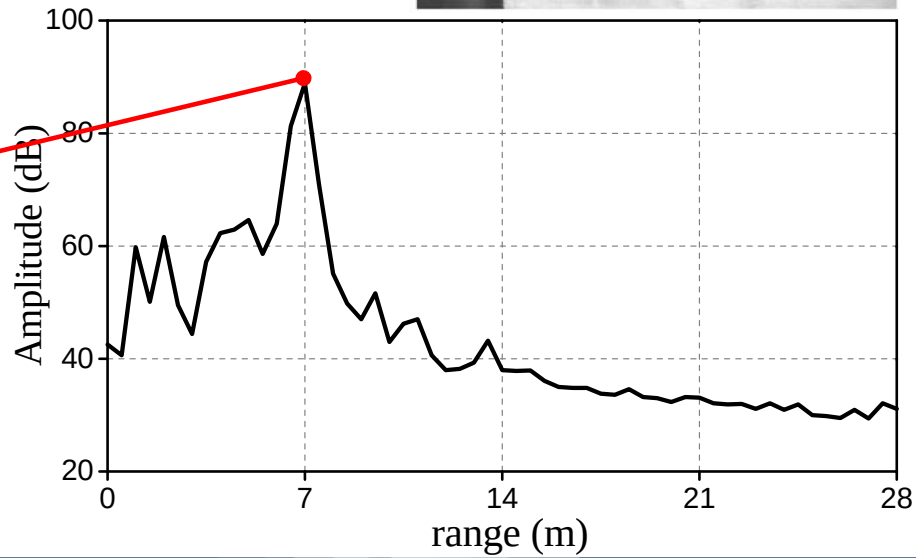


Laboratory test (1)

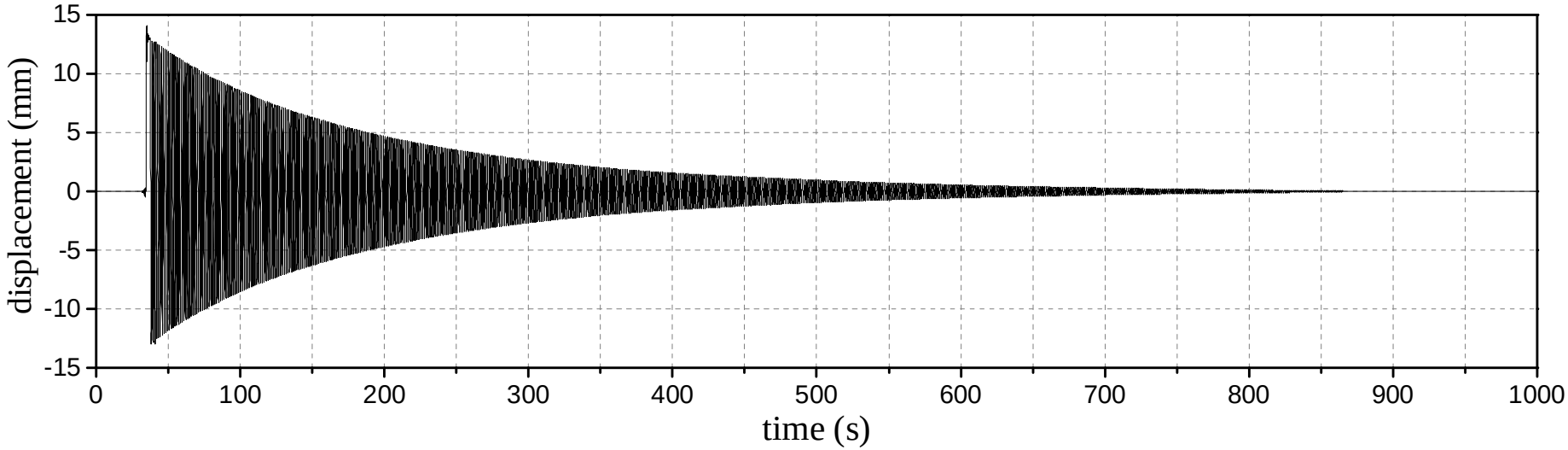


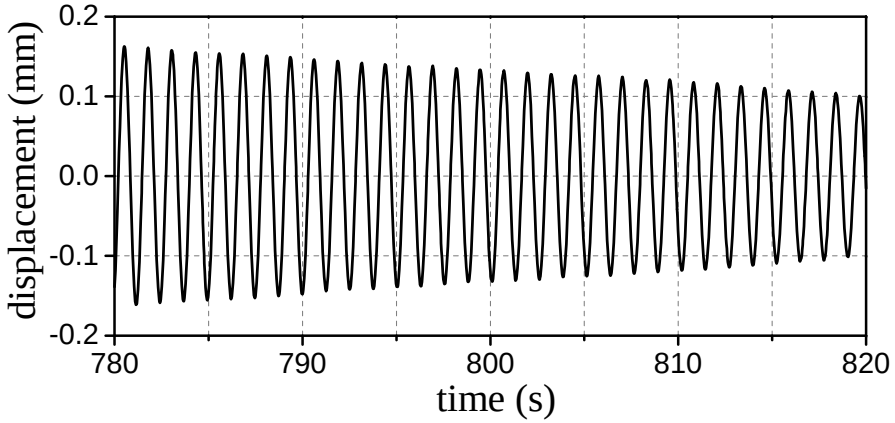


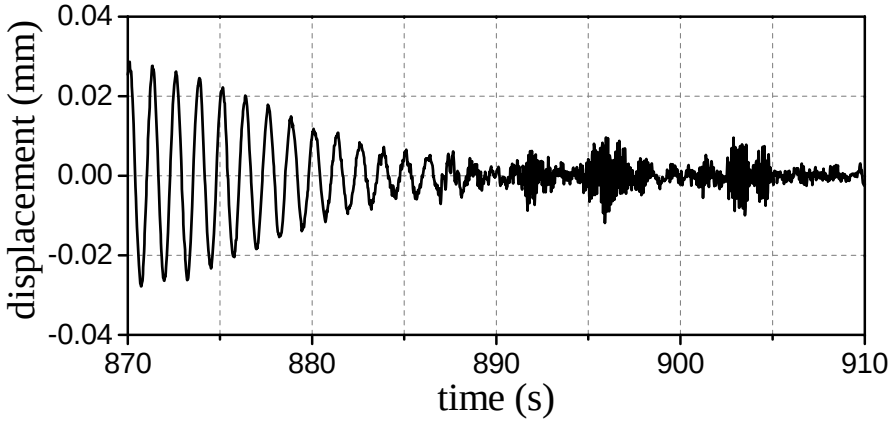
Dominant peak at a range of 7.0 m, correctly identifying the position of the s.d.o.f. system



Laboratory test (2)

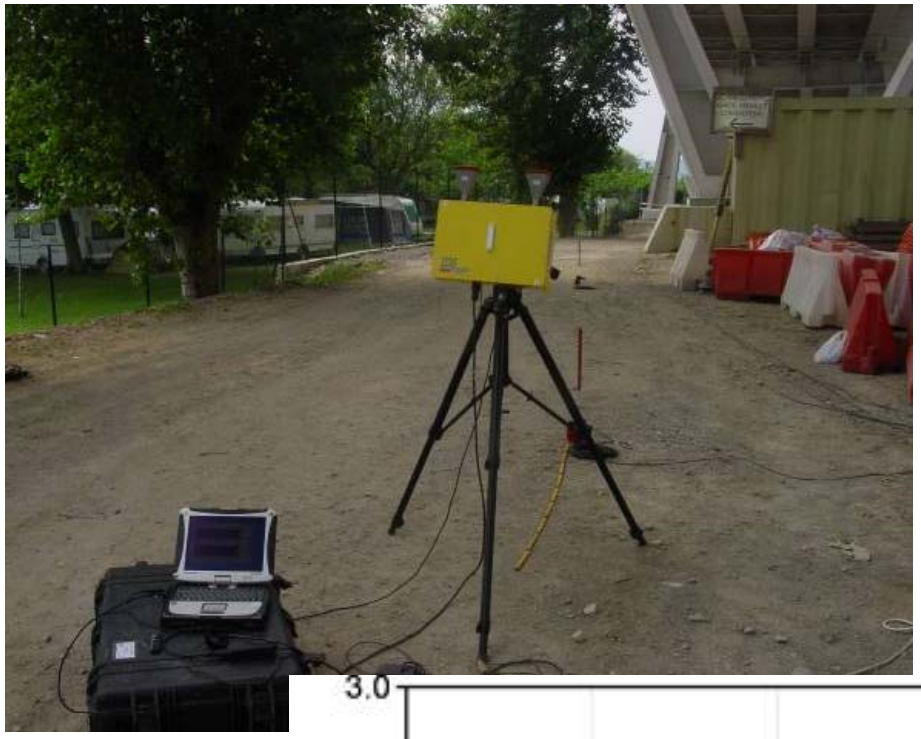


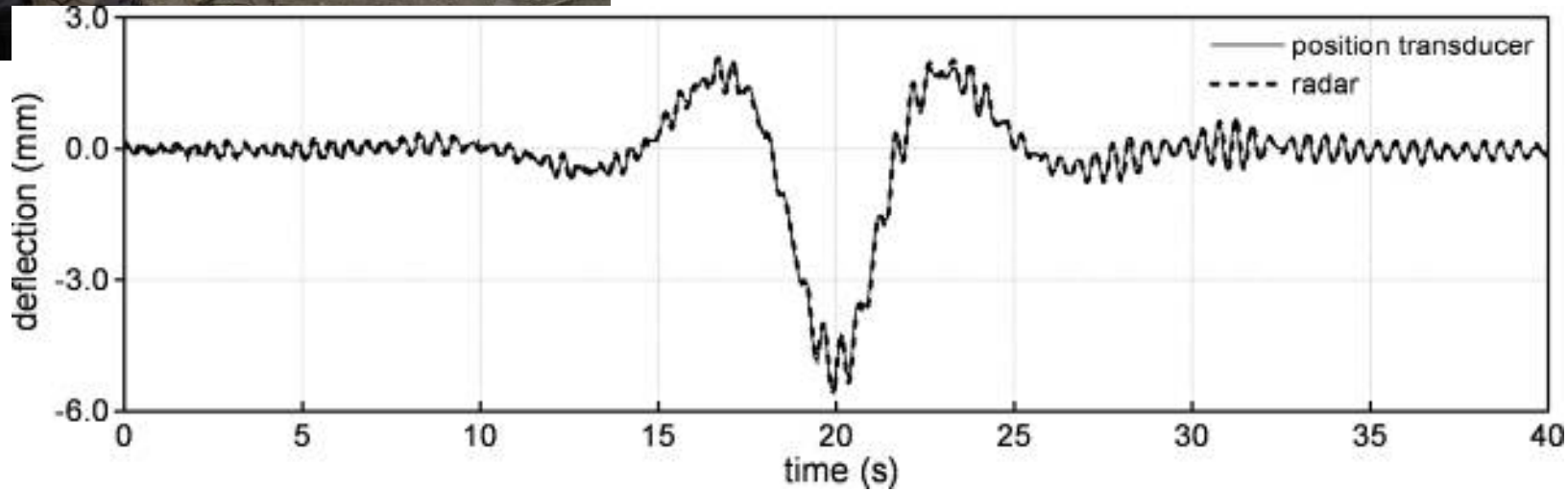




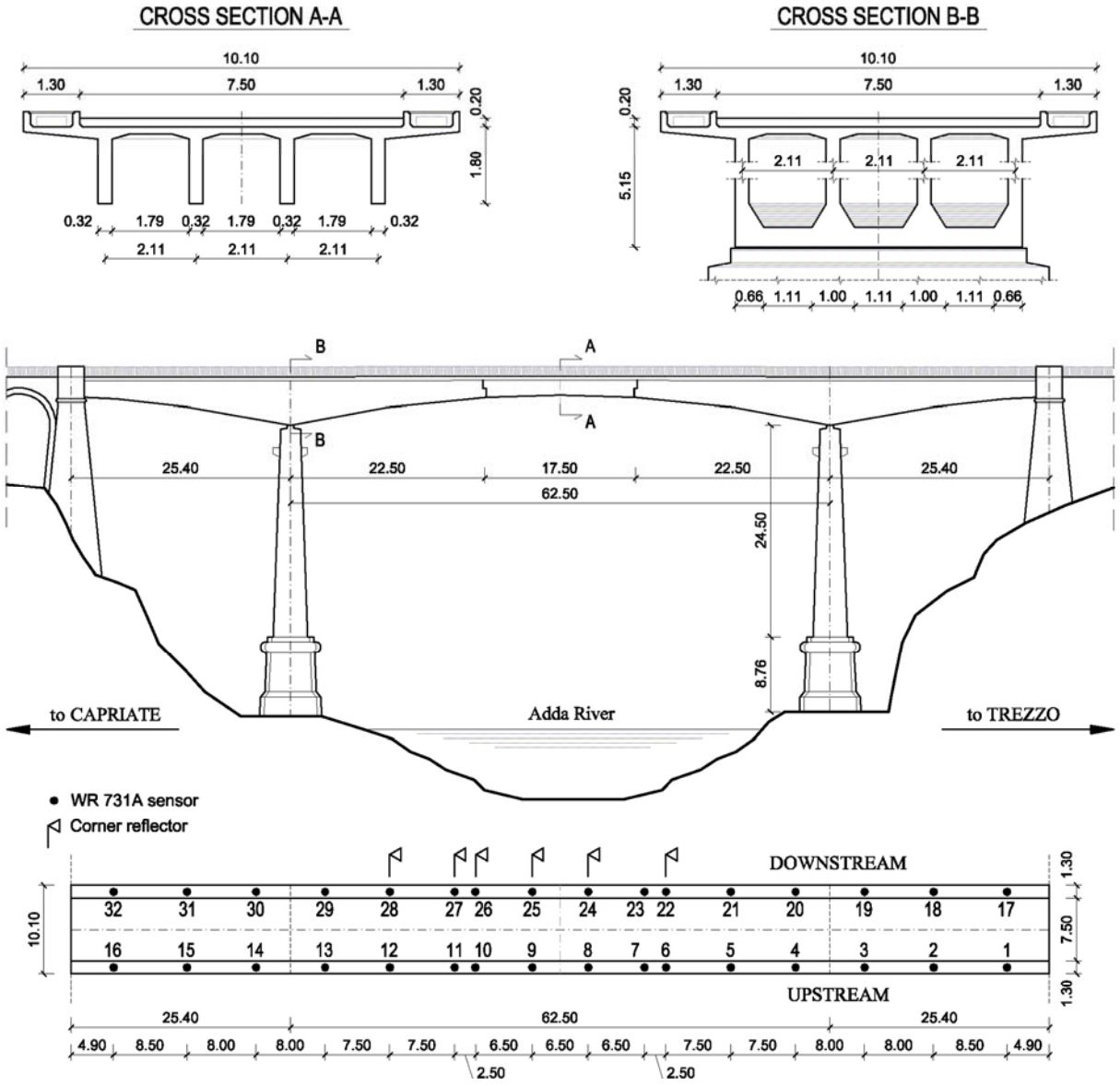
Displacement resolution better than 0.02 mm

On-site test



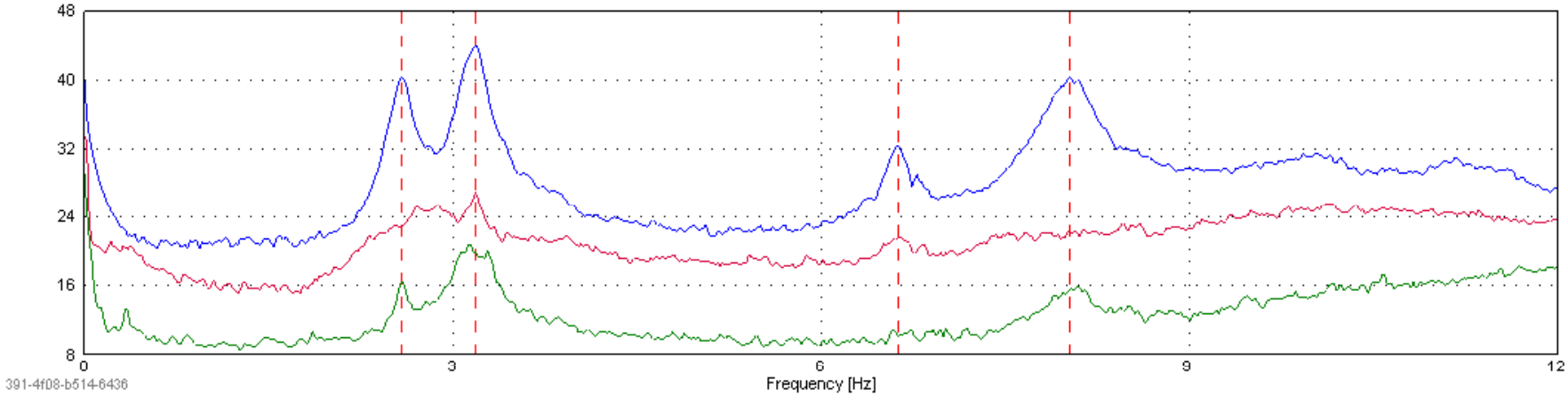

3.0
0.0
-3.0
-6.0
deflection (mm)
0
5
10
15
20
25
30
35
40
time (s)
position transducer
radar

Dynamic test (AVT) of a r.c. bridge (1)

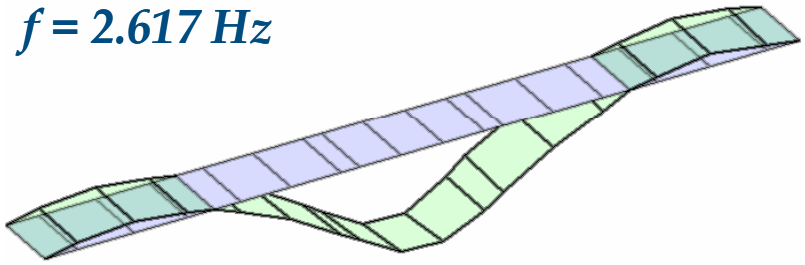


Dynamic test (AVT) of a r.c. bridge (2)

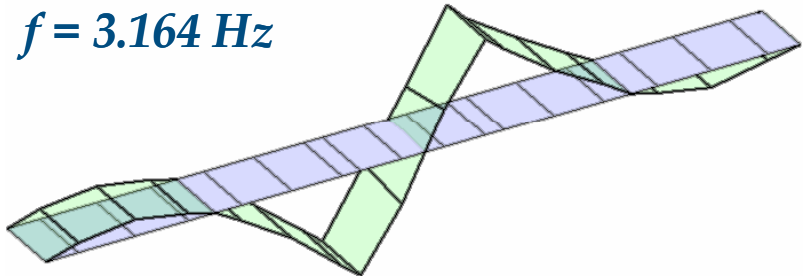
Dynamic behaviour of the bridge (WR 731A accelerometers)



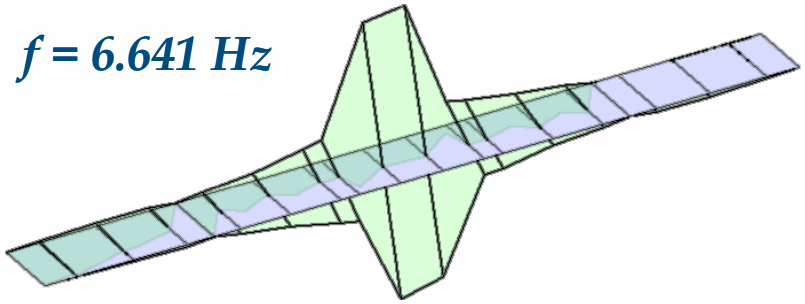
f = 2.617 Hz



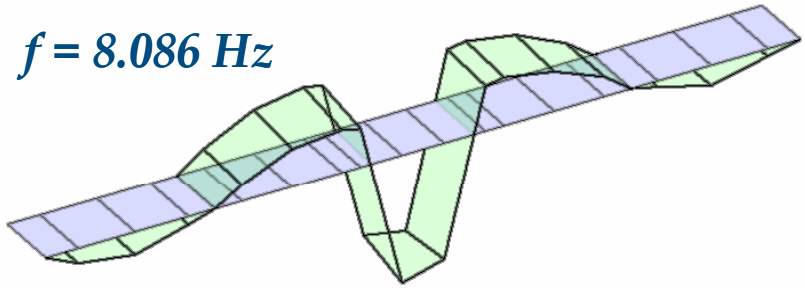
f = 3.164 Hz



f = 6.641 Hz

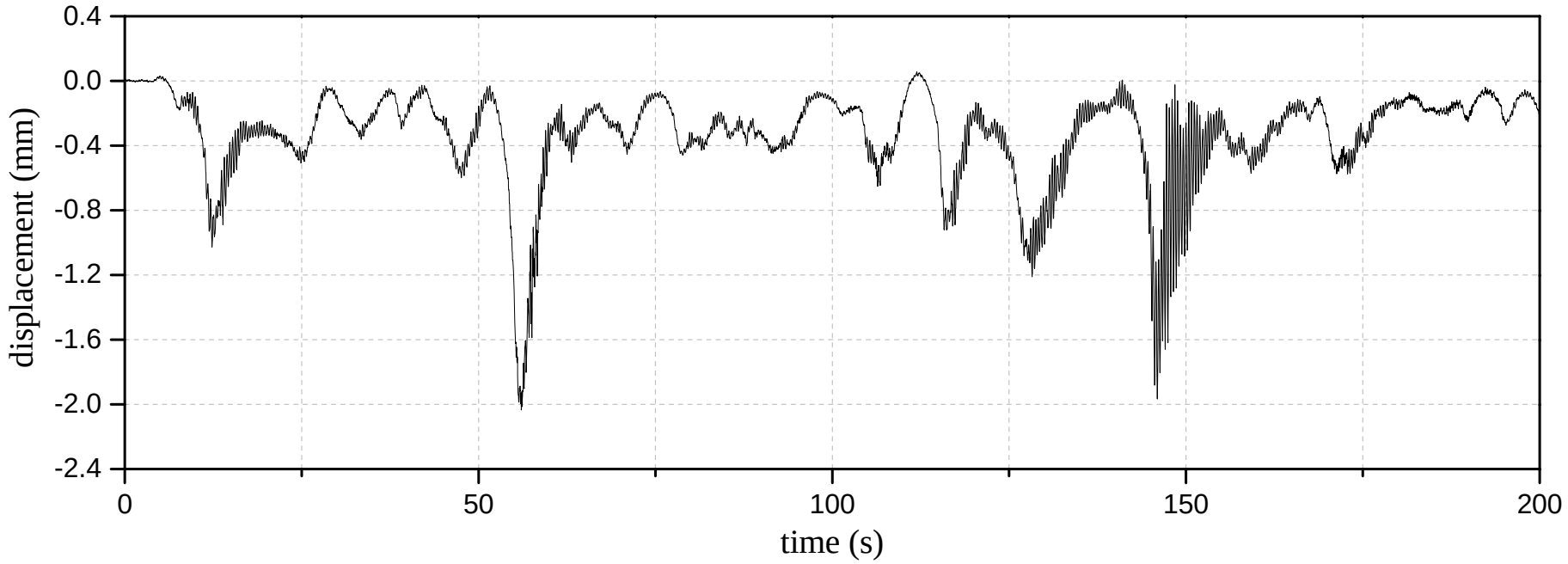


f = 8.086 Hz



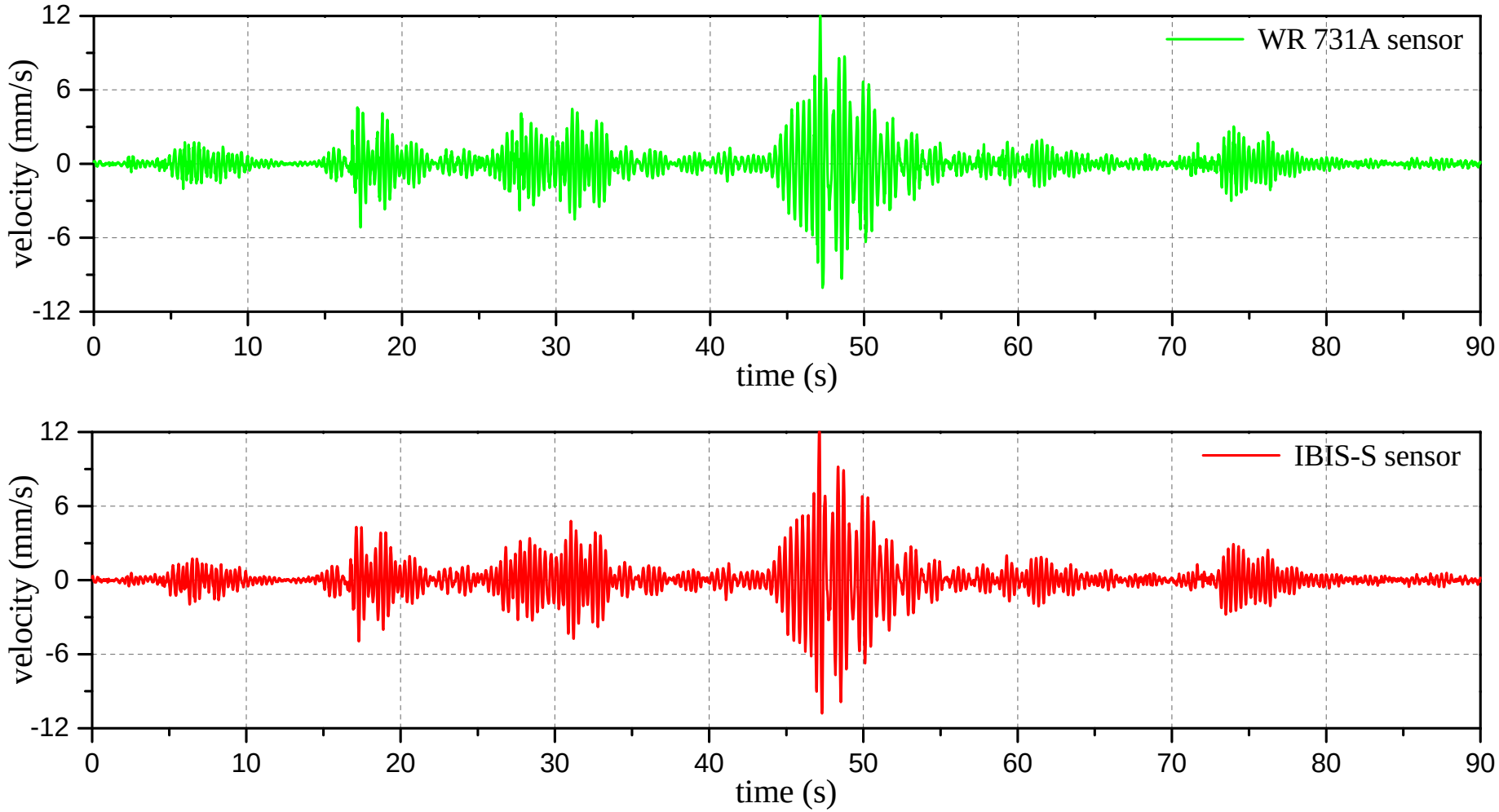
Dynamic test (AVT) of a r.c. bridge (3)

Typical displacement obtained by the IBIS-S sensor at TP25



Displacements are very similar to what expected, based on well-known theoretical models: peculiarly, when the moving load is in the neighbourhood of the test point, the signal is composed by the superposition of one peak and damped harmonic functions

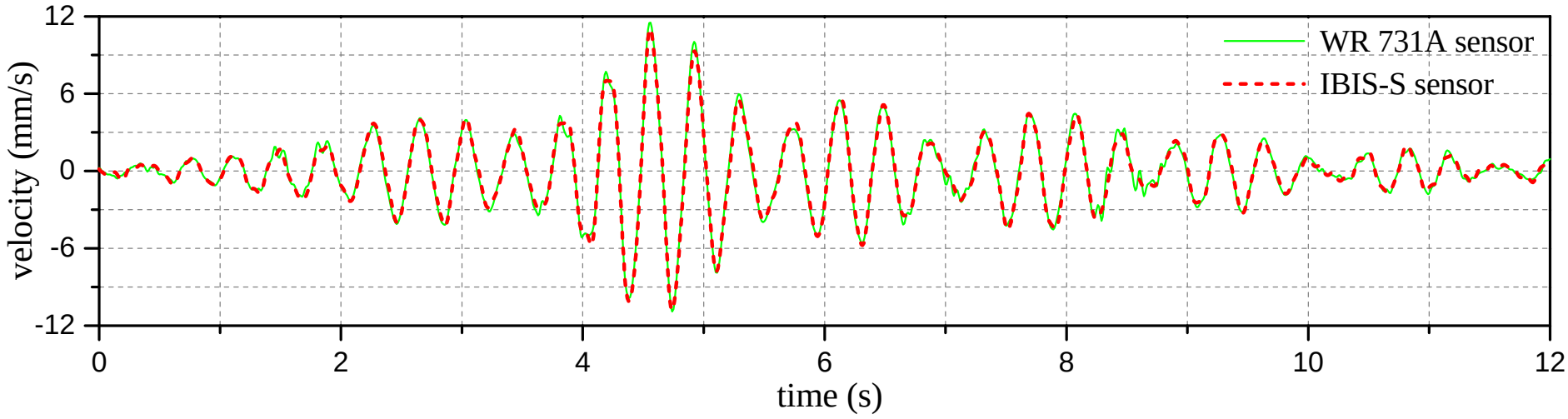
Dynamic test (AVT) of a r.c. bridge (4)



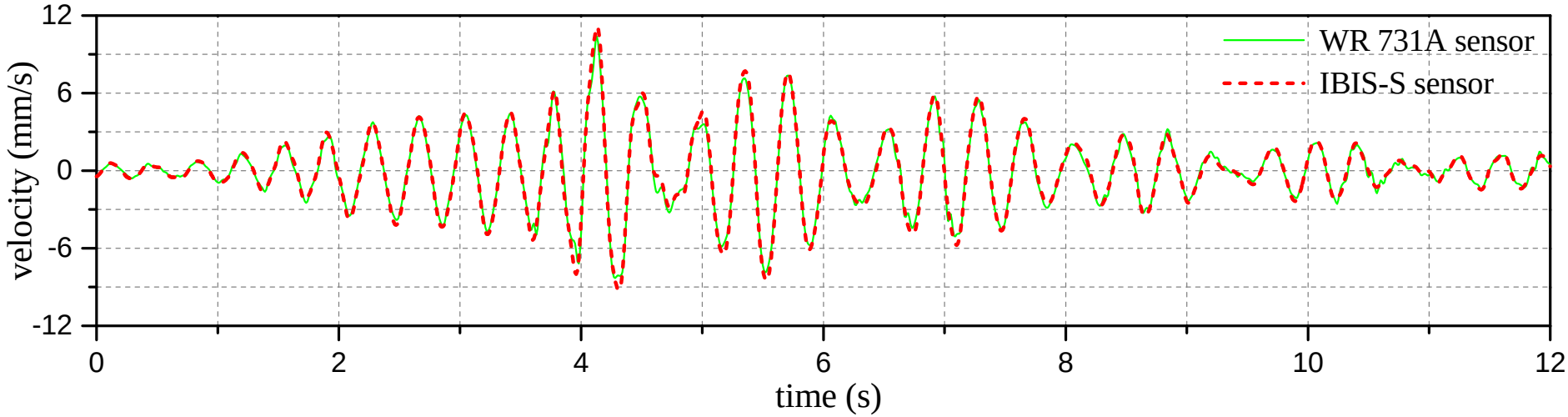
Typical velocity signal recorded at TP26 by WR 731A sensor and IBIS-S sensor

Dynamic test (AVT) of a r.c. bridge (5)

TP22

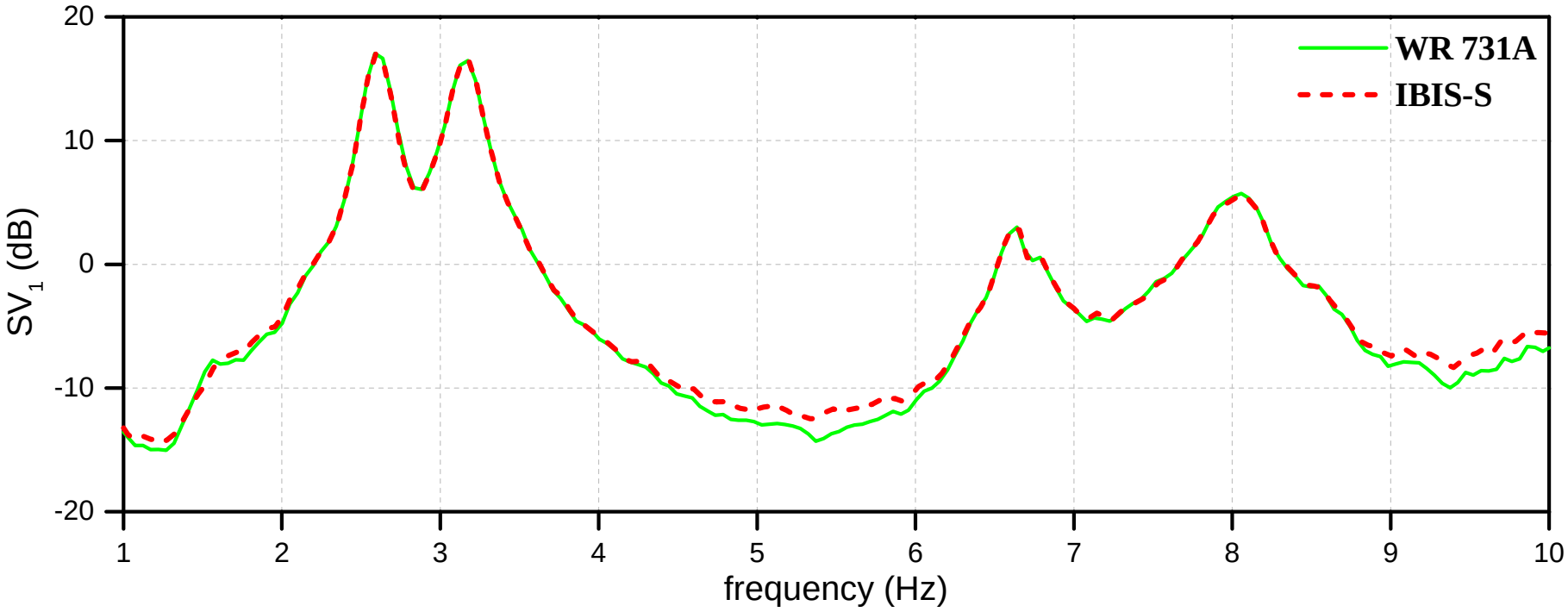


TP27



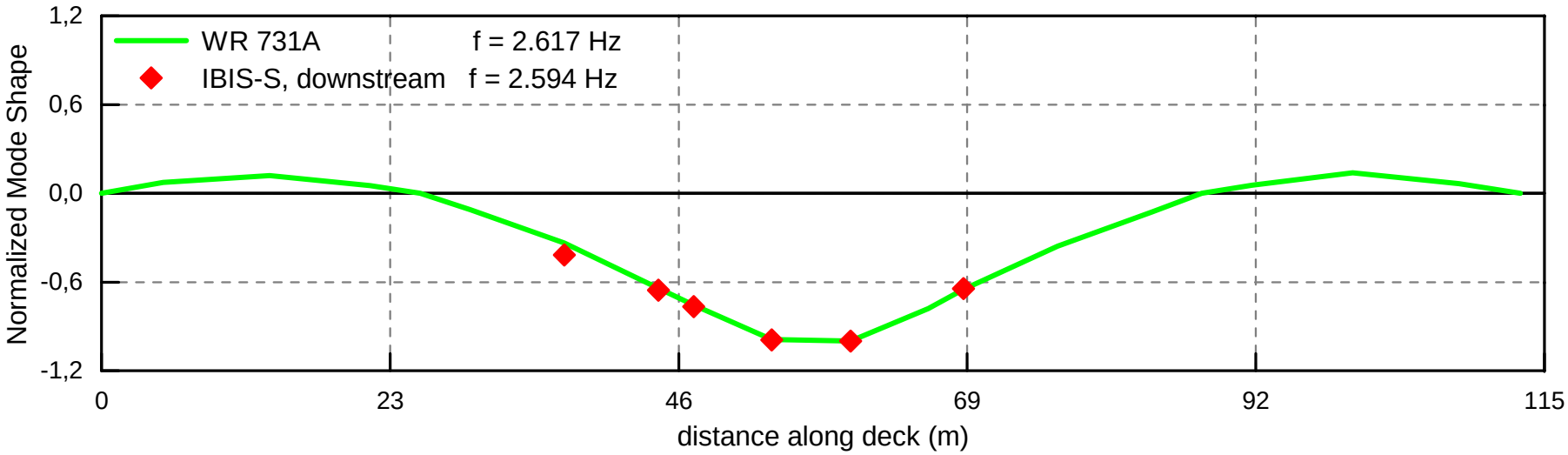
Dynamic test (AVT) of a r.c. bridge (6)

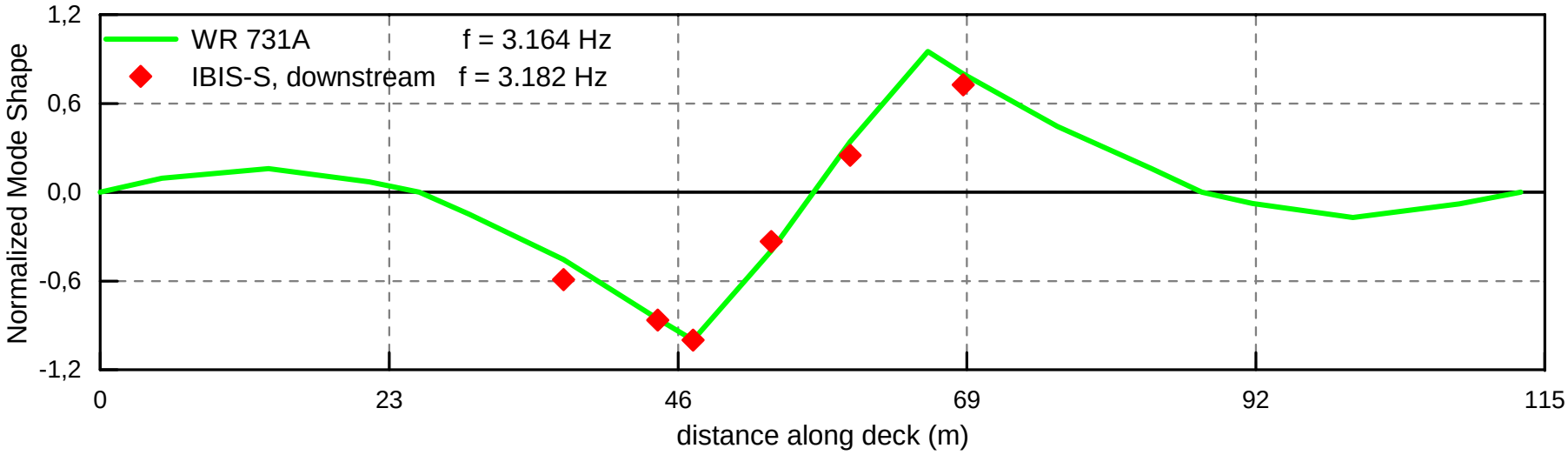
T = 3000s



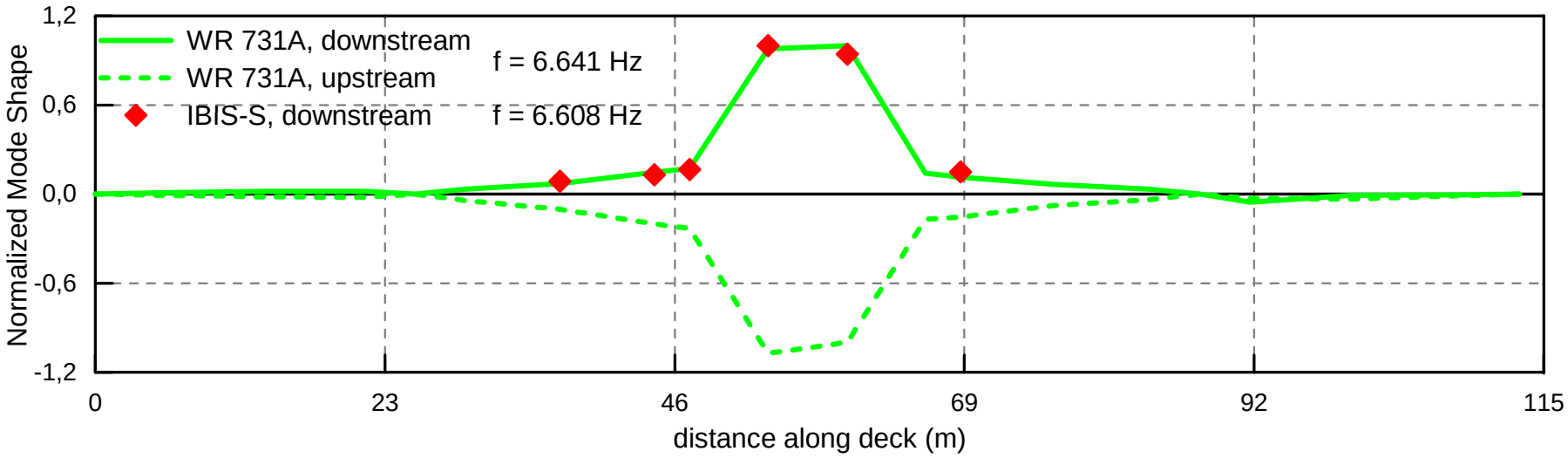
- ***The radar signals describe the important dynamic characteristics of the bridge as well as the signals recorded by the conventional sensors;***
- ***The main differences between radar and conventional signals are conceivably related to different S/N ratios.***

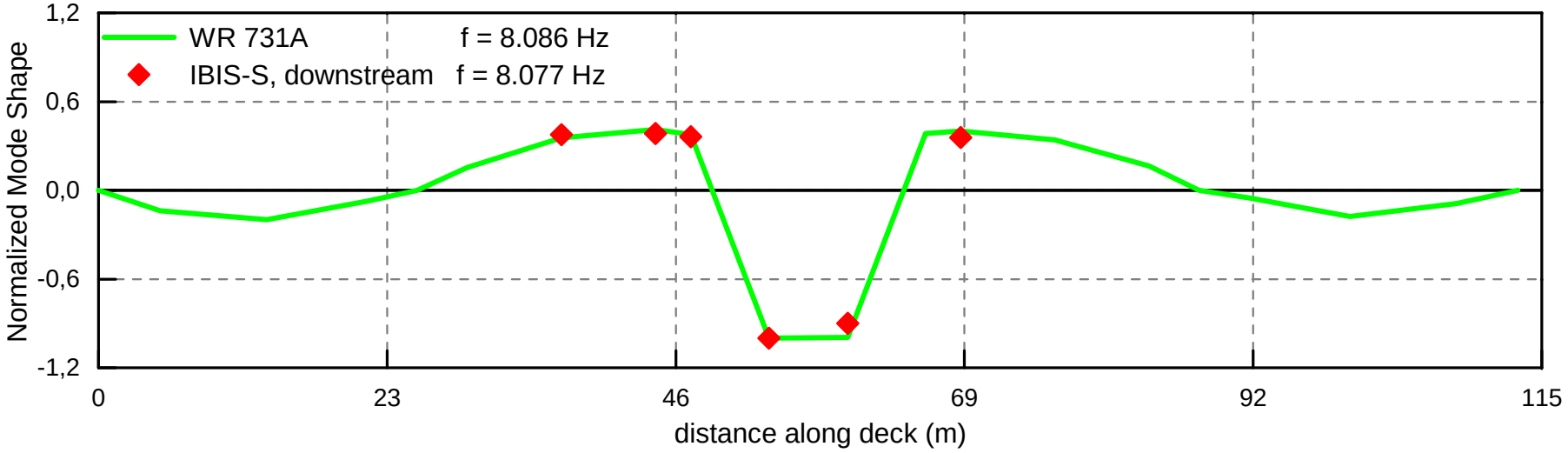
Dynamic test (AVT) of a r.c. bridge (7)



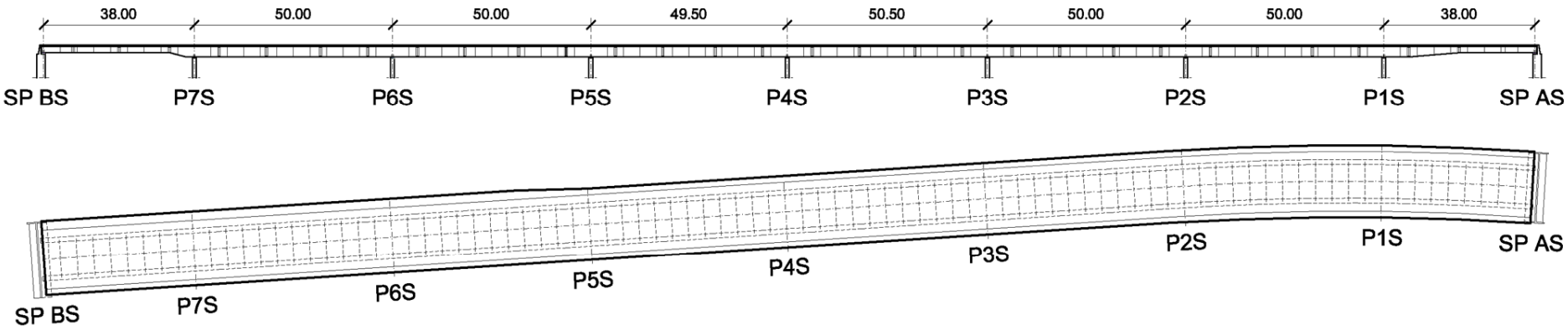


Dynamic test (AVT) of a r.c. bridge (8)



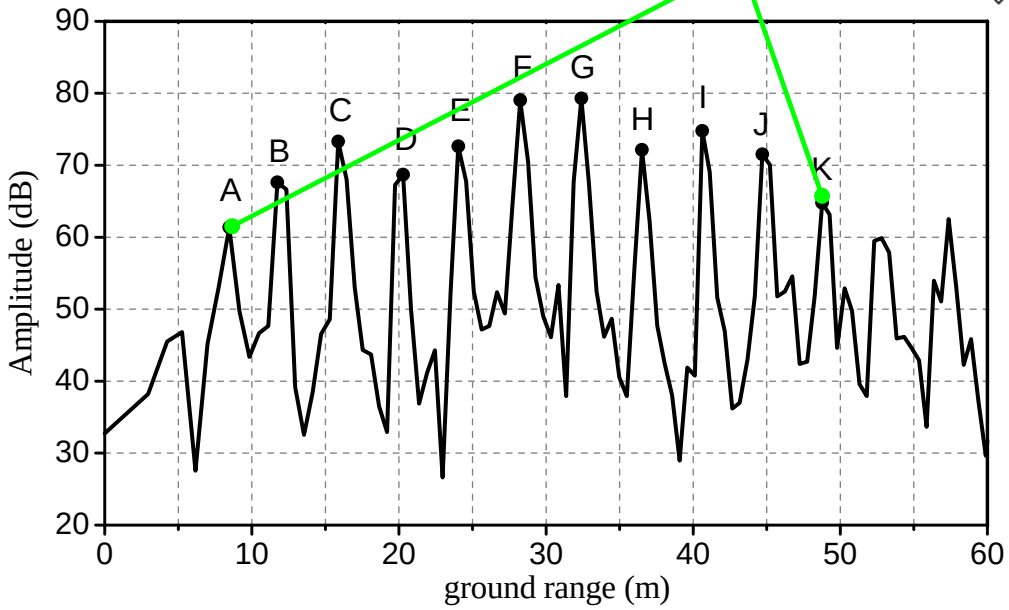


Dynamic test of a steel-composite bridge (1)



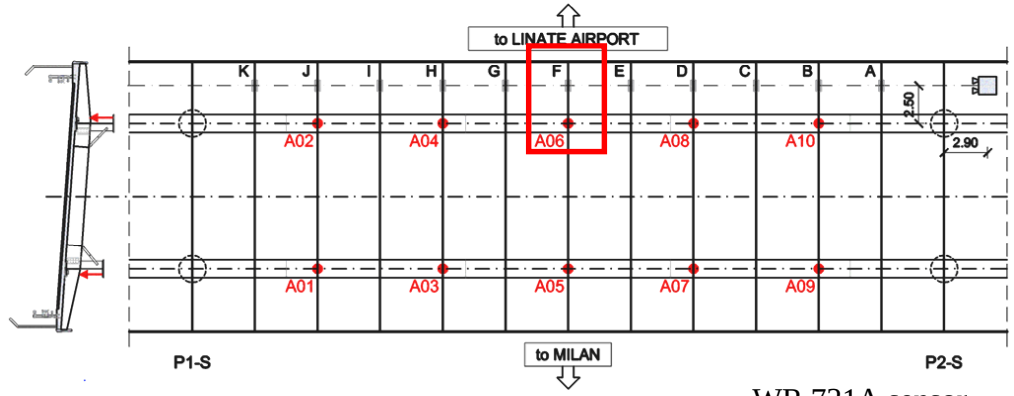
Dynamic test of a steel-composite bridge (2)

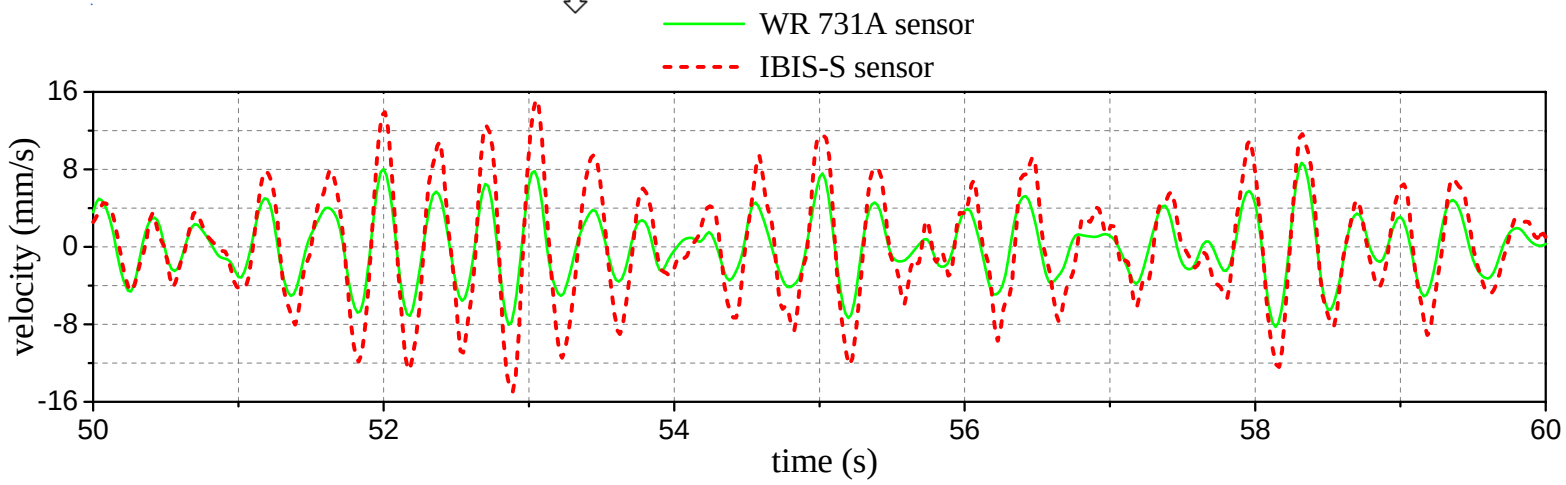
Experimental procedures:



Dynamic test of a steel-composite bridge (3)

Results obtained from the radar sensor: velocity time-series

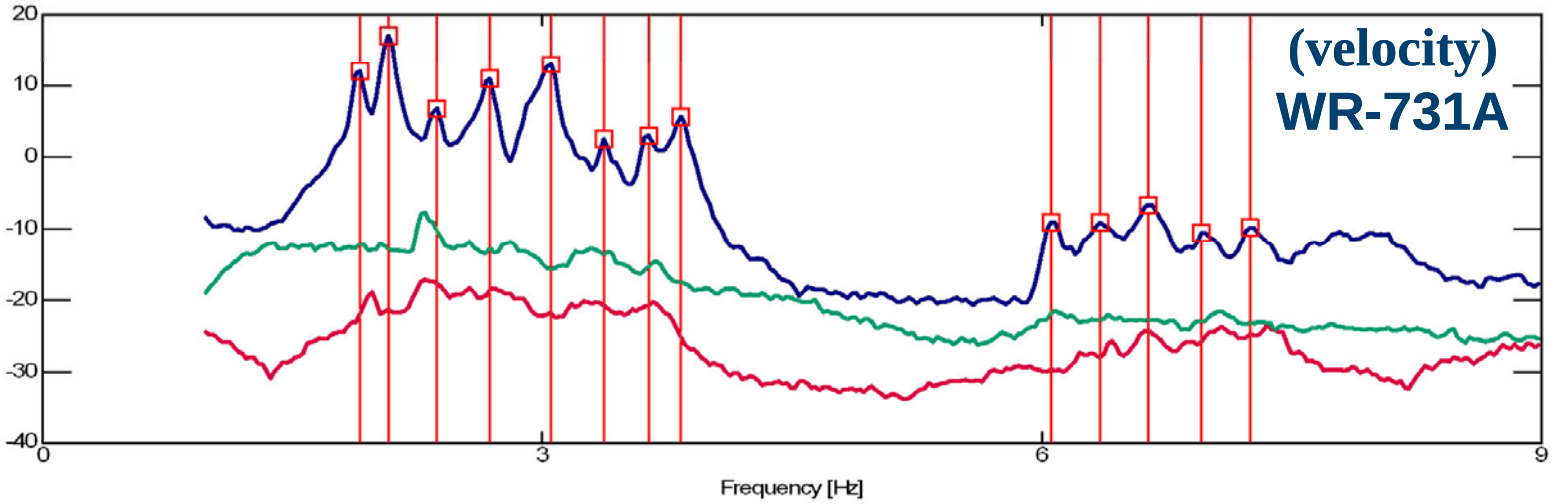




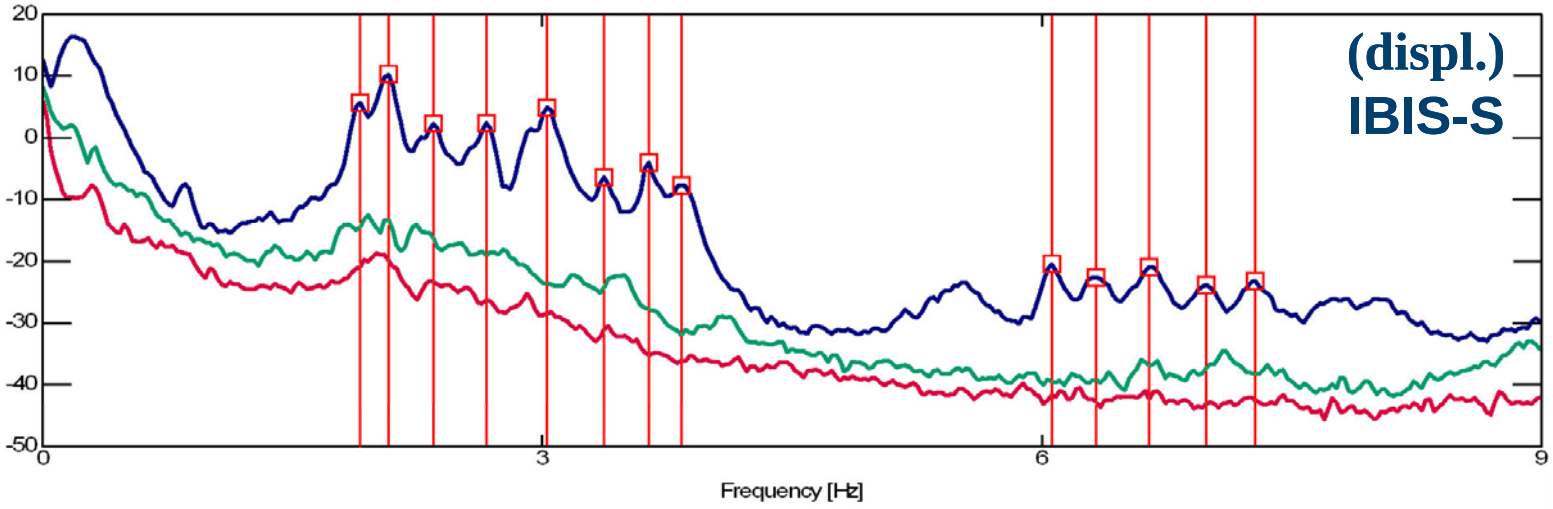
Differently from the Capriate bridge, the time-histories obtained from the radar and from conventional sensors refer to close but different points.

Dynamic test of a steel-composite bridge (4)

Results obtained from the radar sensor: natural frequencies



T = 2260 s



Dynamic test of a steel-composite bridge (5)

Results obtained from the radar sensor: modal parameters

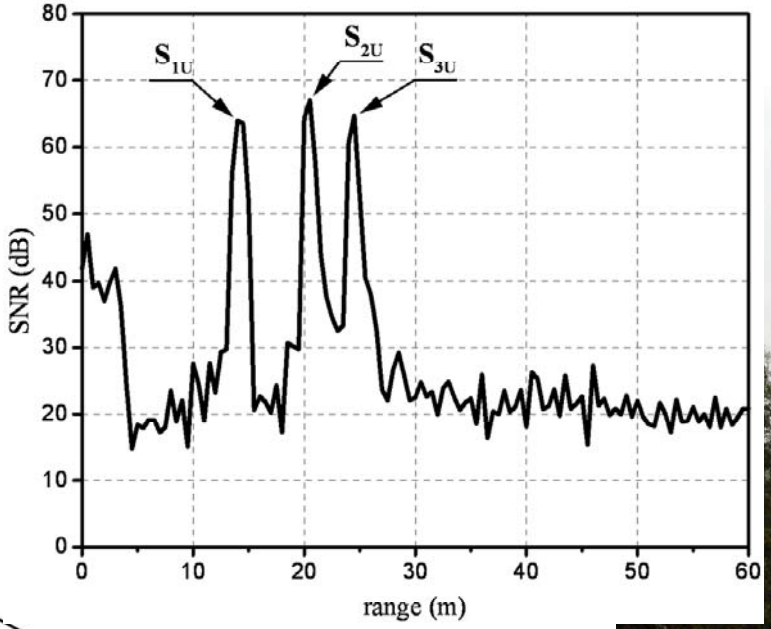
Mode Identifier	*f* (Hz)		*MAC*	Mode Identifier	*f* (Hz)		*MAC*
	WR-731A	IBIS-S			WR-731A	IBIS-S	
B_1	1.904	1.905	0.996	B_7	3.833	3.835	0.998
B_2	2.075	2.076	0.992	T_2	6.055	6.058	0.994
B_3	2.368	2.345	0.989	B_8	6.348	6.327	0.989
B_4	2.686	2.663	0.997	B_9	6.641	6.645	0.985
B_5	3.052	3.029	0.998	B_{10}	6.982	6.987	0.976
B_6	3.369	3.371	0.995	T_3	7.251	7.280	0.984
T_1	3.638	3.640	0.995		–	–	–

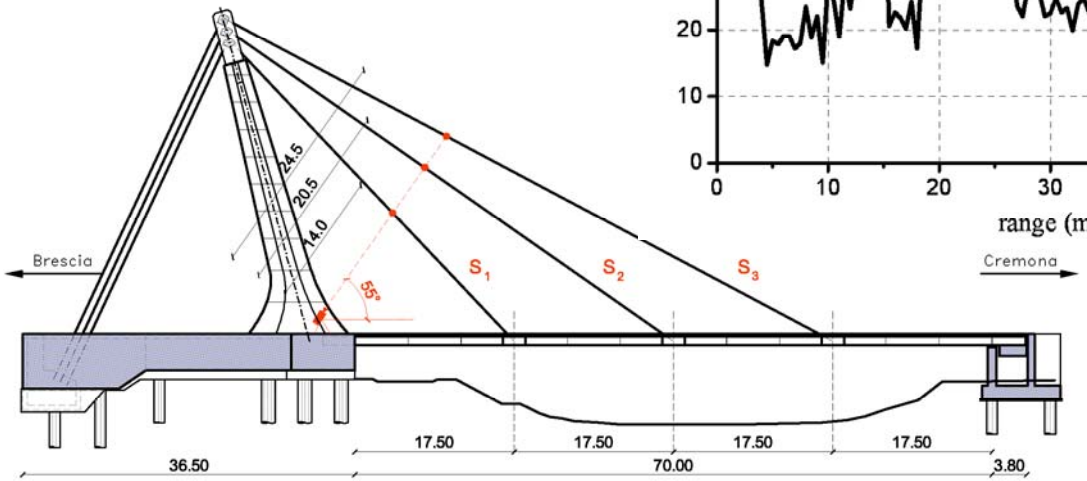
- ***The natural frequencies identified from radar signals are practically equal to those identified from conventional sensors;***
- ***The mode shapes exhibit excellent correlation (MAC very close to 1) as well, provided that the modal deflections were properly normalized.***

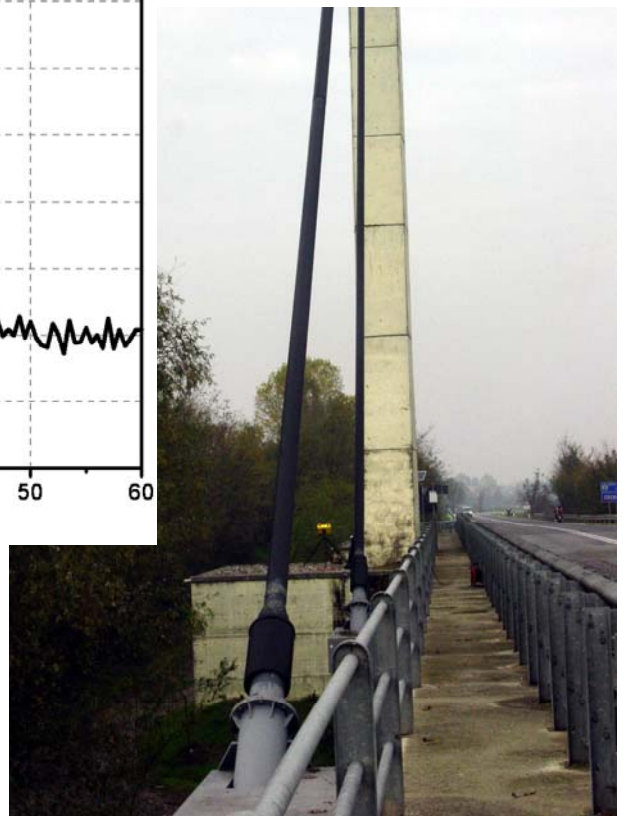
Dynamic measurements on stay cables (1)

The typical position of the sensor is inclined upward; hence, the only targets encountered along the path of the electromagnetic waves are the stays itself so that 1-D imaging capability is perfectly adequate to the test scenario

Upstream Side



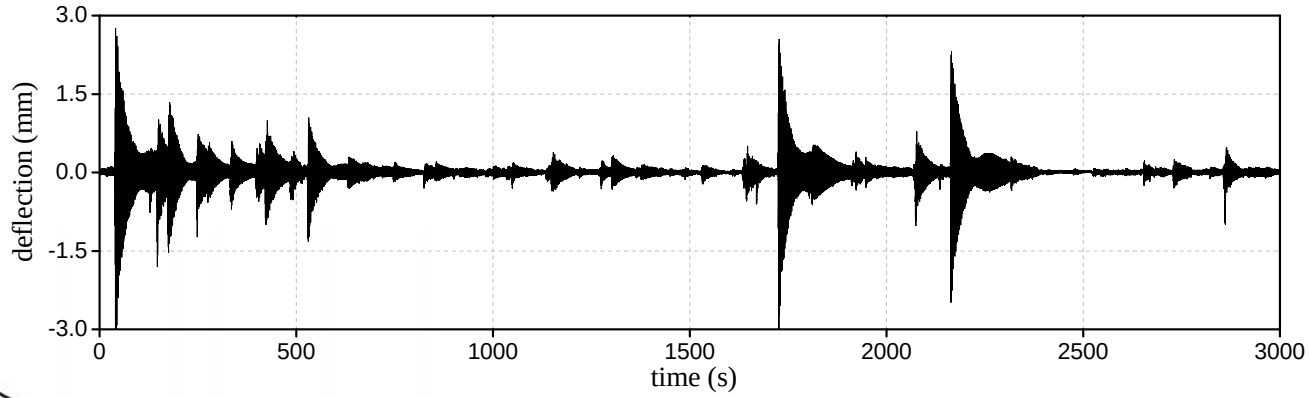


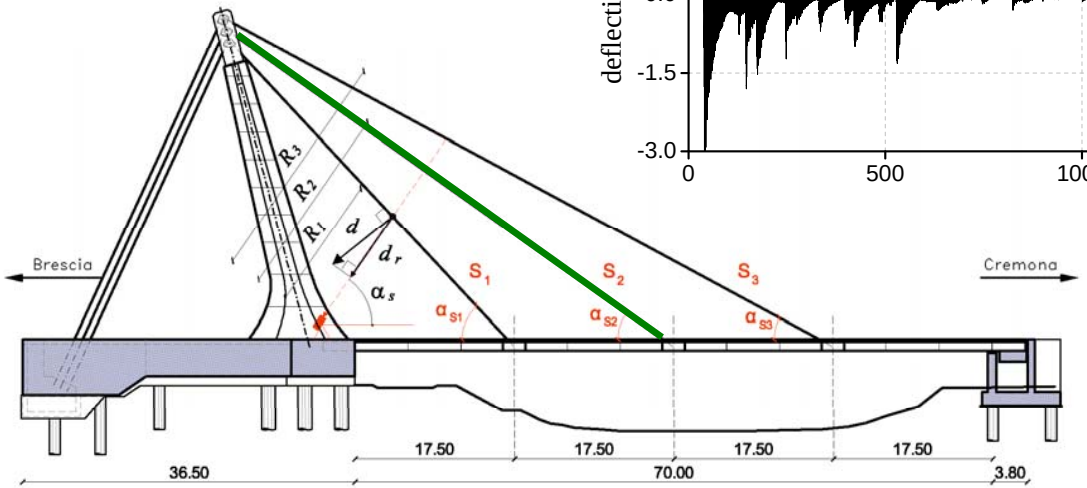


Dynamic measurements on stay cables (2)

By assuming that the in-plane motion of the cable is orthogonal to its axis, the actual deflection *d* of the cable is easily evaluated from the knowledge of the radial deflection d_r, the slope of the cable α_c and the inclination of the sensor α_s:

$$d = \frac{d_r}{\cos\left[\pi/2 - \left(\alpha_c + \alpha_s\right)\right]}$$

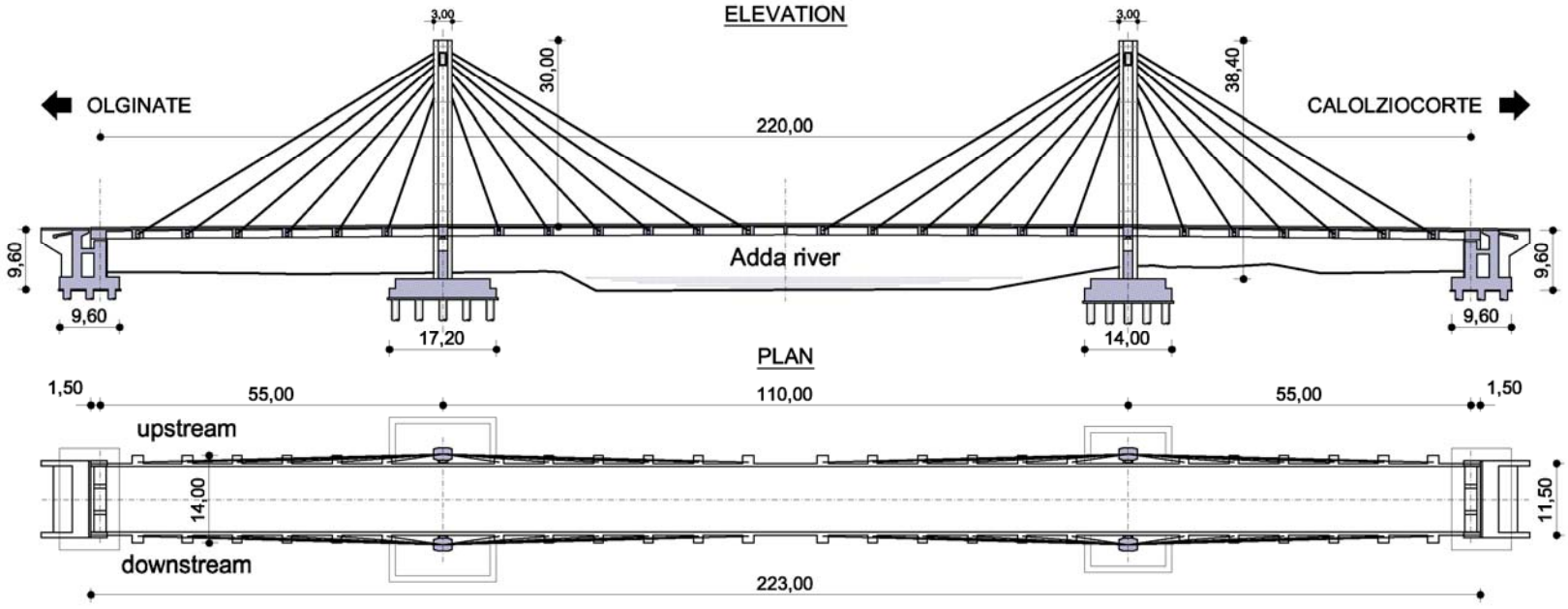




Stay cable S_{2U}

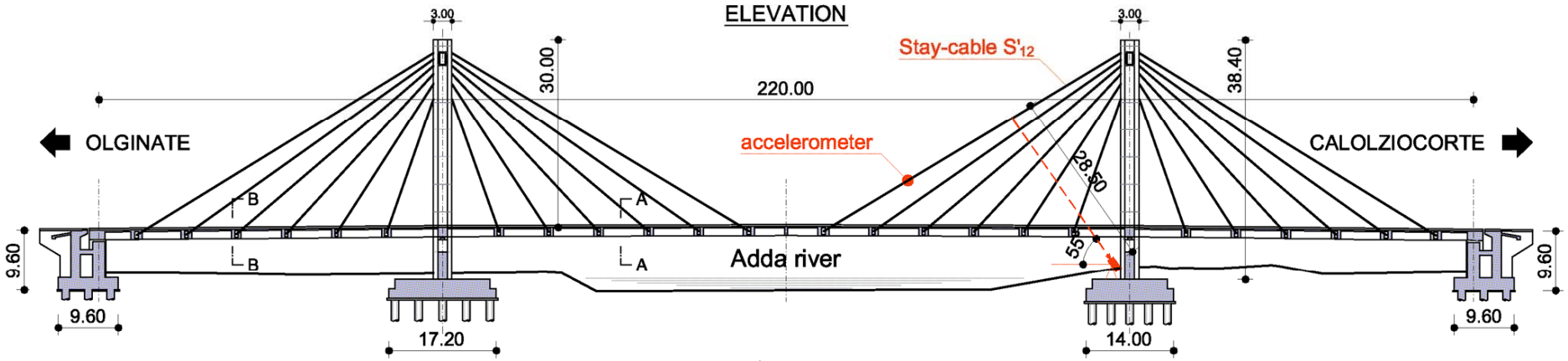
Dynamic measurements on stay cables

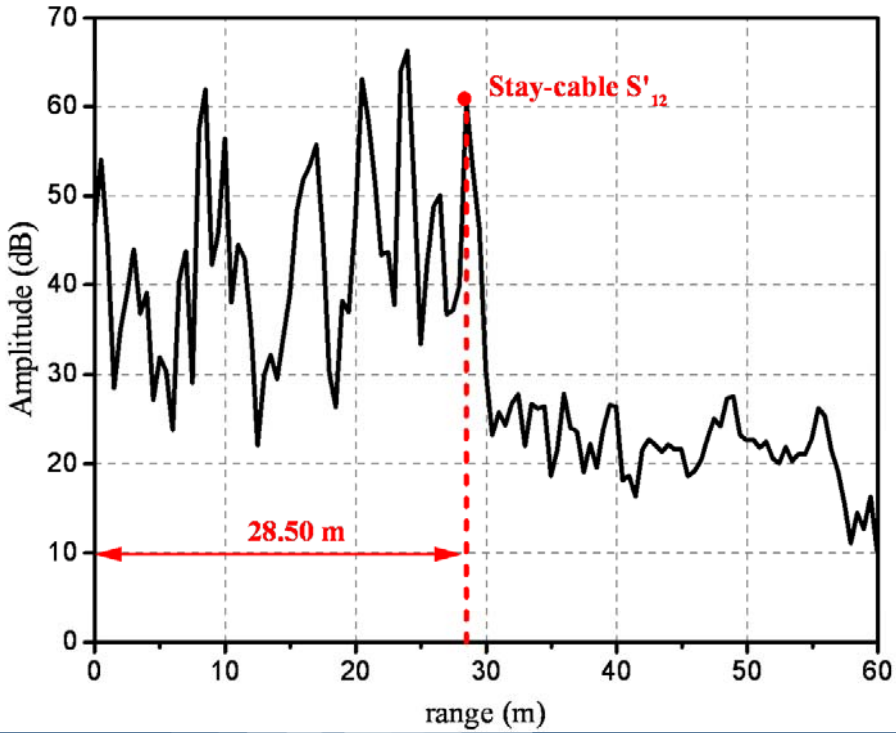
Cable-stayed bridge over the Adda river (1)



Dynamic measurements on stay cables

Cable-stayed bridge over the Adda river (2)

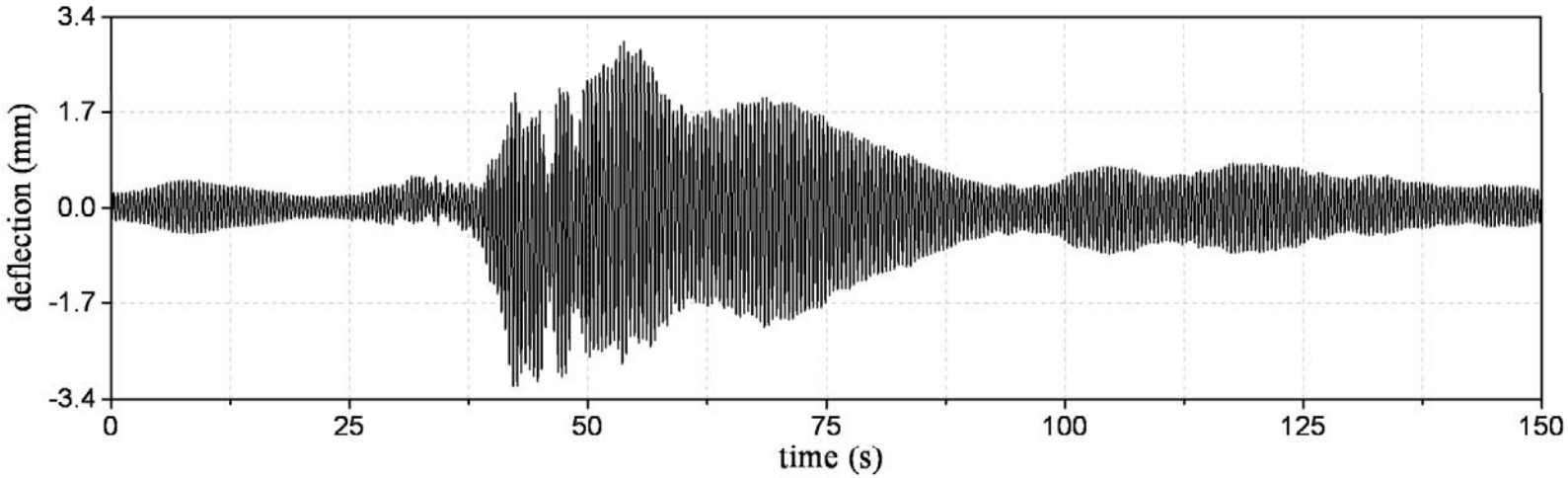




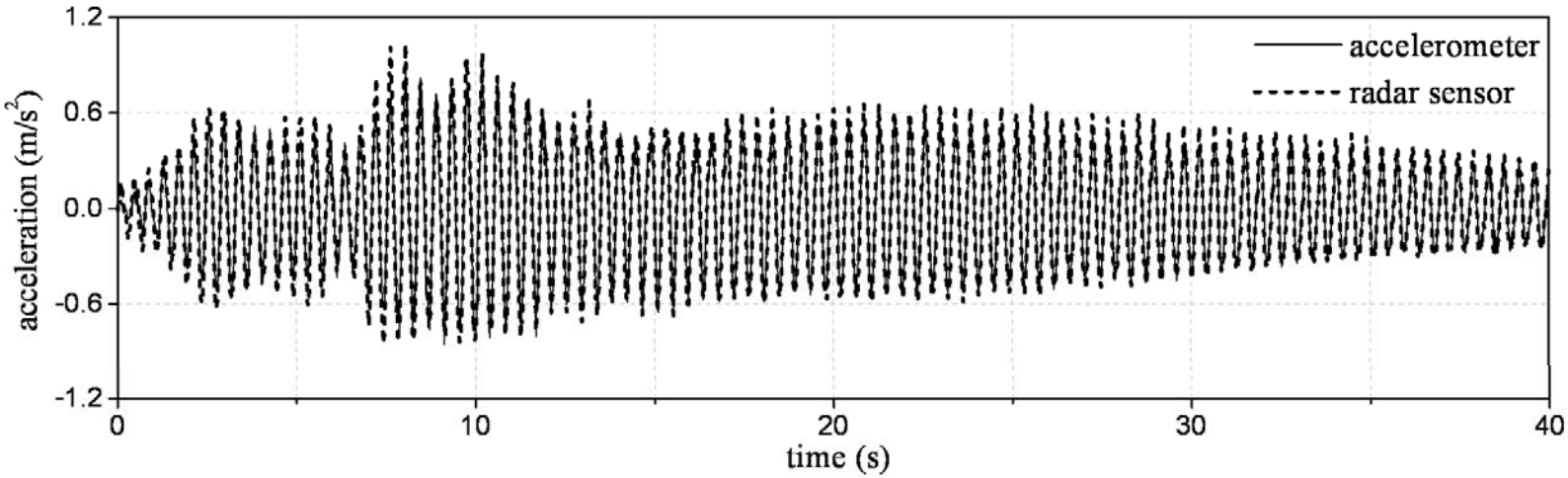
Dynamic measurements on stay cables

Cable-stayed bridge over the Adda river (3)

Typical deflection time-history

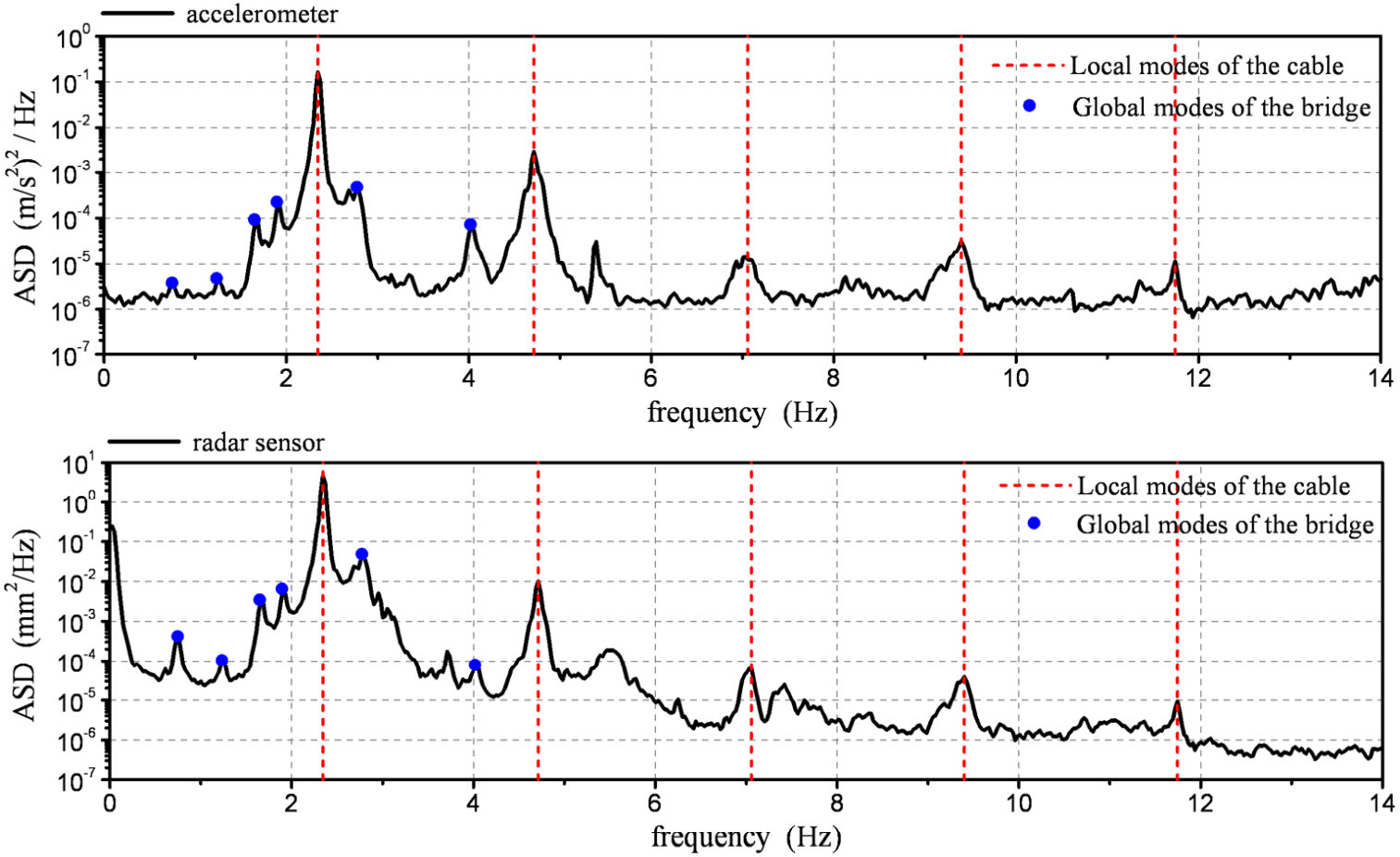


Acceleration time-histories obtained from accelerometer and radar sensor



Dynamic measurements on stay cables

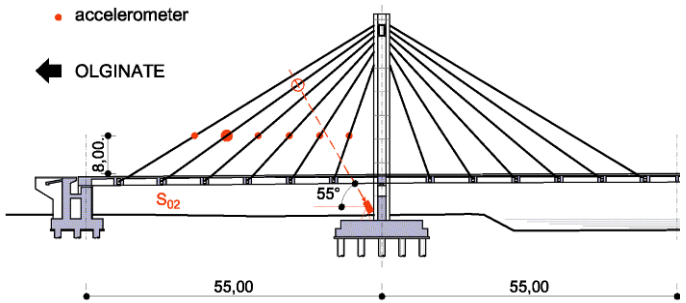
Cable-stayed bridge over the Adda river (4)



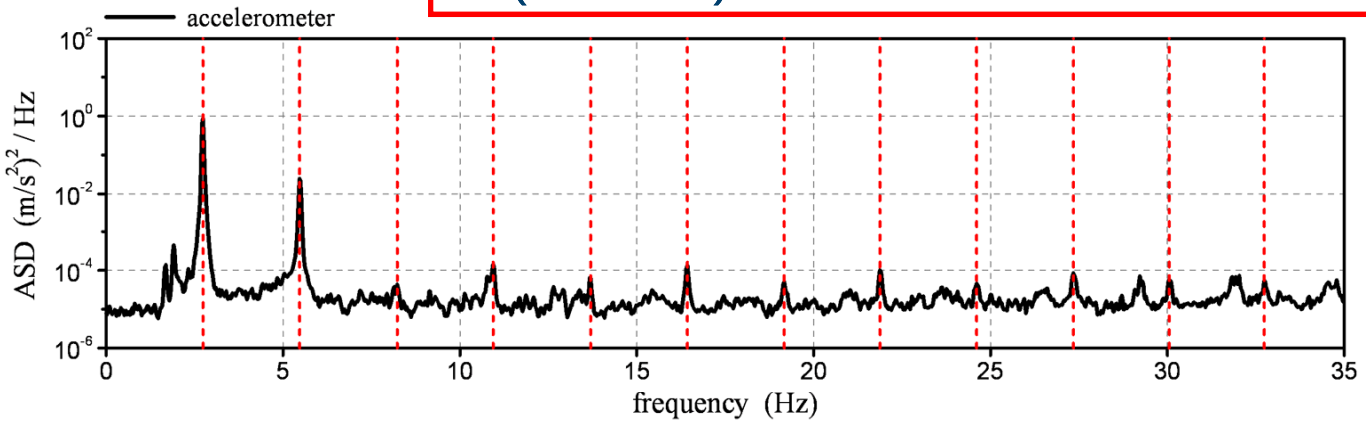
- Excellent agreement in terms of local natural frequencies of the cable (red dashed lines) and in terms of global natural frequencies of the bridge (blue dots), as well

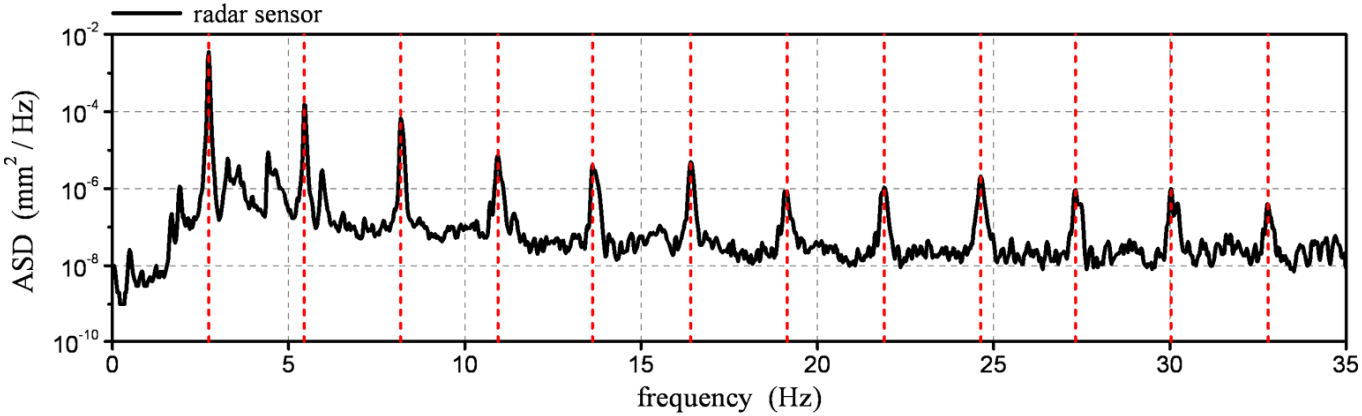
Dynamic measurements on stay cables

Cable-stayed bridge over the Adda river (5)



- Large number of local modes identified;
- The peaks related to the cable natural frequencies are much more evident in the ASD of radar data in the high-frequency range (7-35 Hz)





Dynamic measurements on stay cables

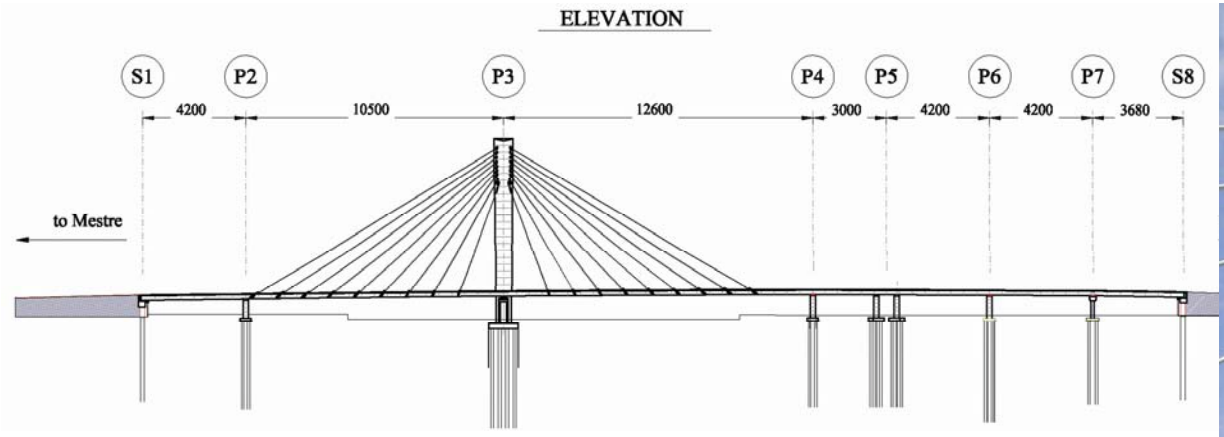
Cable-stayed bridge over the Adda river (6)

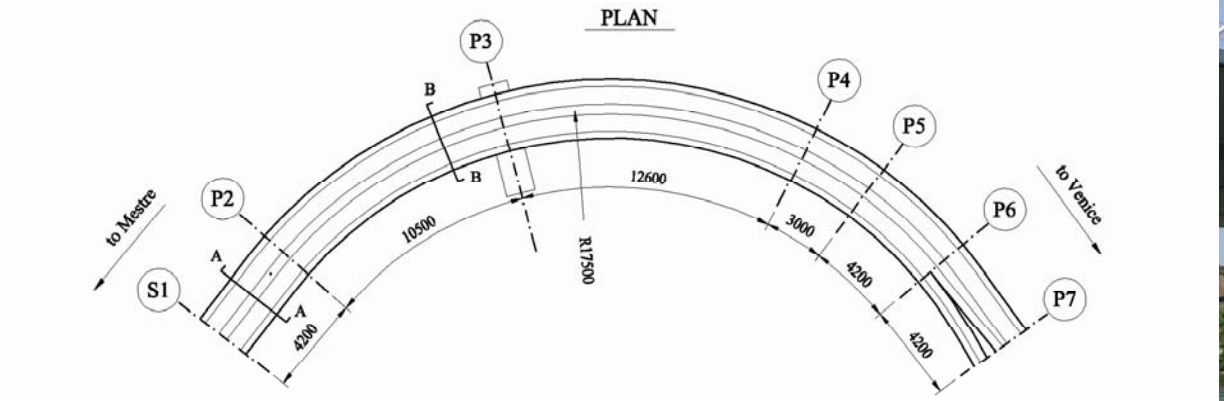
Cable tensions obtained from accelerometer and radar measurements

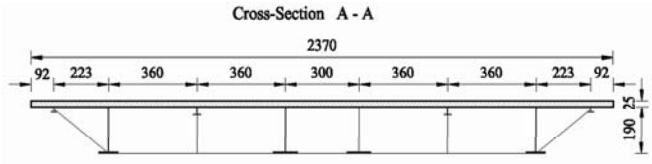
Cable	Sensor	$T(f_1)$ (kN)	$T(f_2)$ (kN)	$T(f_3)$ (kN)	$T(f_4)$ (kN)	$T(f_5)$ (kN)	Average (kN)	$T_{Load\ Cell}$ (kN)
S'_{12}	Accelerometer	2679	2707	2660	2693	2690	2686	2694
	Radar sensor	2679	2707	2679	2693	2690	2689	
S_{02}	Accelerometer	2788	2789	2805	2789	2798	2794	2855
	Radar sensor	2788	2789	2772	2789	2778	2783	

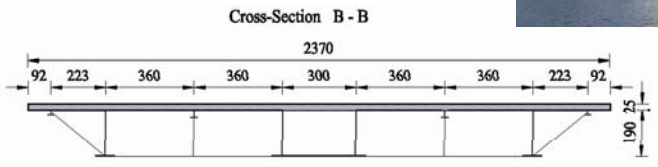
Dynamic measurements on stay cables

Cable-stayed bridge in Porto Marghera (1)



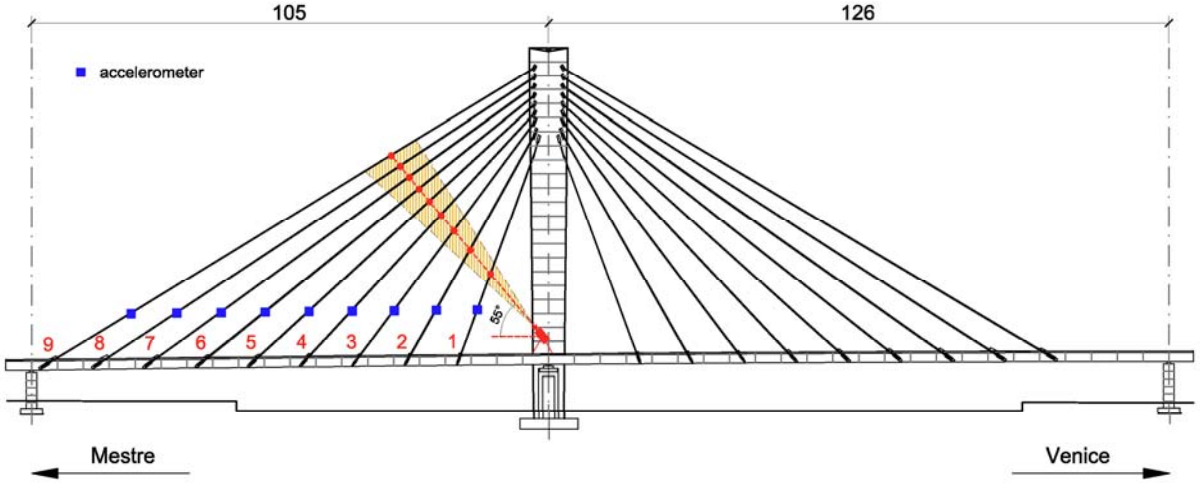


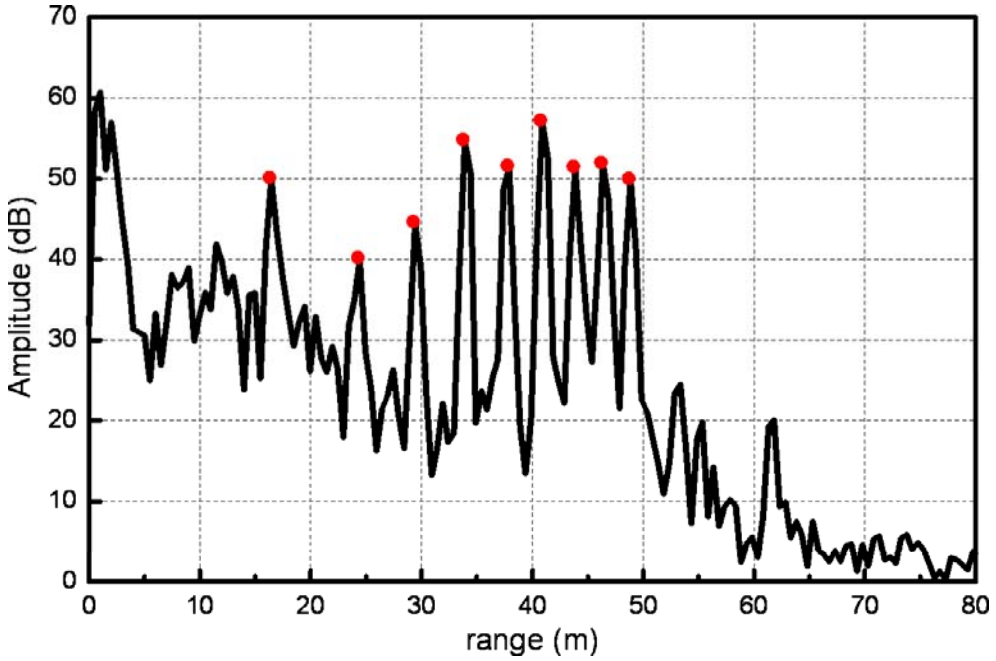




Dynamic measurements on stay cables

Cable-stayed bridge in Porto Marghera (2)

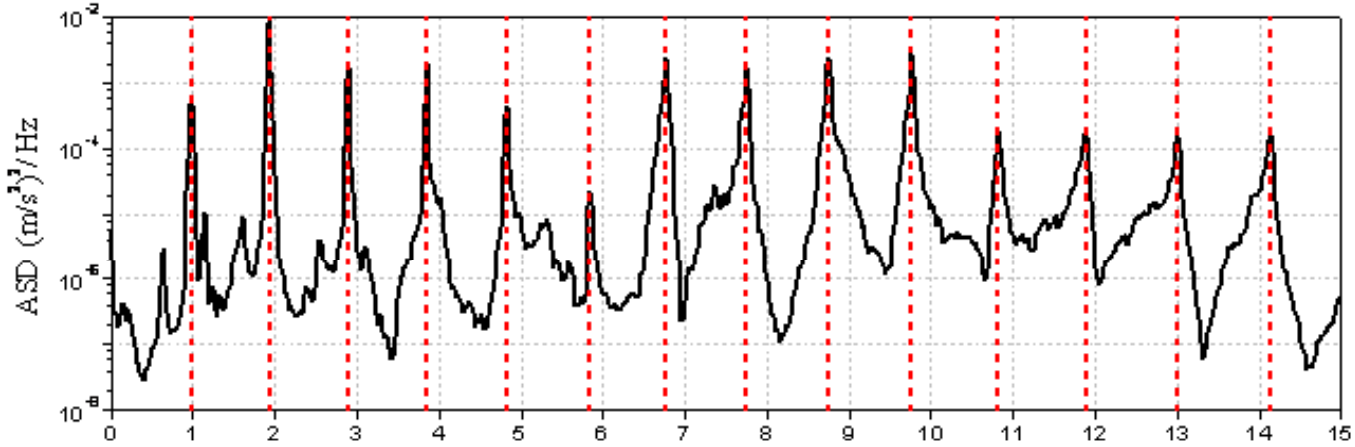


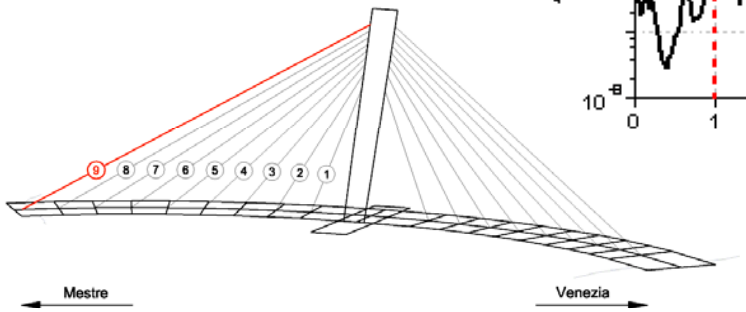


Dynamic measurements on stay cables

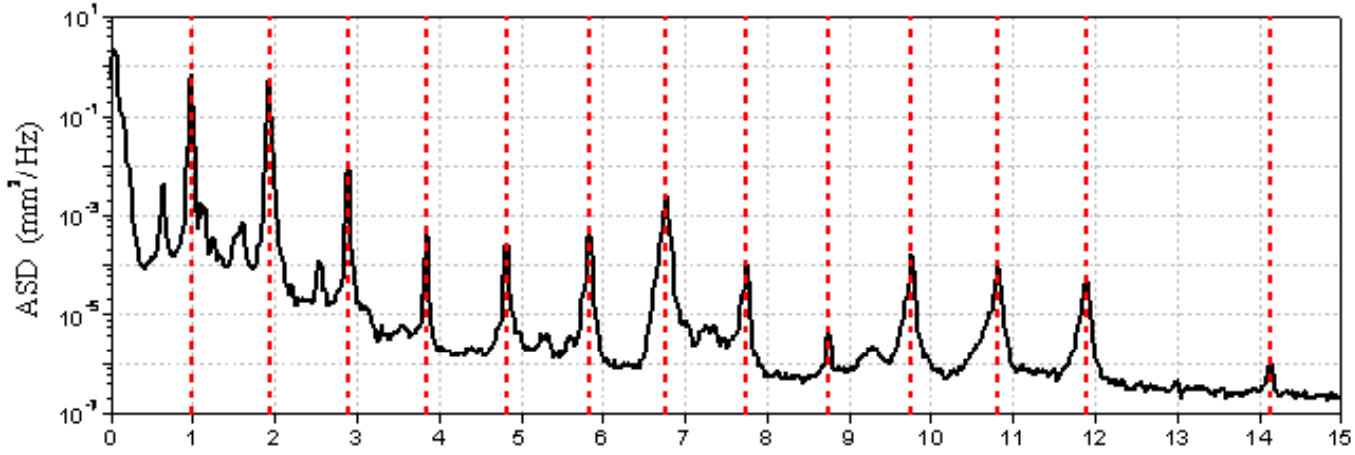
Cable-stayed bridge in Porto Marghera (3)

ASD acceleration (Mestre Side – Stay cable 9)





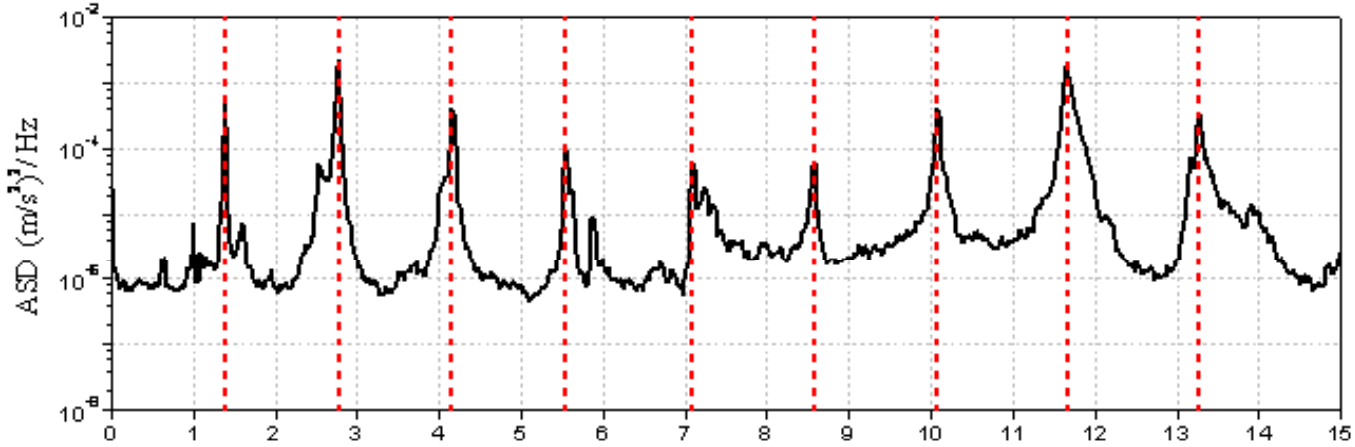
ASD displacement (Mestre Side – Stay cable 9)

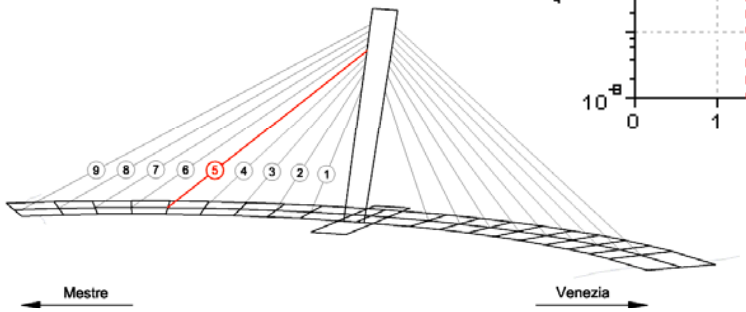


Dynamic measurements on stay cables

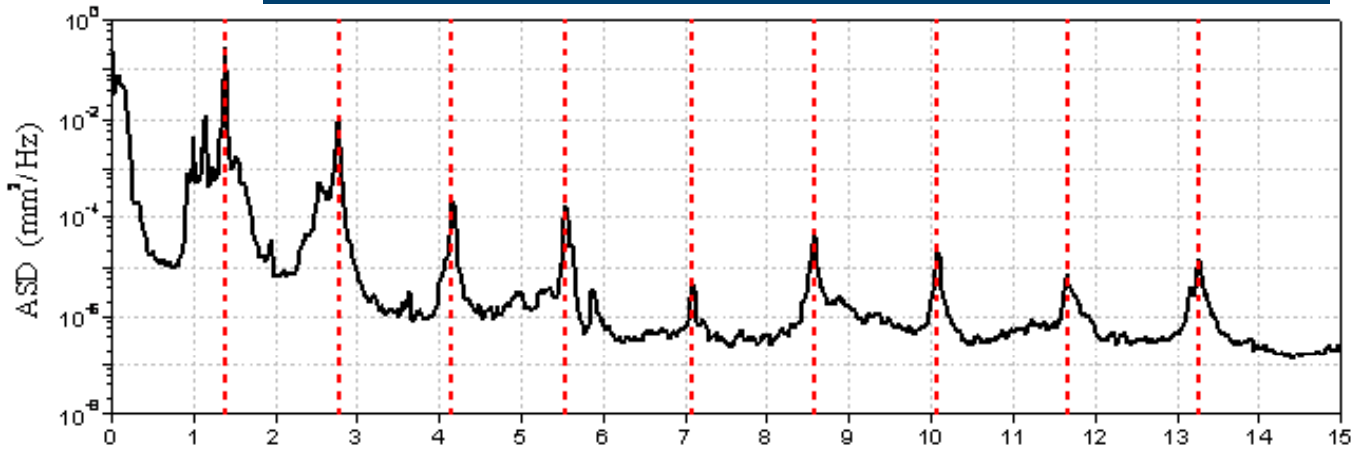
Cable-stayed bridge in Porto Marghera (4)

ASD acceleration (Mestre Side – Stay cable 5)



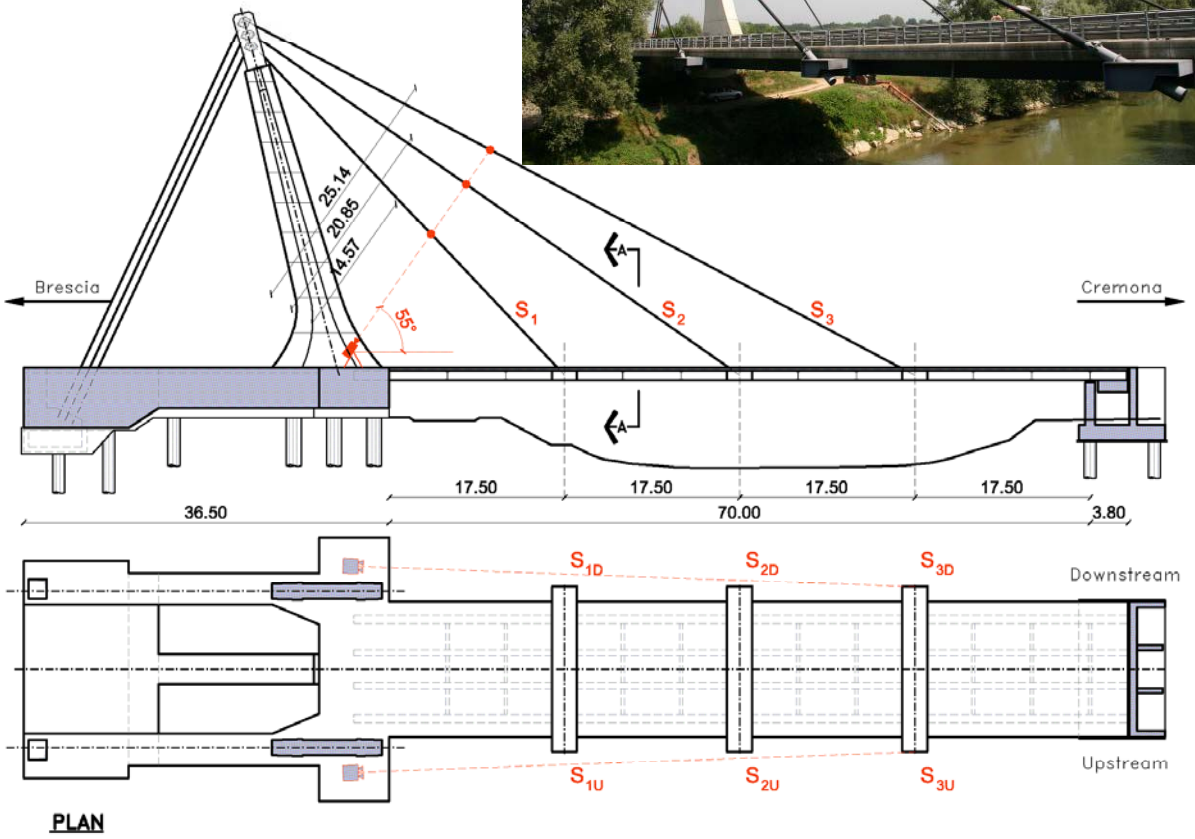


ASD displacement (Mestre Side – Stay cable 5)



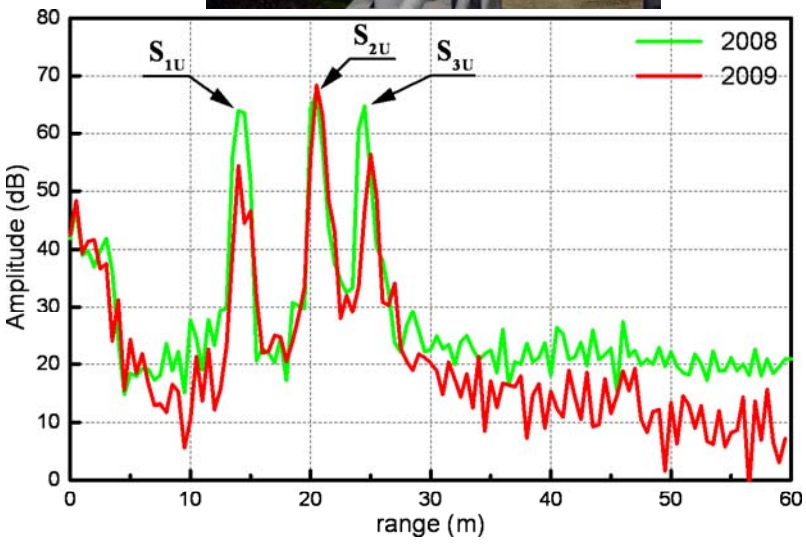
Dynamic measurements on stay cables

Cable-stayed bridge over the Oglio river (1)

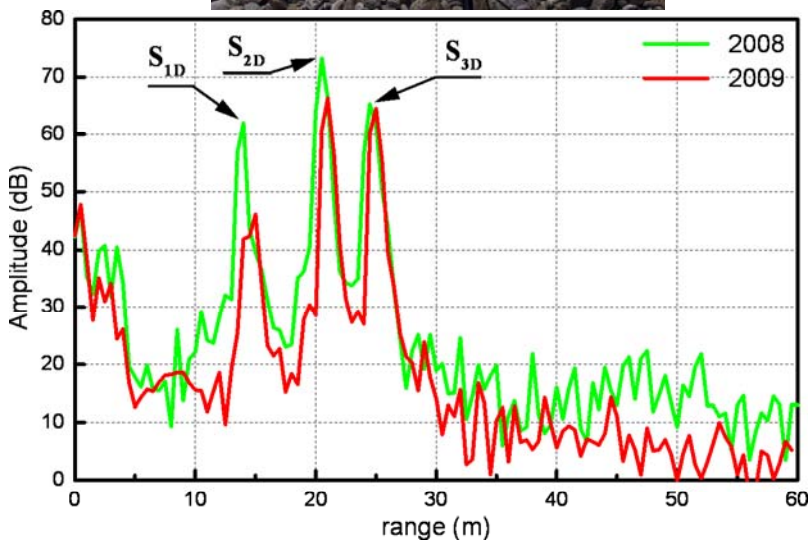


Dynamic measurements on stay cables

Cable-stayed bridge over the Oglio river (2)



Upstream Side

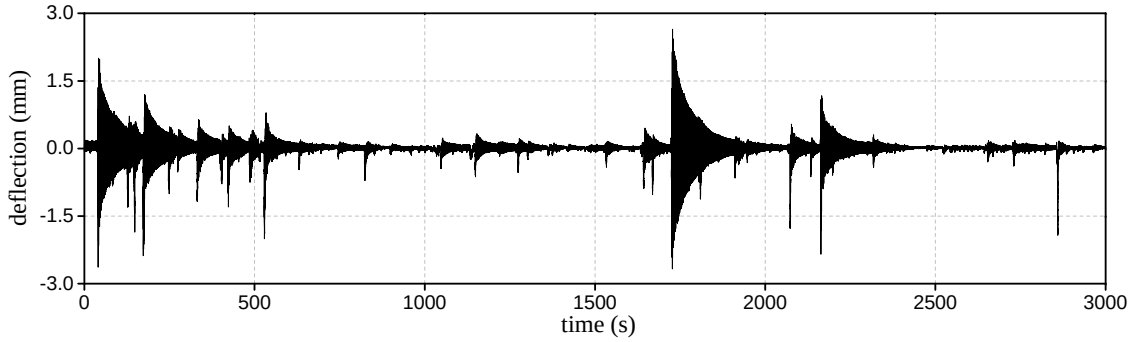


Downstream Side

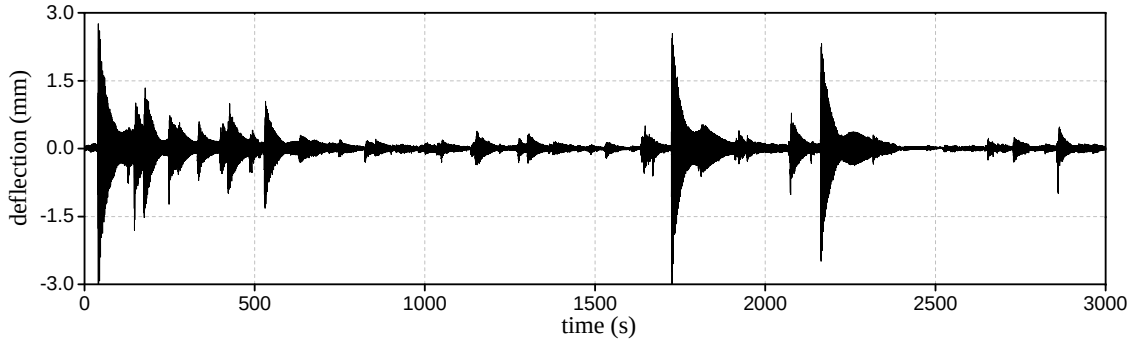
Dynamic measurements on stay cables

Cable-stayed bridge over the Oglio river (3)

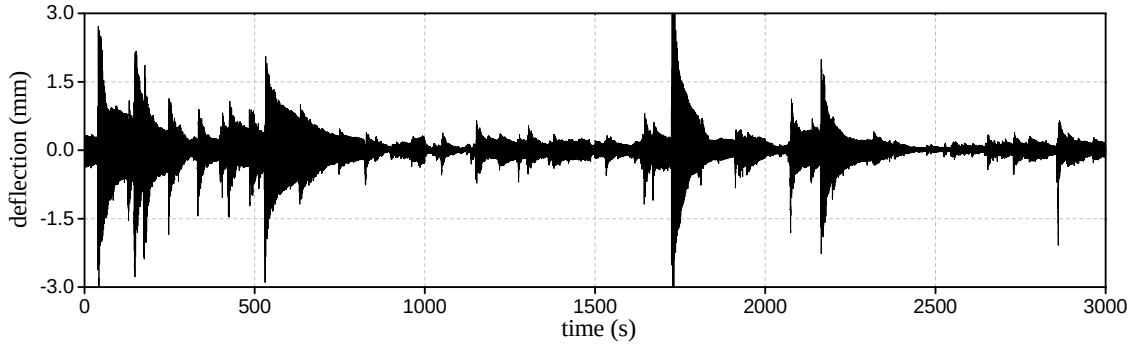
Deflection time-histories of upstream forestays



Stay cable S_{1U}



Stay cable S_{2U}



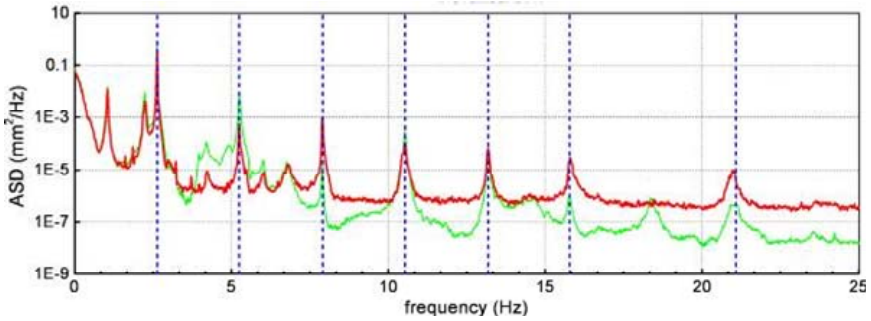
Stay cable S_{3U}

Dynamic measurements on stay cables

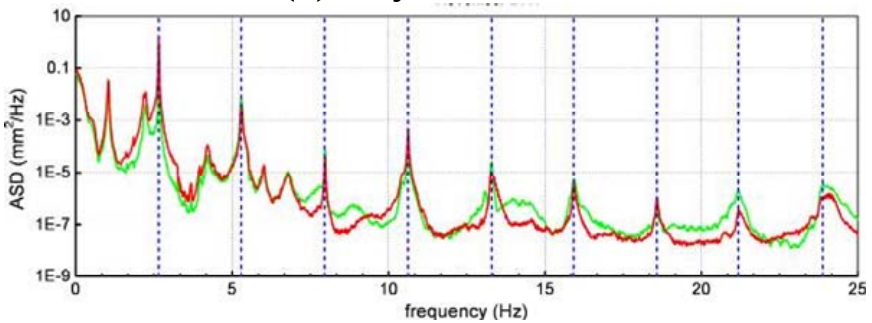
Cable-stayed bridge over the Oglio river (4)

November 2008
November 2009

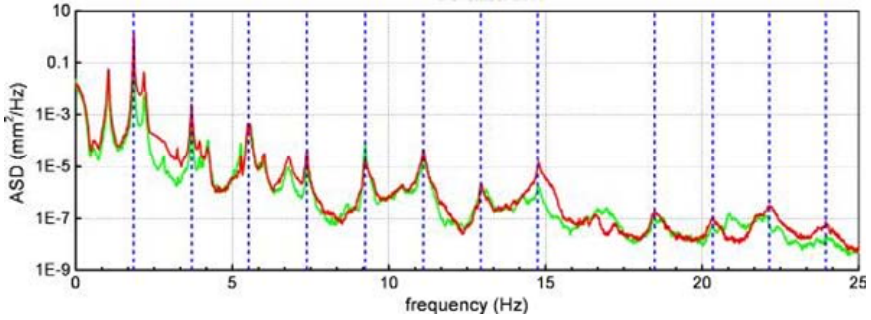
(a) Stay cable S_{1U}



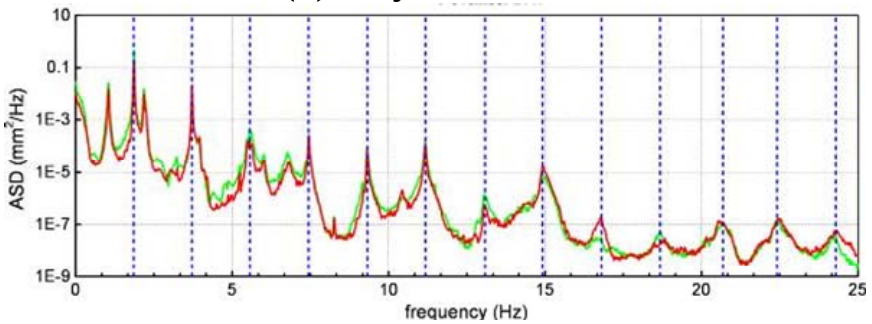
(b) Stay cable S_{1D}



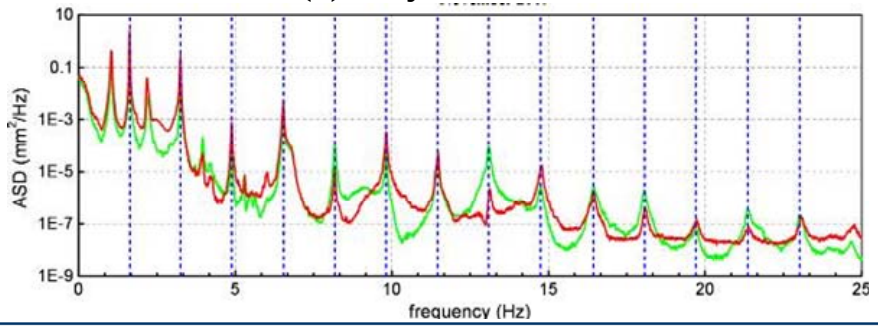
(c) Stay cable S_{2U}



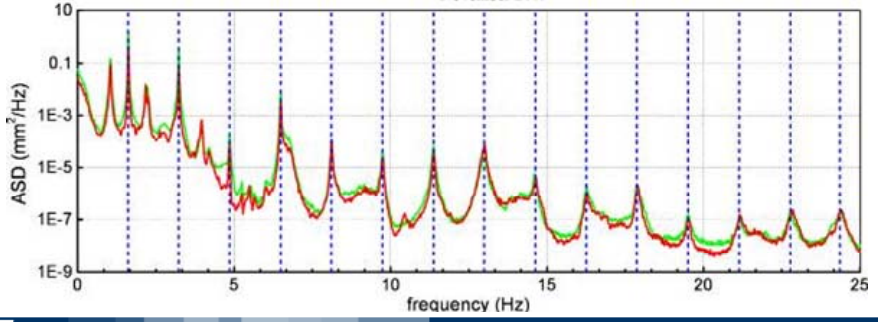
(d) Stay cable S_{2D}



(e) Stay cable S_{3U}



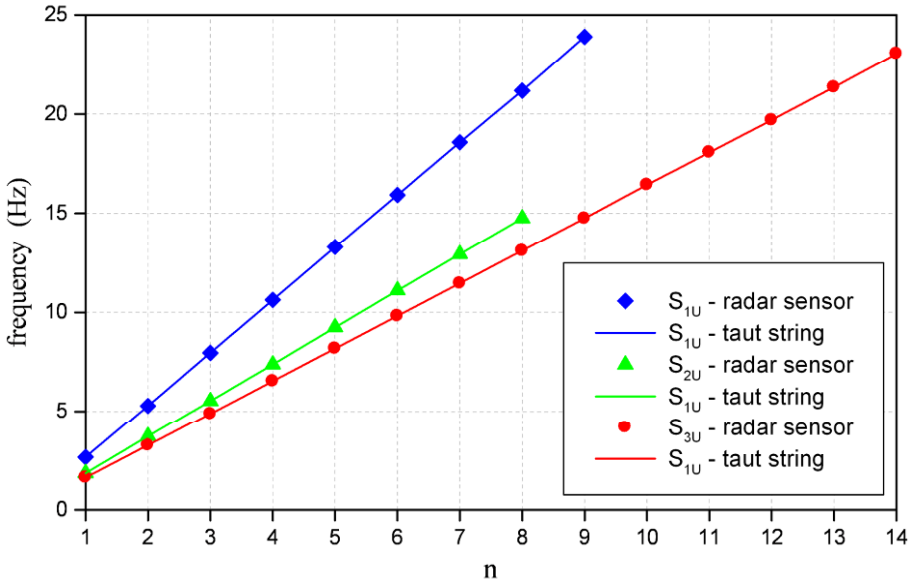
(f) Stay cable S_{3D}

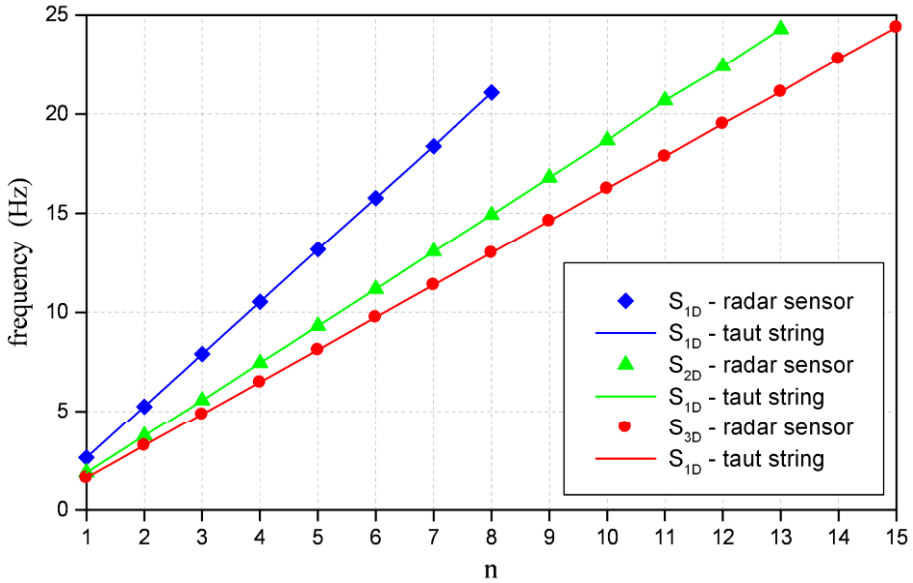


Dynamic measurements on stay cables

Cable-stayed bridge over the Oglio river (5)

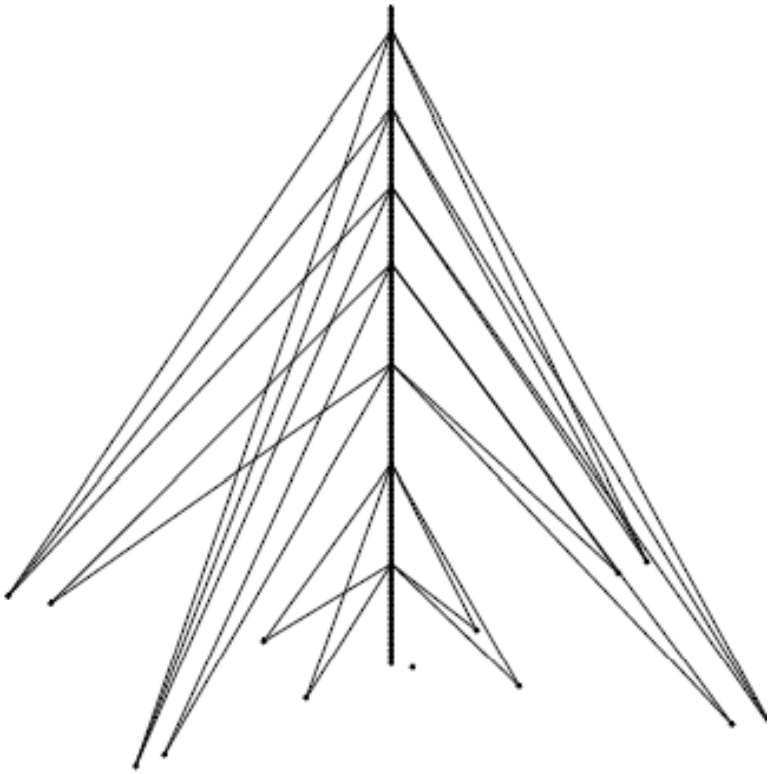
Experimental and taut-string based natural frequencies of the stay cables



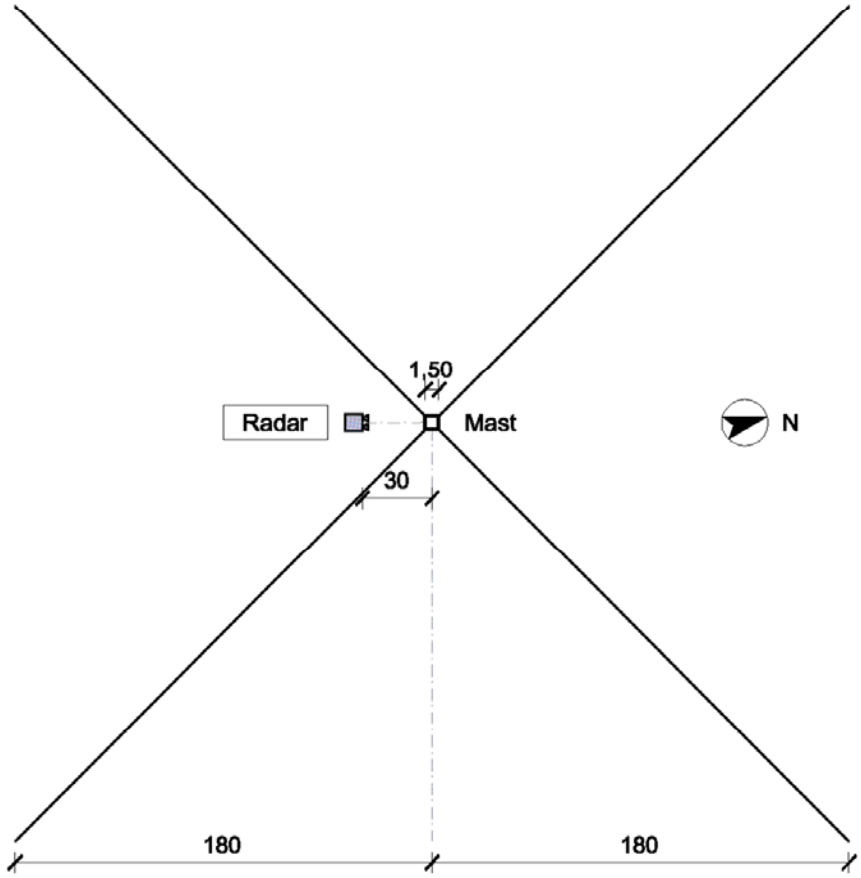


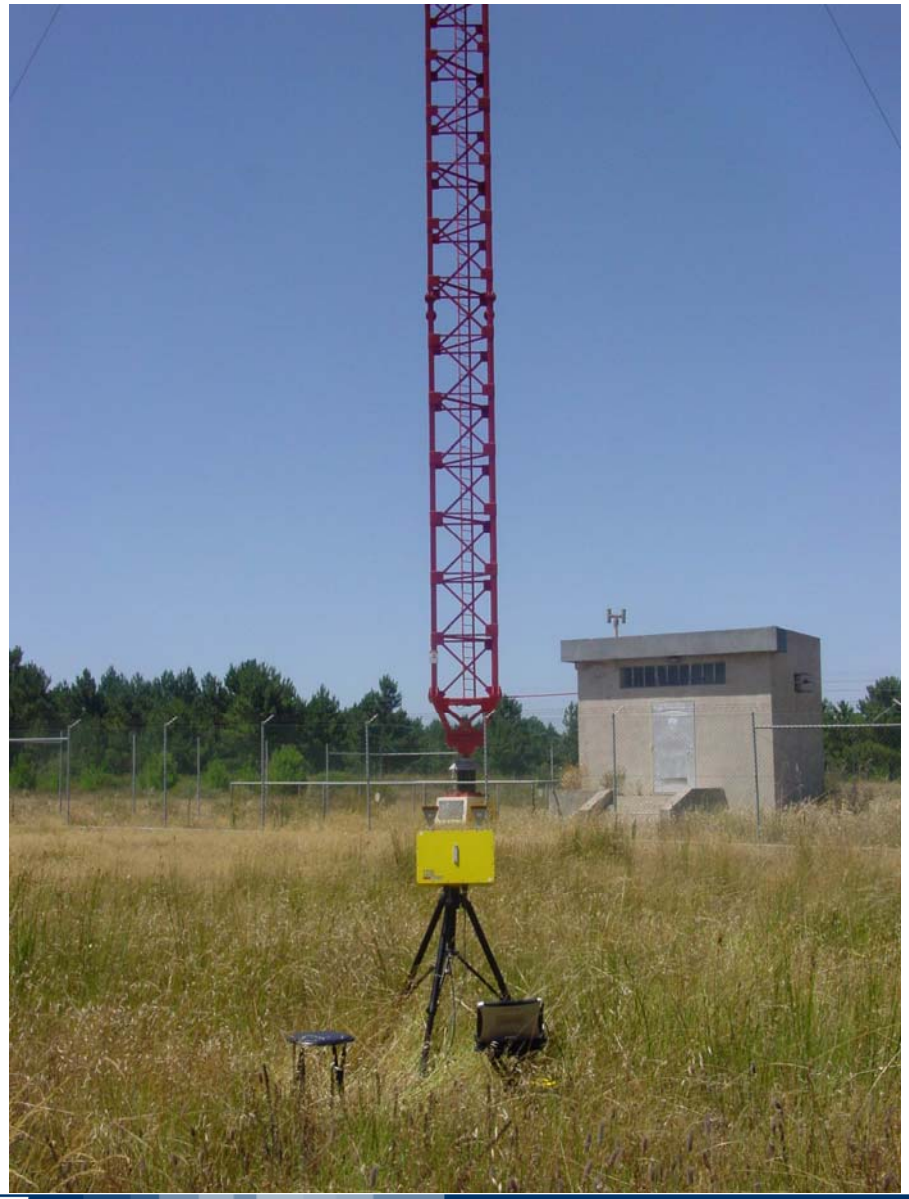
Stay cable	$T(f_1)$ (kN)	$T(f_2)$ (kN)	$T(f_3)$ (kN)	$T(f_4)$ (kN)	$T(f_5)$ (kN)	$T(f_6)$ (kN)	$T(f_7)$ (kN)	Average (kN)
S_{1U}	2704	2692	2712	2716	2722	2716	2715	2711
S_{1D}	2655	2654	2671	2670	2674	2662	2657	2663
S_{2U}	2923	2943	2924	2924	2939	2945	2936	2933
S_{2D}	3003	2982	2949	2982	2986	2982	2995	2983
S_{3U}	4054	4052	4073	4098	4113	4113	4120	4089
S_{3D}	3990	3997	4031	4037	4039	4062	4063	4031

Muge guyed mast (1)

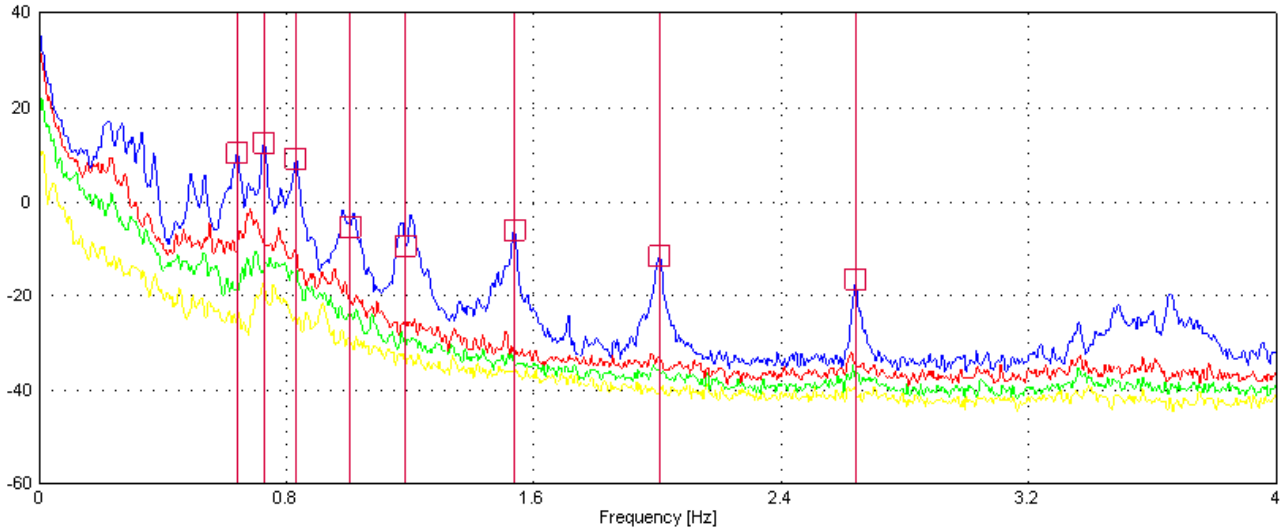


Muge guyed mast (2)

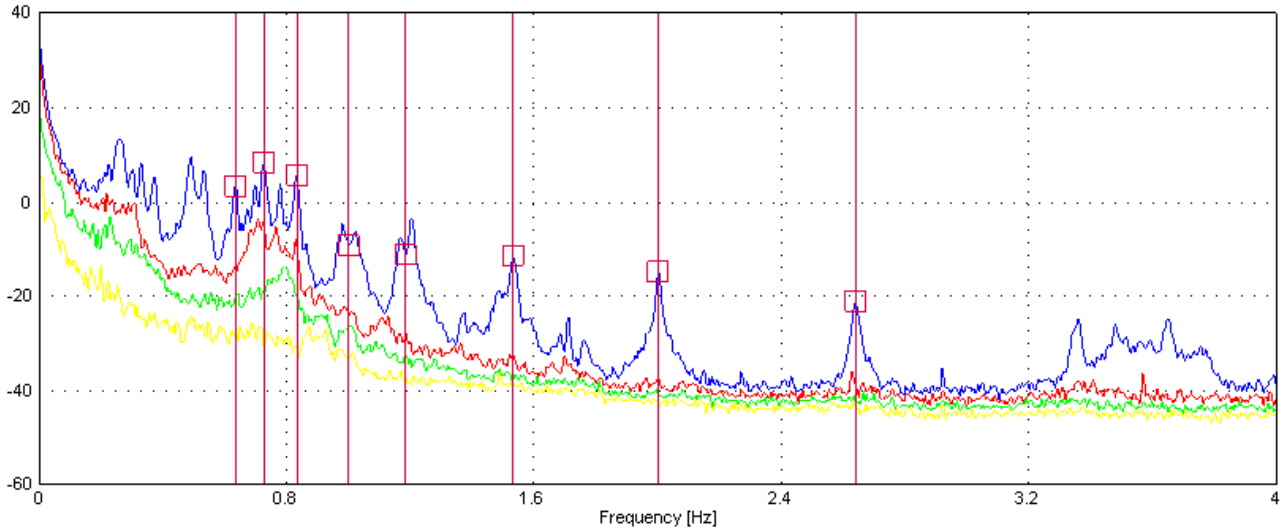




Muge guyed mast (3)

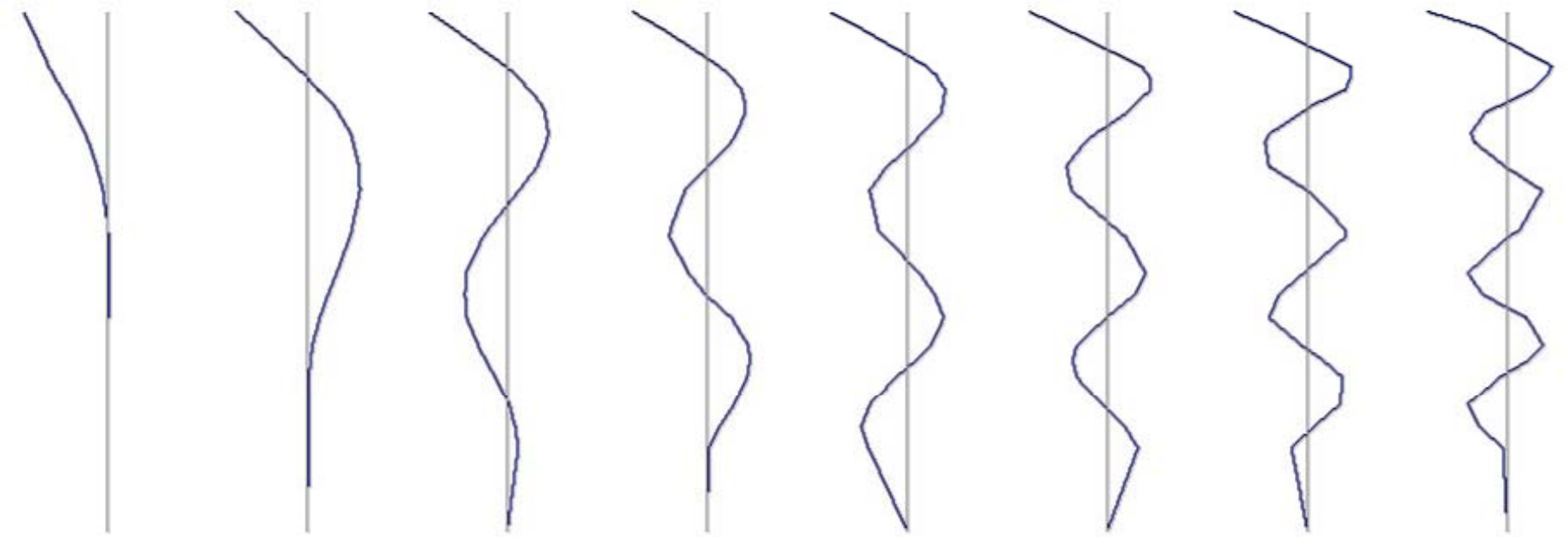


T = 1800 s



T = 3600 s

Muge guyed mast (4)



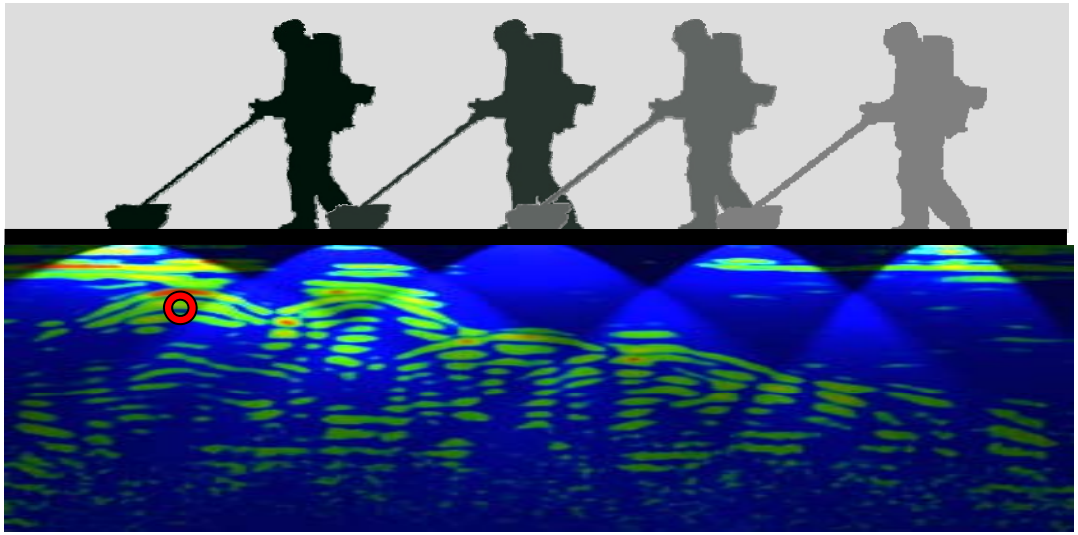
0.640 Hz | 0.728 Hz | 0.830 Hz | 1.006 Hz | 1.187 Hz | 1.538 Hz | 2.007 Hz | 2.642 Hz

CONCLUSIONS

… to be continued

GeoRadar Division

Innovative radar technology for engineering, environment and security



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IDS INGEGNERIA DEI SISTEMI

IDS Ingegneria dei Sistemi S.p.A.

- founded in 1980
- about 380 employees
- core expertise in Applied Electromagnetics, Radar Systems, System Engineering

The offices:

- Headquarter in Pisa - Montacchiello
- GeoRadar office in Pisa - Montacchiello
- Branch office in Rome
- Subsidiary in Brisbane (IDS-Australasia)
- Subsidiary in Southampton (IDS-UK)
- Subsidiary in Sao Paulo (IDS-Brazil)
- Subsidiary in Montreal (IDS-North America)

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Organization

IDS UK | IDS Brazil | IDS North America | IDS Australasia

Local offices across the world provide expertise, services and 24/7 support for industries with time, quality and cost critical requirements.

Highly trained agents and distributors worldwide extend the IDS network over 40 countries.

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IDS INGEGNERIA DEI SISTEMI

Customers

Naval Division

Aeronautical Division

Aeronavigation Division

Georadar Division

IDS Laboratories

Computer Science & Information Technology Lab.

EM Design Framework Lab.	Avionics Lab.	RADAR Systems Lab.	Air Navigation Systems Lab.	Signatures Techologies Lab.

Measurements & Trials Lab.

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IDS INGEGNERIA DEI SISTEMI

Mission

Naval Division

*To provide Navies and Industries with an **innovative design capability** aimed at optimizing ship EM performances and signature control.*

That means:

Maximizing mission success probability

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IDS INGEGNERIA DEI SISTEMI

Mission

Aeronautical Division

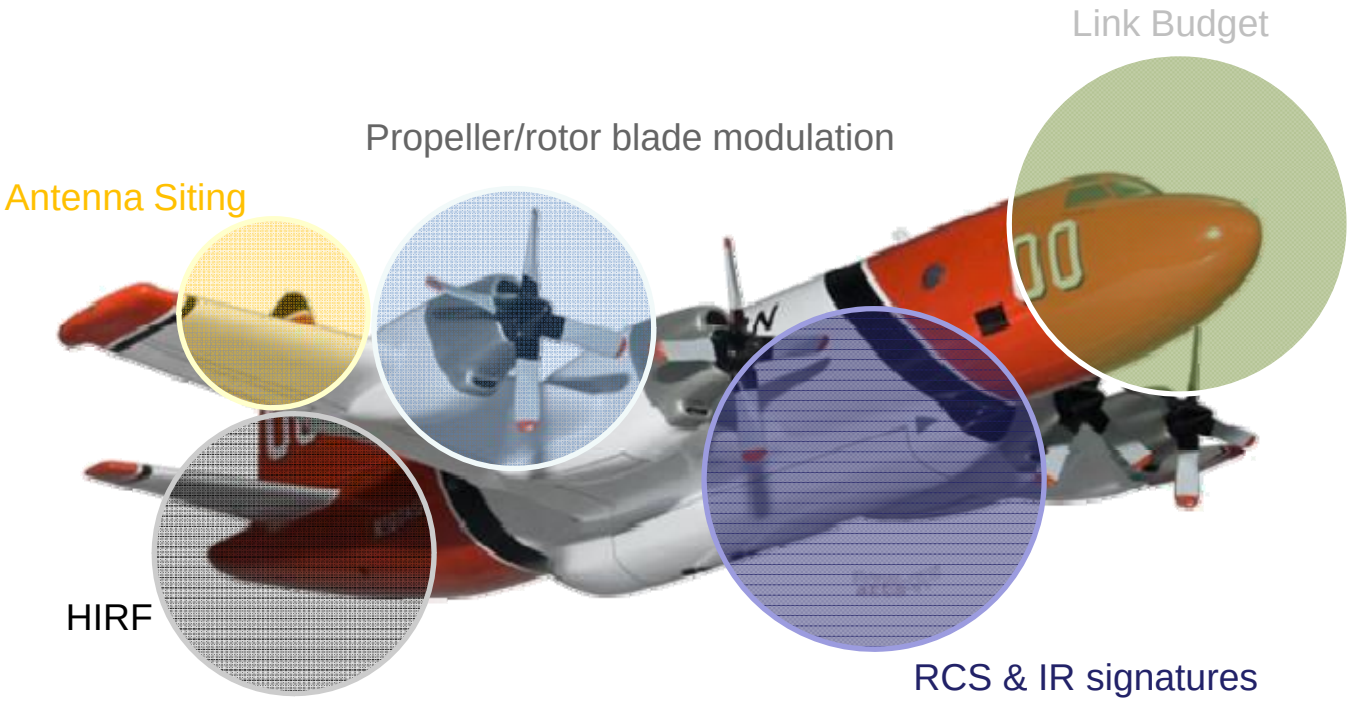
To support governmental authorities and aeronautic industry with product and services aimed at improving design process' efficiency, especially in conceiveng stealth aircrafts .

To provide also flight control systems and avionics design services for fixed/rotary wing platforms and UAVs.

Analysis and EM design

Aeronautical Division

EM design means to deal with the following matters:



*A **different approach** in the design phase, integrating EM simulation and innovative prediction tools ensure the attainmnet of the **desired performances**.*

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Aeronautical Division

Main programs

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IDS
INGEGNERIA DEI SISTEMI

Air Navigation Division

Mission, product

Delivering systems and performing services for the air transport market segment and specifically targeted to Air Navigation Service Providers and Aviation Authorities (Civil, Military)

Systems are mainly **built and maintained in house** with minor off-the-shelf components from third party providers

Operating worldwide through and with the four IDS subsidiaries and through a number of dealers/partners

IDS Aeronavigation Systems are now installed in about **30 countries** for a total of **40 accounts**

"..IDS has the largest installed base of any supplier in the field, including four of the five most influential operators in air navigation. Customers, including all the organisations represented here and more, range from large standard setting ANSPs on four continents to specialist service providers…"

Airnavigation Division

Flexible approach for an “enterprise” solution

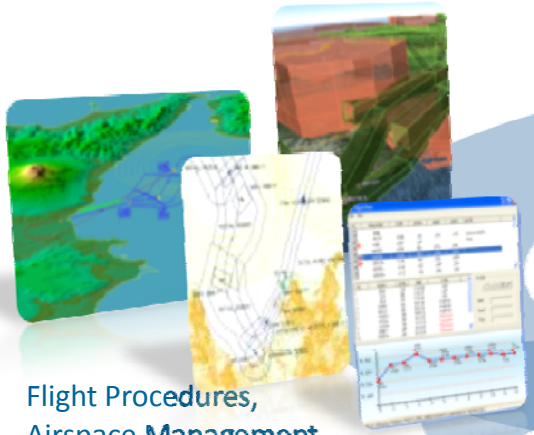
eTOD
Terrain & Obstacle Database
Obstacle Charting

Digital Data Distribution

EAD European AIS Database
ARINC 424, AIXM, DAFIF

Aeronautical
Data Publishing

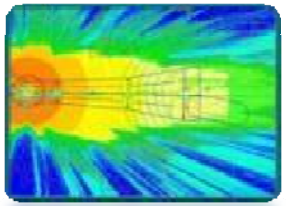
AeroDB
AIS &
Project
Database



Flight Procedures,
Airspace Management

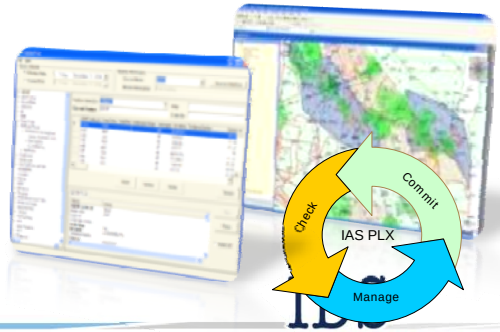
Aeronautical Charting

FPSAT
Flight Procedure Ground
Validation



EMACS
Virtual Flight Inspection

Aeronautical Information
and Workflow Management



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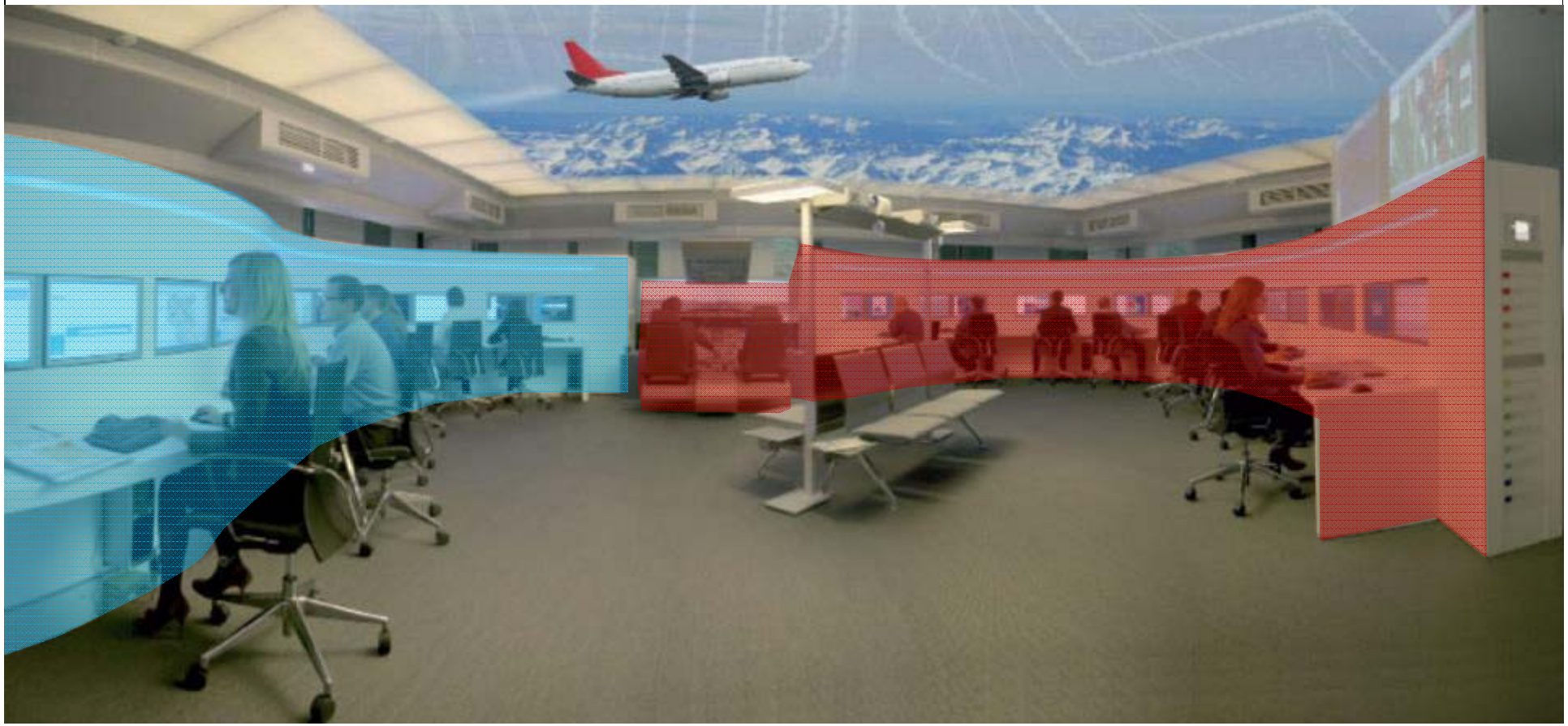
INGEGNERIA DEI SISTEMI

Airnavigation Division

Operational testing room

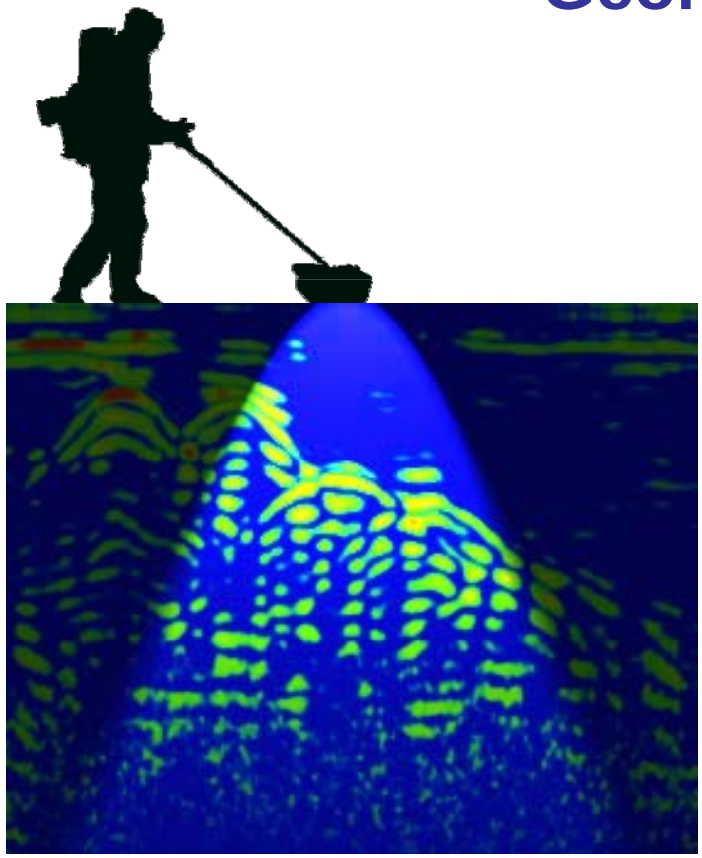
AIS Production Systems
(Information Management and Data Distribution)

Engineering Systems
(Design and Validation)



Mission

Georadar Division



To transfer IDS competencies in the radar field and system engineering to "low power" ***radar systems for engineering, environmental and security applications***

Pursuing the product excellence through the creation of application-specific, innovative products, able to bring valuable benefits to the user

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IDS GeoRadar facts

- ***Leader in Multi-frequency, Multi-channel Ground Penetrating Radar Systems***
  - IDS began to study GPR technology since 1991 in connection with the need of Telecom Italia of improving the capabilities of mapping subsoil Utilities
  - IDS was the first to introduce in GPR market the **multi-frequency**, **multi-channel array** systems, dramatically improving utilities detection performance
  - Since 1999 IDS began the worldwide commercialization of GPR products
  - IDS is now one of the key players in GPR market, with a continuously growing market share
- ***Innovative radar interferometry technology for the Earth Environment***
  - In 2007 IDS introduces IBIS on the market, the first Ground-Based interferometric SAR

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Current worldwide dealers of commercial radar products

(*) In USA IDS is represent by Ditch Witch Subsite Electronics

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Product Lines

Ground Penetrating Radar (GPR):

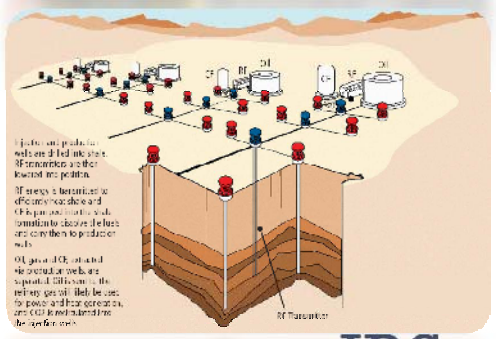
Innovative, application-specific products for geo-applications

Interferometric Radar:

A new approach, through radar interferometric technology, for monitoring ground and structure displacements

Solutions:

Provide high-level, specialized solutions and services, based on the Division technology and know-how



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IDS INGEGNERIA DEI SISTEMI

Product Overview by Application

Utilities

Transportations

Civil and Structures

Geology and Environment

Archaeology and Cultural Heritage

Forensic and Security

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IDS INGEGNERIA DEI SISTEMI

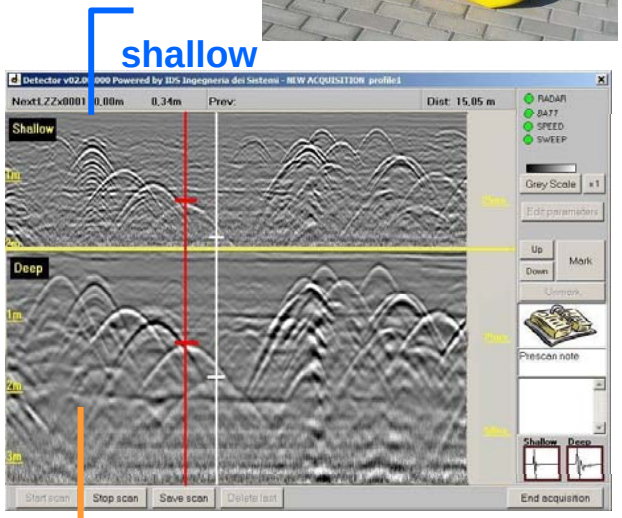
Utilities Detection and Mapping

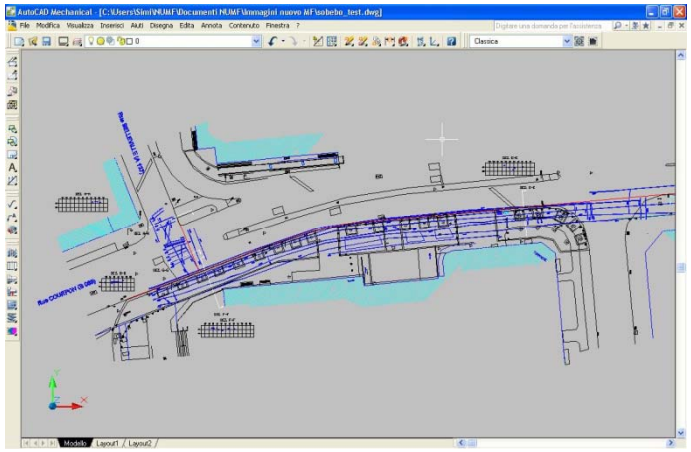
Detector Duo:

real-time detection of pipes

RIS MF Hi-Mod:

Utilities mapping on all zones





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IDS INGEGNERIA DEI SISTEMI

Utilities Detection and Mapping

Stream: massive arrays for the fast mapping of utilities

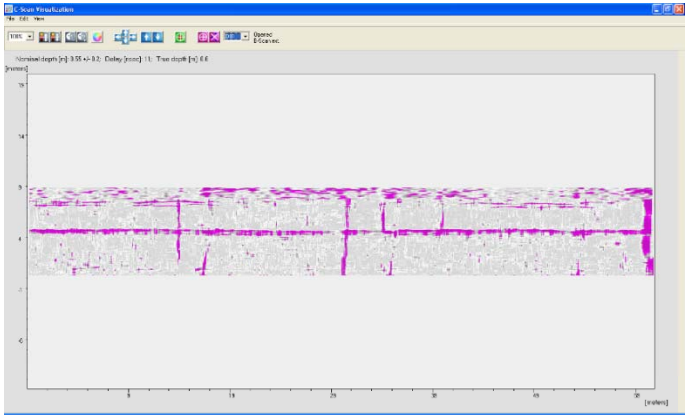
Stream EM:

Vehicle towed array for extensive road utility mapping

Stream MT:

Fast utility mapping for Mini-Trenching applications

Underground road mapping obtained by simple vehicle passages, up to 15 km/h



Mapping by single, longitudinal passage along the trench line

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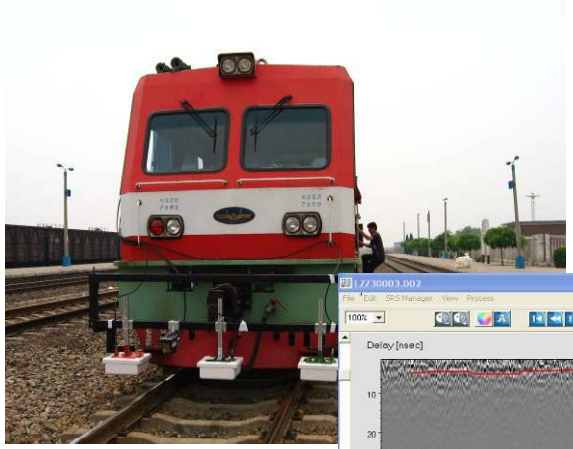
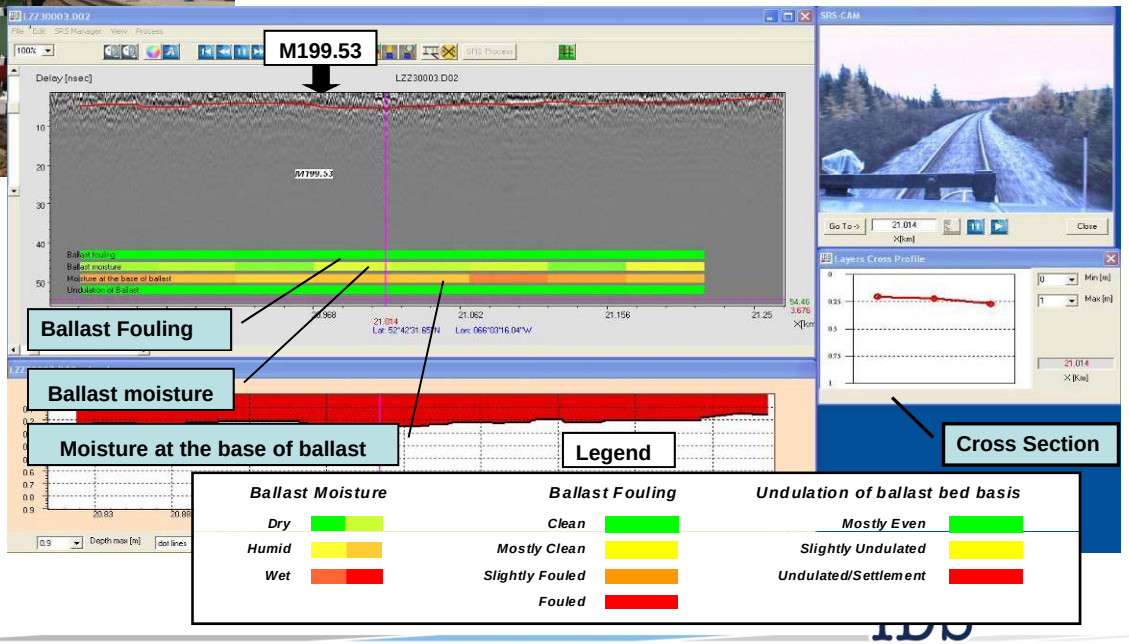
IDS INGEGNERIA DEI SISTEMI

Railway Engineering

SafeRailSystem (SRS):

Continuous mapping of railway ballast status





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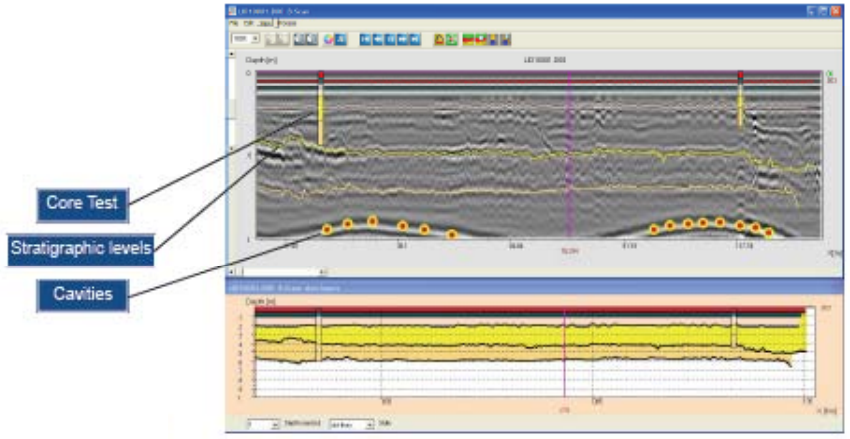
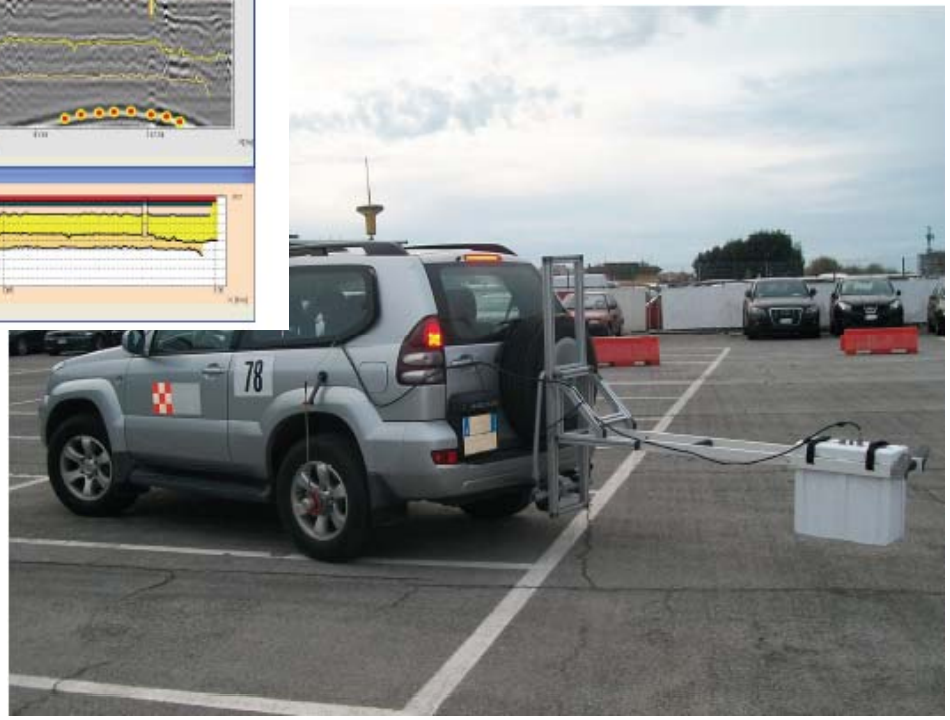
Road Engineering



Imaging of the different levels of the road, with cores and cavities



RIS Hi-Pave:

The fastest and most flexible solution for road assessment surveys

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IDS INGEGNERIA DEI SISTEMI

Civil and Structure Engineering

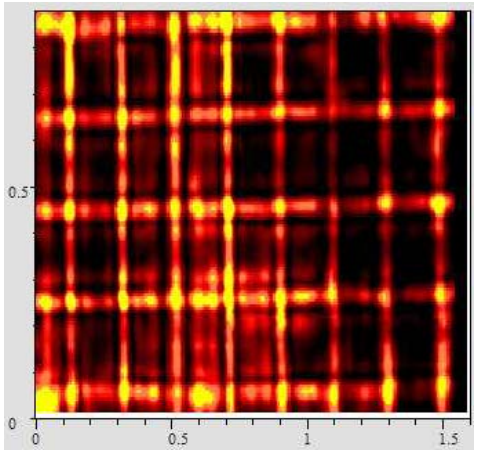
RIS Aladdin:

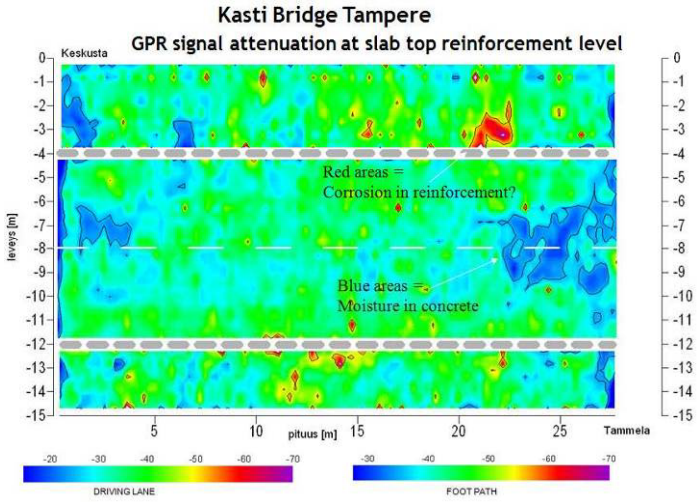
Analysis of the internal status of structures

RIS Hi-BrigHT:

Array for bridge deck survey

Imaging of concrete rebar and internal structures





Bridge deck maps for the evaluation of layer thicknesses, moisture and corrosion damages

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IDS INGEGNERIA DEI SISTEMI

Civil and Structure Engineering:

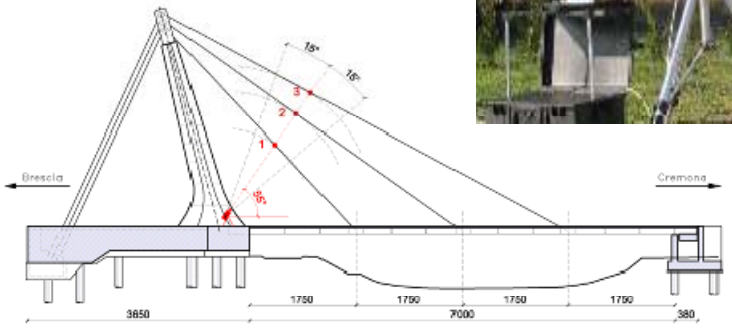
Interferometric Radar: IDS is currently the only one world manufacturer of radar technology for structural displacement applications

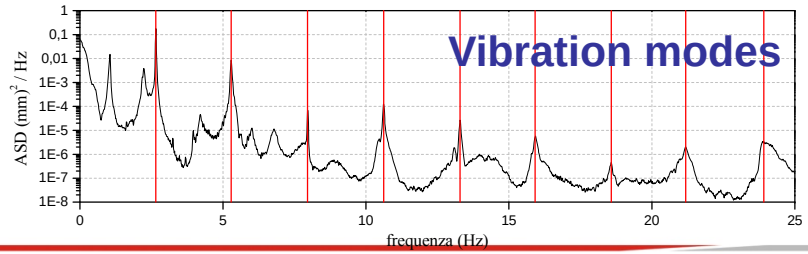
IBIS-S:

Dynamic and static monitoring of bridges and linear structures

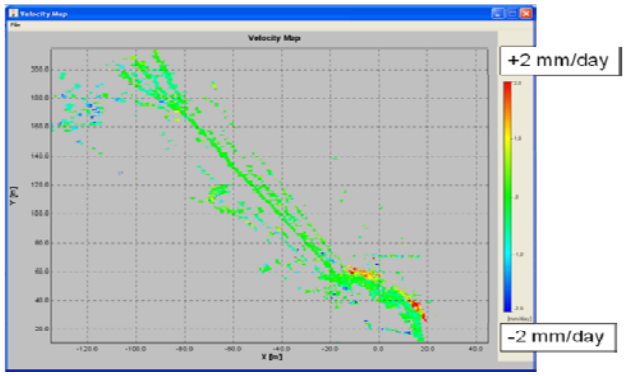
IBIS-L:

Static monitoring of large structures





Vibration modes



Dam displacements

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IDS INGEGNERIA DEI SISTEMI

Geology and Environment

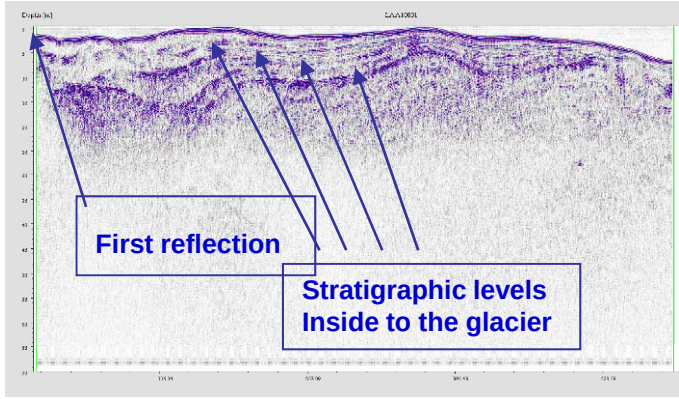
Stream-X:

Fast environment survey and clearance of large areas

RIS ONE-PLUS:

Flexible and complete solutions for geology

Tomographic maps showing archeological structures in large areas



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IDS INGEGNERIA DEI SISTEMI

Geology and Environment

IBIS-M, a dedicated configuration to enter into the Mining Market

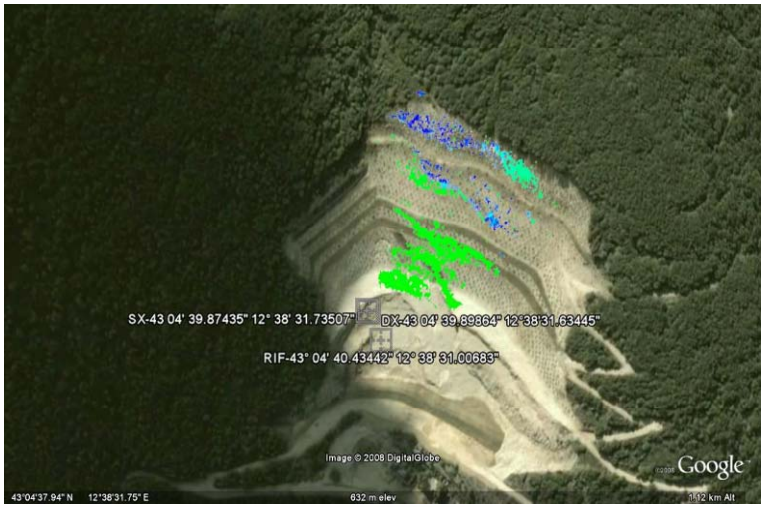
IBIS-L:

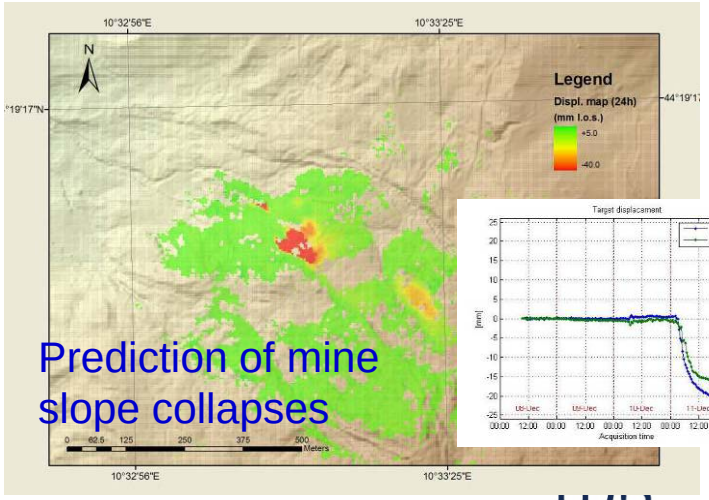
Monitoring of landslides

IBIS-M:

Early Warning for mine slope instabilities

Slope displacement map overimposed on a Google picture





Prediction of mine slope collapses

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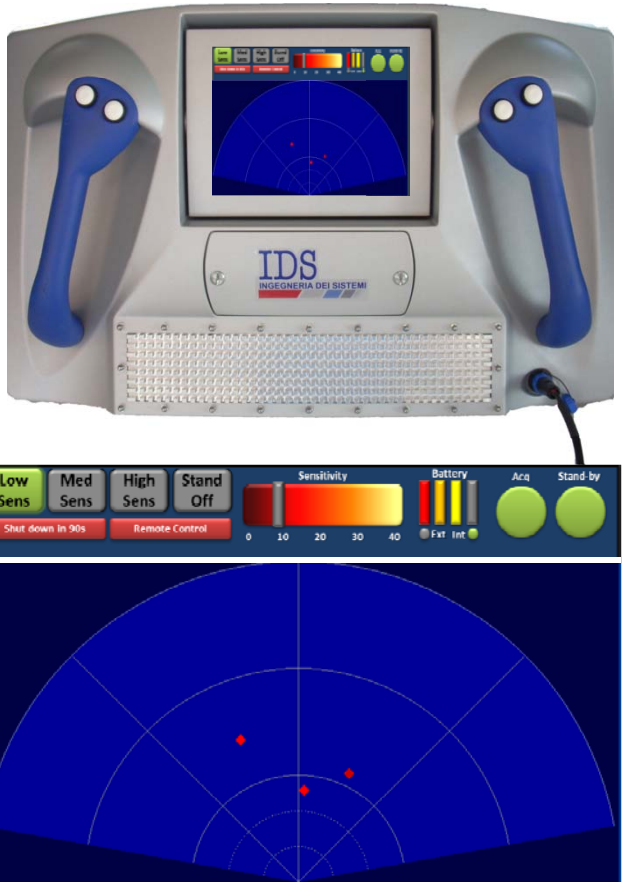
Forensic and Public Security

Sila system:

Location of cavities, tunnels, buried bodies



TWR

(Through Wall Radar);

(under development)

Location of people behind walls

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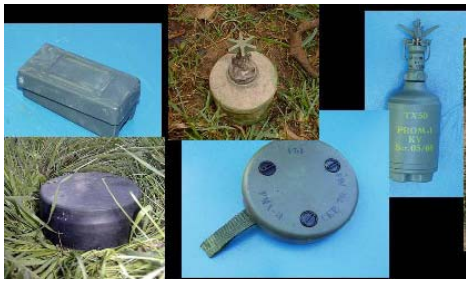
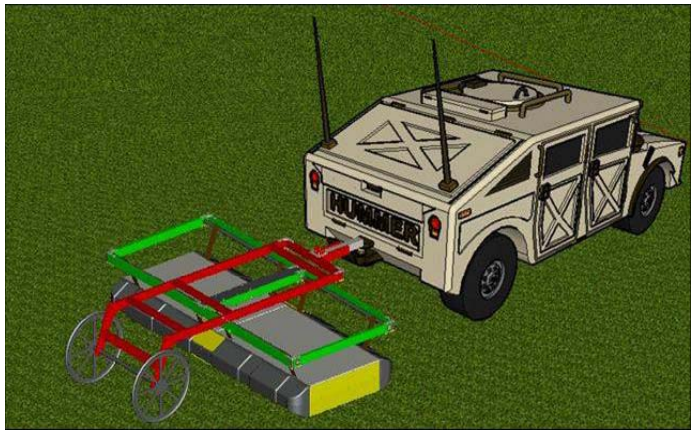
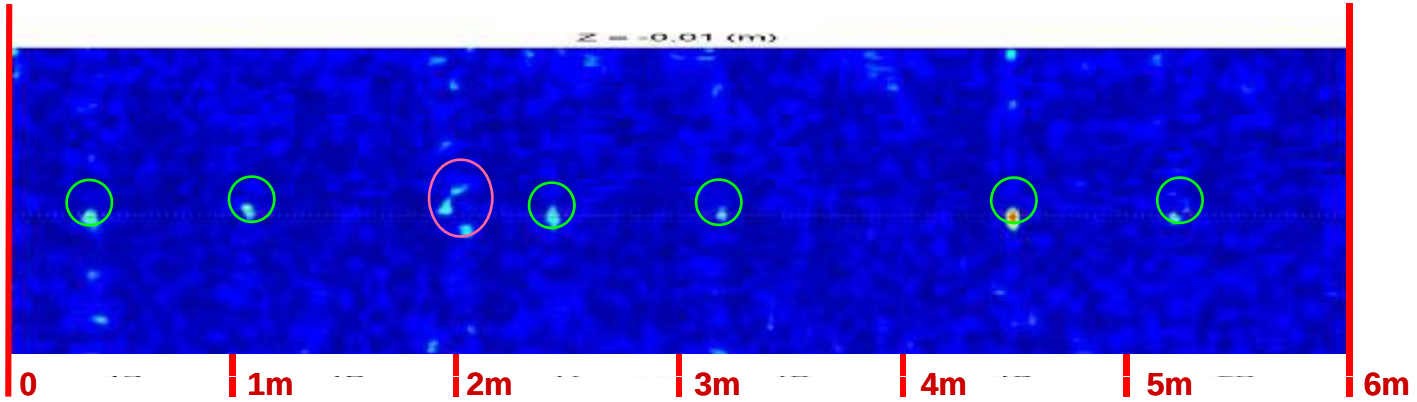


IED/UXO/mine detection



Configuration proposed for IED (Improvised Explosive Device), UXO (Unexploded Ordnance) and mine detection (under development)



Focalised GPR data at shallow depth

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UTILITIES DETECTION AND MAPPING

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SPECIALIZED SOLUTIONS FOR EACH APPLICATION

UTILITY DETECTION AND MAPPING

- Real Time Detection
  - DETECTOR DUO
  - Add on for PIT TEST
- Detection and Mapping
  - RIS MF Hi-Mod
- Mapping for Trencher
  - EXPLORER
- New Product for extensive utilities mapping
  - STREAM

IDS INGEGNERIA DEI SISTEMI

Detector Duo

A dual frequency antenna radar for detecting metallic and non-metallic pipes.

Collapsible trolley, easy to transport and assembly.

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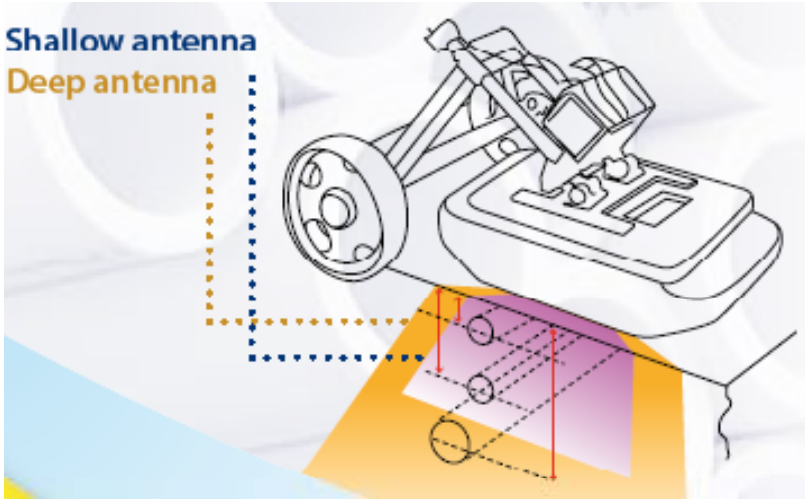
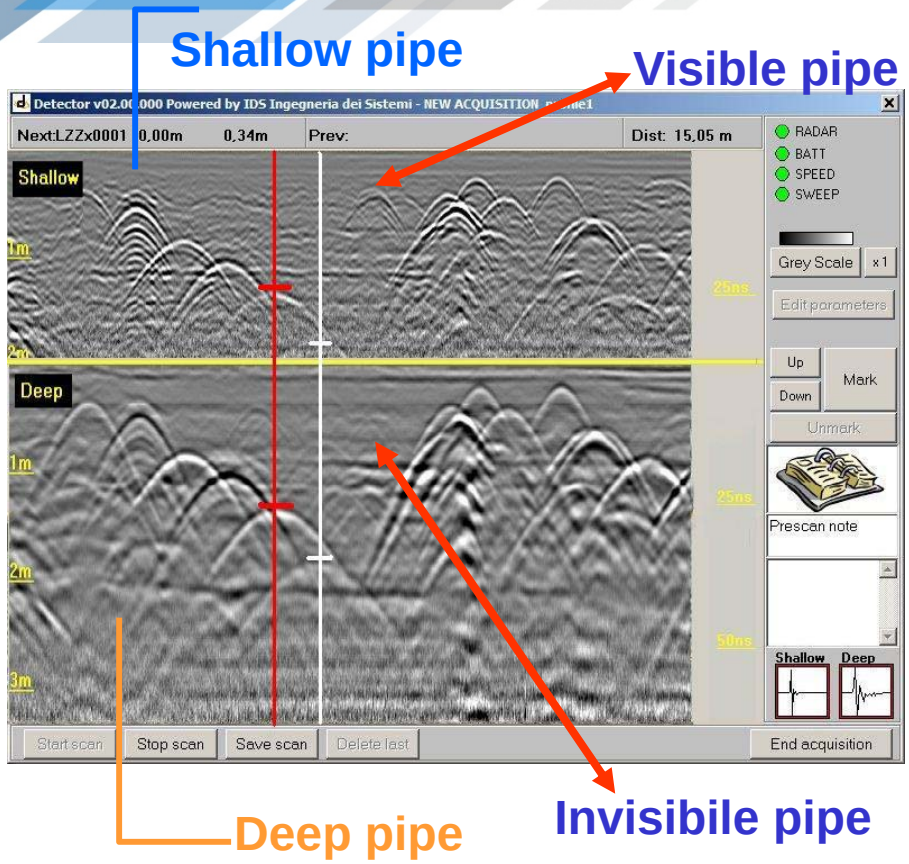
IDS INGEGNERIA DEI SISTEMI

Innovative Features

- Deep and Shallow antennas in one compact box (250 – 700 MHz)
- Antenna footprint: 60x37 cm
- Real time display of deep and shallow channels in the same screen





- Highest performance with simultaneous display of deep and shallow pipes
- Highest productivity with a single scan
- Only 30 minutes training required

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RIS MF Hi-Mod

The only end-to-end “industrial” solution for accurate utility mapping

- 4 dual frequency antennas (200 MHz and 600 MHz)
- 2 m wide Antenna Array for 3D mapping
- Modular design suited to urban environment and narrow passages
- High productivity post-processing SW
- CAD/GIS automatic rendering
- Data Base for rational storage of large quantities of data

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IDS INGEGNERIA DEI SISTEMI

MODULAR COMPOSITION and UPGRADABILITY

CONFIGURATION MODEL	ANTENNAS	PICTURE	UPGRADABILITY
BASIC RIS MF Hi-Mod #1	1		
INTERMEDIATE RIS MF Hi-Mod #2 or RIS MF Hi-Mod #3	2 or 3		
FULL RIS MF Hi-Mod #4	4		

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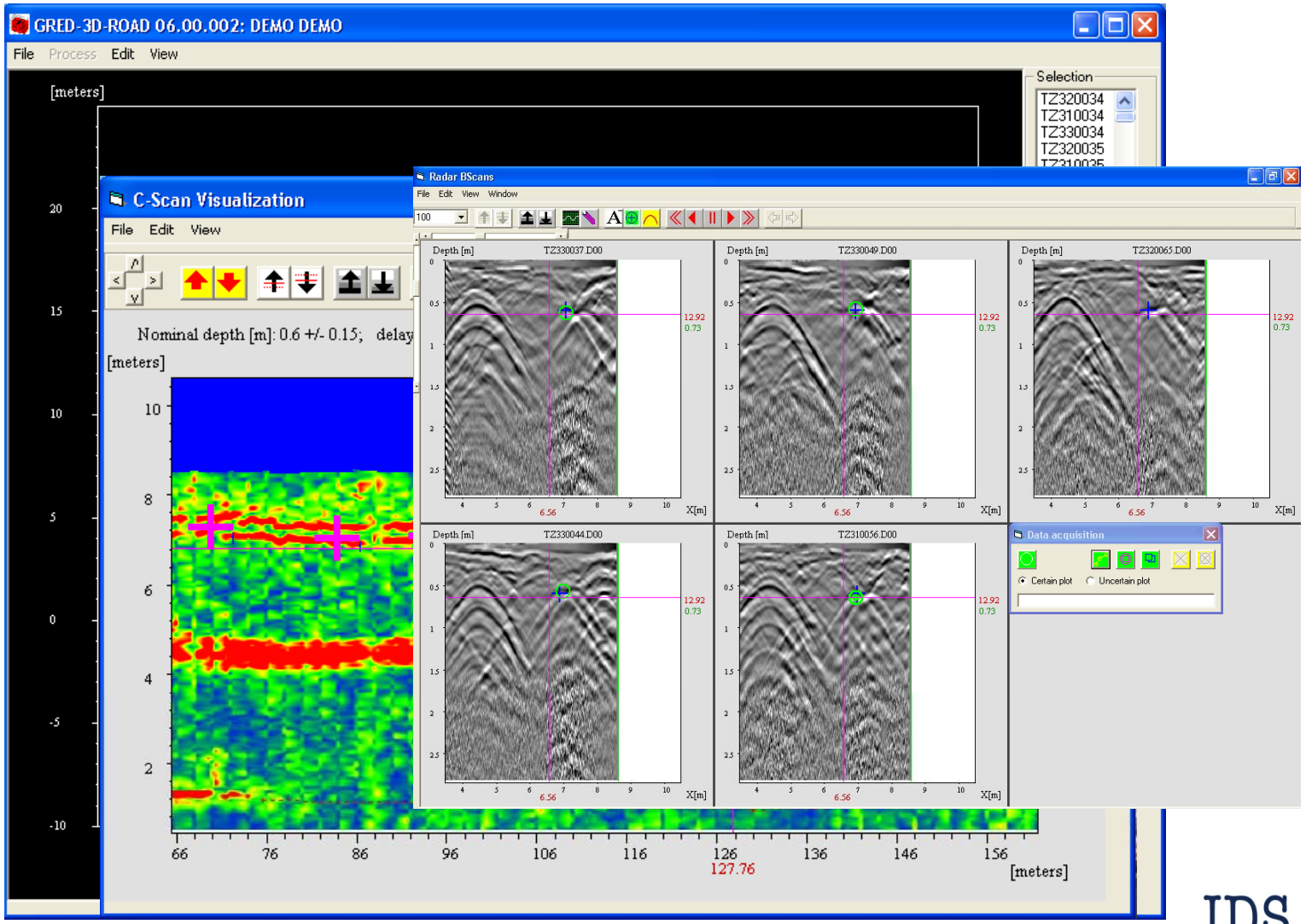
GRED 3D UTILITIES: POST PROCESSING SOFTWARE

Automatic target detection



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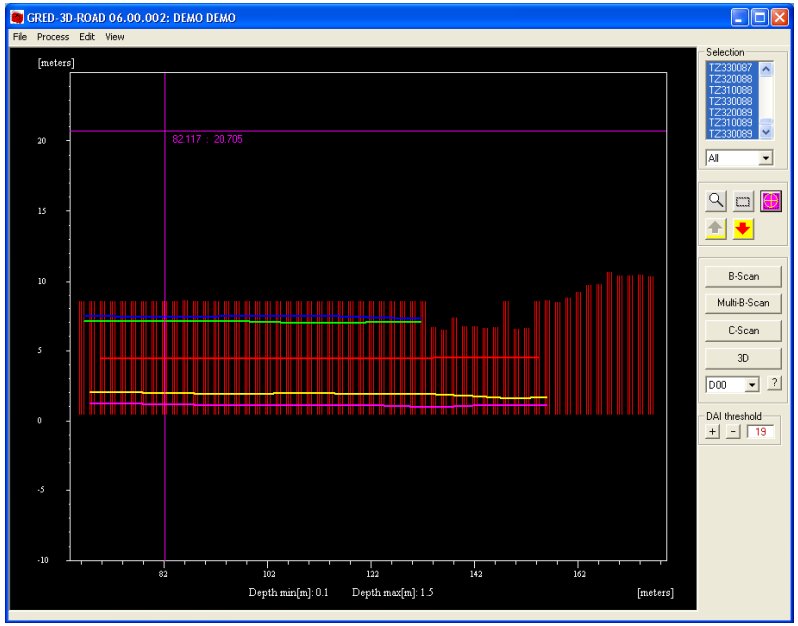
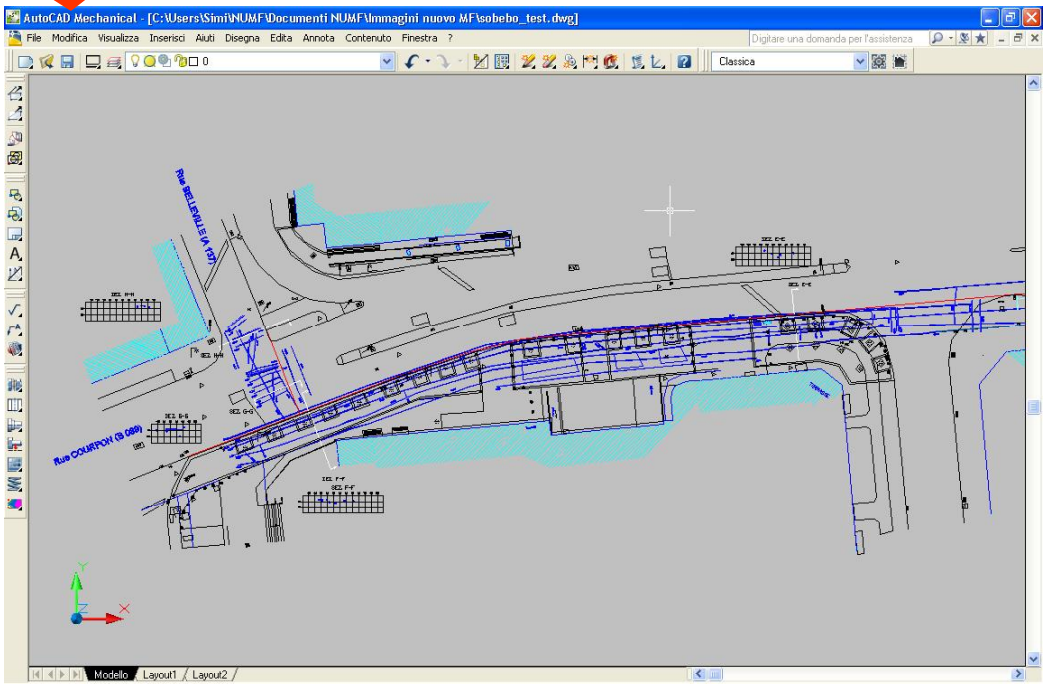
IDS INGEGNERIA DEI SISTEMI

GRED 3D UTILITIES: POST PROCESSING SOFTWARE





Export data to CAD

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IDS INGEGNERIA DEI SISTEMI

STREAM family

IDS innovative solutions for "*massive array*" radar

Stream-EM

Stream-X

Stream-MT

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IDS INGEGNERIA DEI SISTEMI

STREAM philosophy and user BENEFITS:

"Making possible what was only a dream"

- Stream is a new family of products based on arrays of large numbers of antennas (20-50; "massive arrays") with unique features, such as:
  - High acquisition speed
  - Multi-frequency or multi-polarization
  - Dense sampling
  - Highly reconfigurable
  - Modular architectures
- User benefits:
  - High field productivity (avoiding many scans, transversal scans etc.)
  - No need to block traffic in road surveys
  - High quality of data
  - Adaptable to other applications with suitable kits (archaeology, environment)
- **Sets new standards in utility mapping accuracy and productivity**

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The core of *STREAM* technology

- The new DAD Fast Wave control unit:
  - High acquisition speed
  - High number of antenna channels (“massive arrays”)
  - “Networking” of up to 4 DAD’s for driving multiple arrays
- Antenna technology:
  - Antenna arrays specifically designed (not just the collocation of standard antennas)
  - Compact antennas enabling the construction of very dense arrays
  - Ability to put together antenna at different frequencies or polarization
  - Large bandwidth and efficiency giving high data quality

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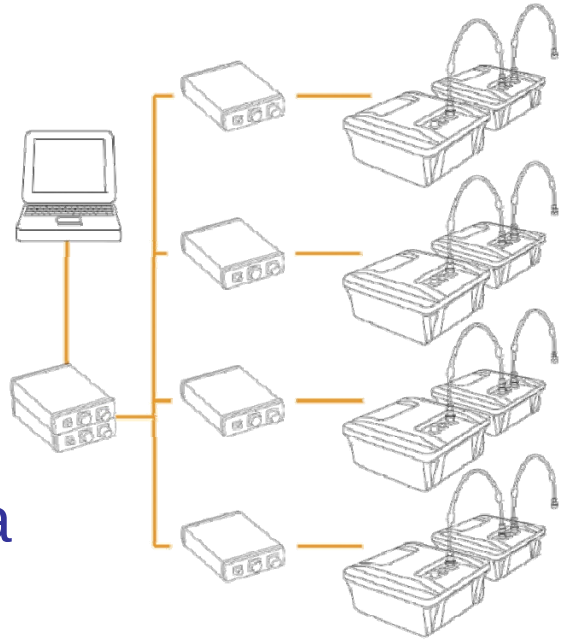
FAST WAVE : the new DAD control unit

New DAD FastWave unique features:

- 6 times faster than the previous DAD K2
- The fastest control unit on the market:
  - 4760 scan/sec @128 samples
  - 2 channels acquired simultaneously
- Chain connection:
  - Antenna elements connected in “cascade”
- Multiple DAD can be synchronized in a “network of DAD’s”



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IDS INGEGNERIA DEI SISTEMI

The *STREAM* family for utilities mapping

The STREAM family includes currently the following solutions:

- ***STREAM-EM***: the solution for extensive utility mapping
- ***STREAM-MT***: the solution supporting micro and minitrenching

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STREAM-EM

IDS INNOVATIVE SOLUTION FOR EXTENSIVE UTILITY MAPPING

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IDS INGEGNERIA DEI SISTEMI

STREAM-EM: main benefits

- GPR solution towed by a vehicle (speed > 15 Km/h).
- Data collection in longitudinal direction (without the need of moving the array in the transversal directions) but detection of utilities and connections.
- High productivity
- High modular structure
- High detection capability
- Avoid blocking the road traffic
- Exploit the same advanced processing feature of RIS MF Hi-Mod
- Possibility of different kind of towing frames

Stream EM System: complete configuration with 3 array of antennas

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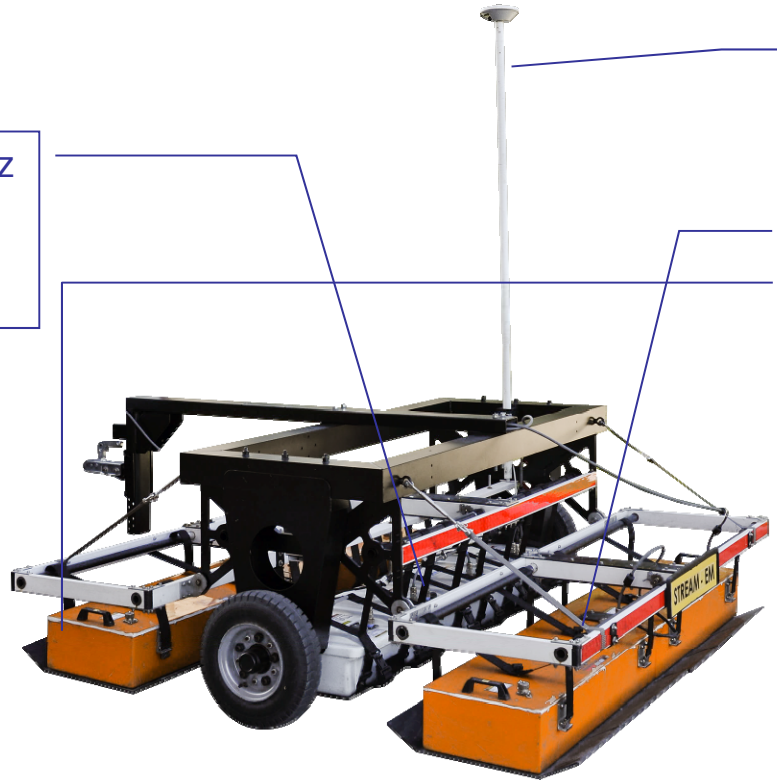
IDS INGEGNERIA DEI SISTEMI

STREAM-EM: modularity and array architectures

GPS or Total Station

4 dual frequency 200-600 MHz antennas (DCL array) for the detection of shallow and deep junctions (HH polarization)



1x200 MHz DML array for detecting main pipes along the road (6 cm transversal sampling; VV polarization)

MF Hi-Mod: the DCL array can be extracted from the Stream-EM to be used in the MF Hi-Mod configuration for mapping sidewalks and areas with difficult accessibility.

Stream X: the DML array can be extracted from the Stream-EM to be used in the Stream-X configuration for archeology or environment surveys.

Modular composition: easily reassembled

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IDS INGEGNERIA DEI SISTEMI

STREAM-EM: Trolley easily collapsible

- Stream-EM trolley permit to adjust the distance of each array module from the soil
- DML 1 and DML 2 antennas can be collapsed up to 90° to reduce the overall dimension of the trolley
- Stream-EM trolley can be connected to any car or van with drag-hook
- The collapsed trolley can be easily stored in the van for transportation

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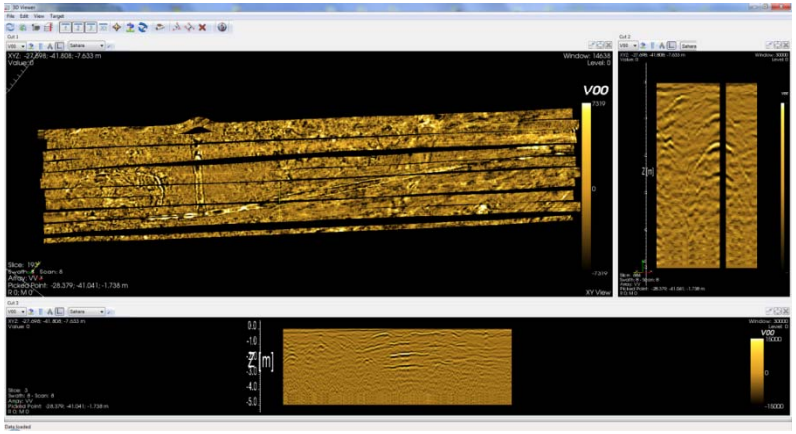
IDS INGEGNERIA DEI SISTEMI

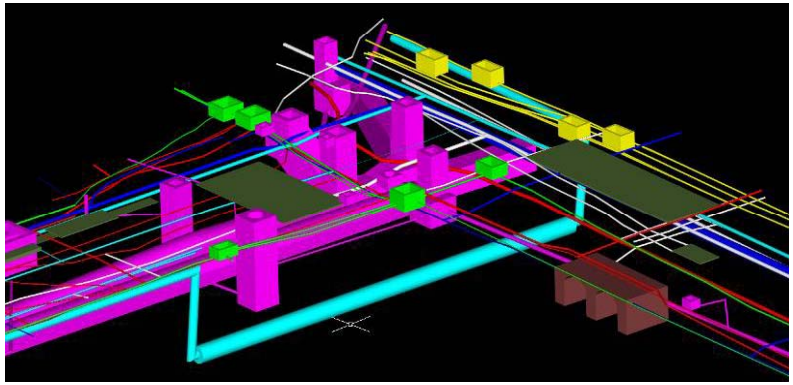
STREAM-EM: Work Flow

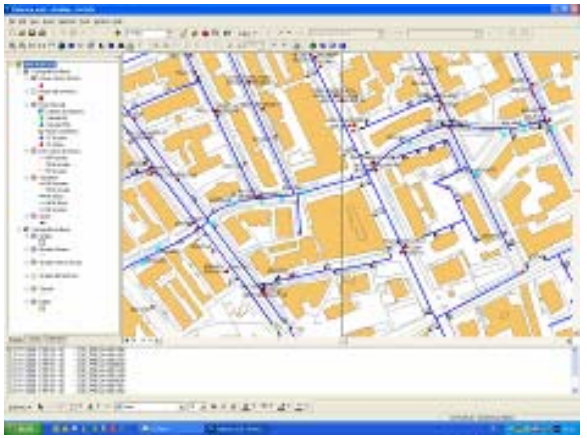
1. Data acquisition

2. Data processing (office)



3. 3D view of the utility network in CAD/GIS environment





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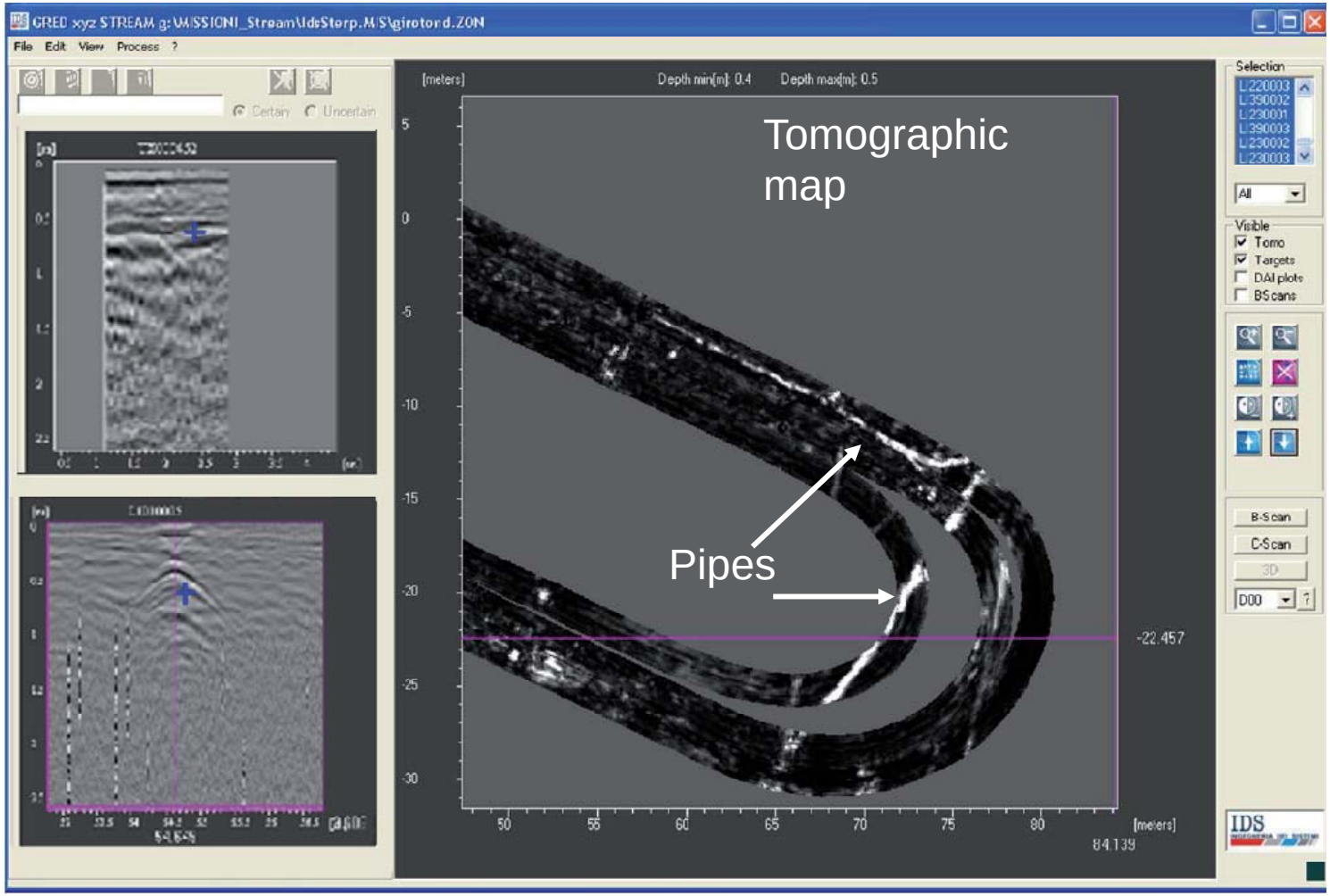
IDS INGEGNERIA DEI SISTEMI

GRED 3D Utilities STREAM: the post processing software

Transversal map

Longitudinal map



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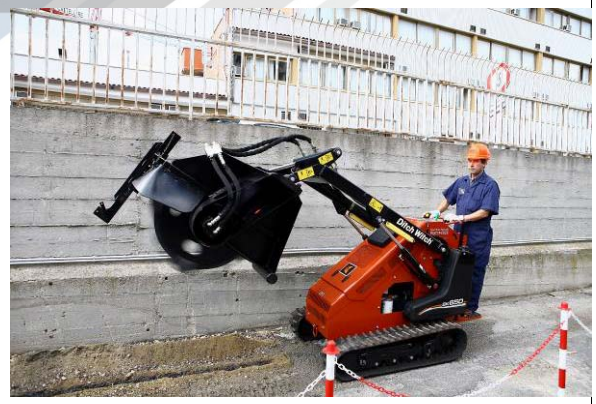
IDS INGEGNERIA DEI SISTEMI

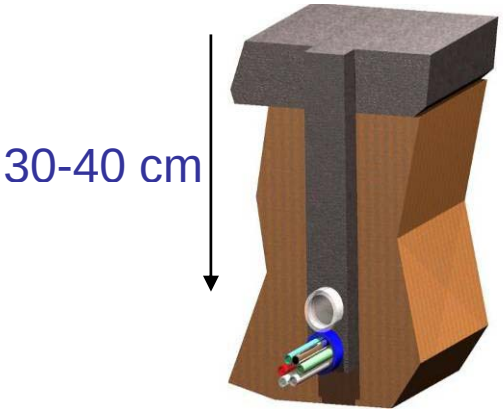
STREAM-MT:
dedicated solution for Mini/Micro Trenching technology



• Micro and Mini trenching is a new installation technology, alternative to the traditional excavation and No-Dig solutions, offering lower costs and lower environmental impact. This new technology is mainly suitable for the following new installations:

- TLC cables
- Public illuminations
- Video surveillance
- Traffic lights cables.

5 up to 30 cm



30-40 cm

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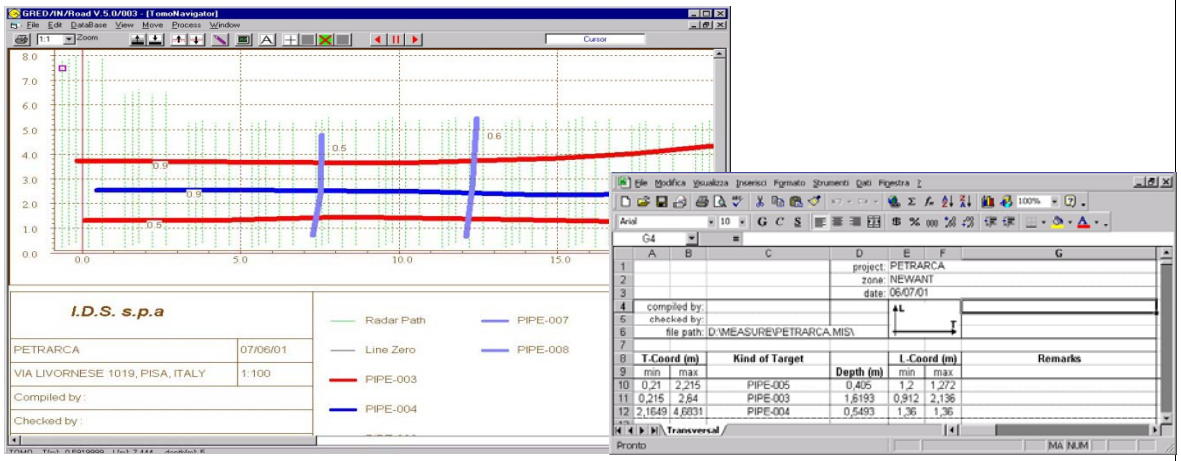
IDS INGEGNERIA DEI SISTEMI

STREAM-MT: main benefits

- Data collection only with longitudinal scans: no need of transversal scans
- With only one scan you can detect all the main pipe and connections
- High detection capability: very shallow pipes and cables thanks to the unmatched data density and the double polarization.
- High resolution capability: 1 GHz array of antenna
- Compact and easy to move in narrow area
- Processing software allowing an efficient representation of the end results

Stream MT: acquisition unit



GRED ROAD: end results including a schematic 2D map and an excel file with the position of the detected targets

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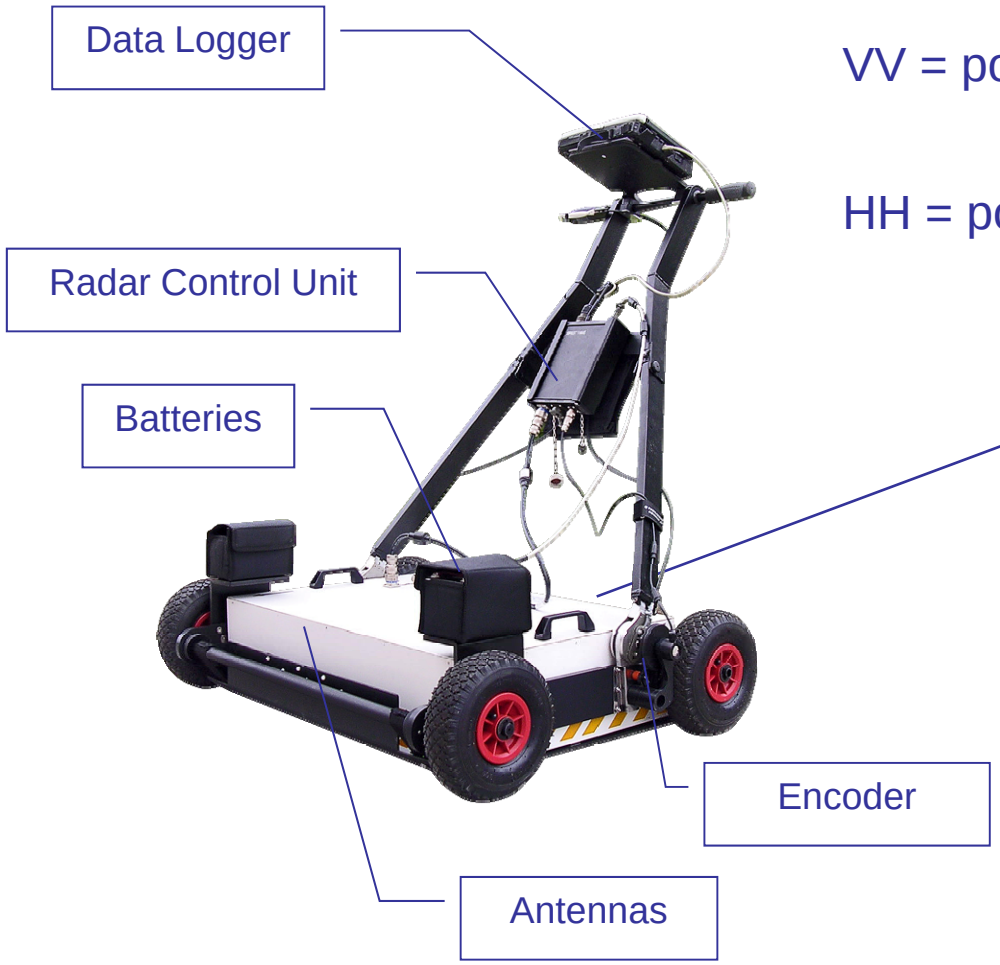
IDS INGEGNERIA DEI SISTEMI

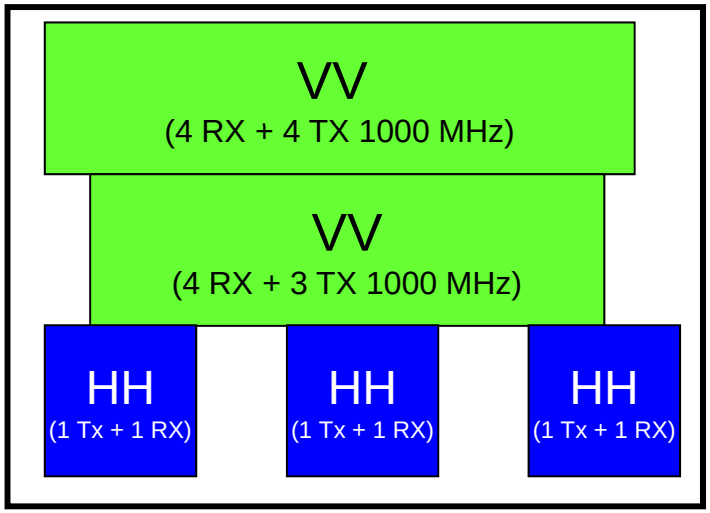
STREAM-MT: the system and array architectures



VV = polarization of the antenna modules

HH = polarization of the antenna modules

Antenna architecture



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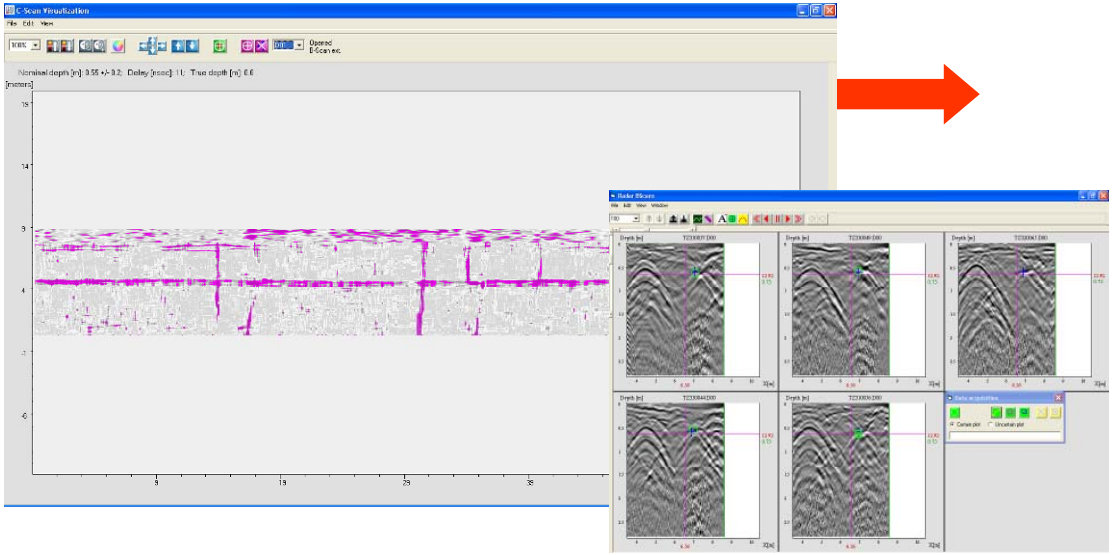
IDS INGEGNERIA DEI SISTEMI

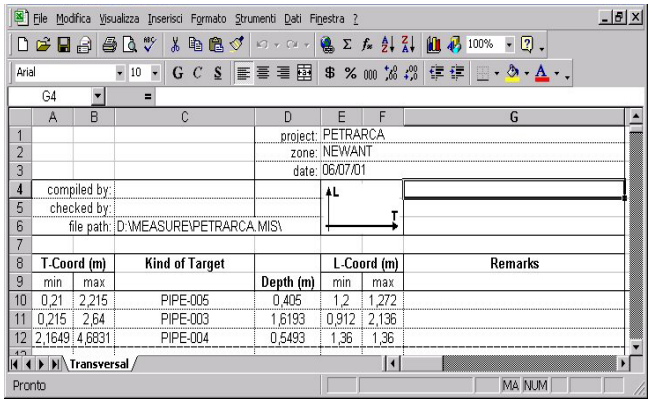
STREAM-MT: Work Flow

1. Data acquisition

2. Data processing (office)



3. End results includes a schematic table of the pipes position and a 2D schematic map



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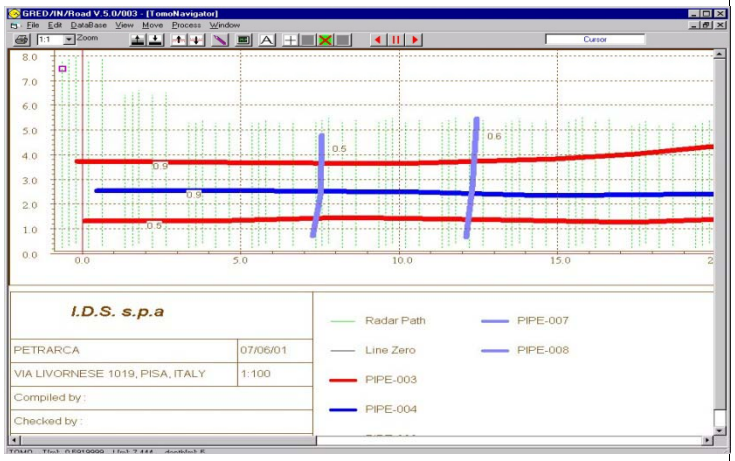
2				zone:	NEWANT		
3				date:	06/07/01		
4	compiled by:						
5	checked by:						
6	file path:	D:\MEASURE\PETRARCA.MIS\					
7							
8	T-Coord (m)		Kind of Target		L-Coord (m)		Remarks
9	min	max		Depth (m)	min	max	
10	0,21	2,215	PIPE-005	0,405	1,2	1,272	
11	0,215	2,64	PIPE-003	1,6193	0,912	2,136	
12	2,1649	4,6831	PIPE-004	0,5493	1,36	1,36	



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CIVIL ENGINEERING

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RIS Hi-BrigHT

Bridge High Resolution Tomography

IDS SPECIFIC RADAR SOLUTION

FOR BRIDGE DECK SURVEY

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IDS INGEGNERIA DEI SISTEMI

RIS Hi-BrigHT: Features

- High Bandwidth: >2 GHz → best resolution of defects
- 16 antennas array → permitting 3D Tomography and saving acquisition time
- Double polarisation: 8 antennas in VV polarisation + 8 antennas in HH → providing more information on defects
- High manoeuvrability: compact and lightweight design → easing and speeding data collection

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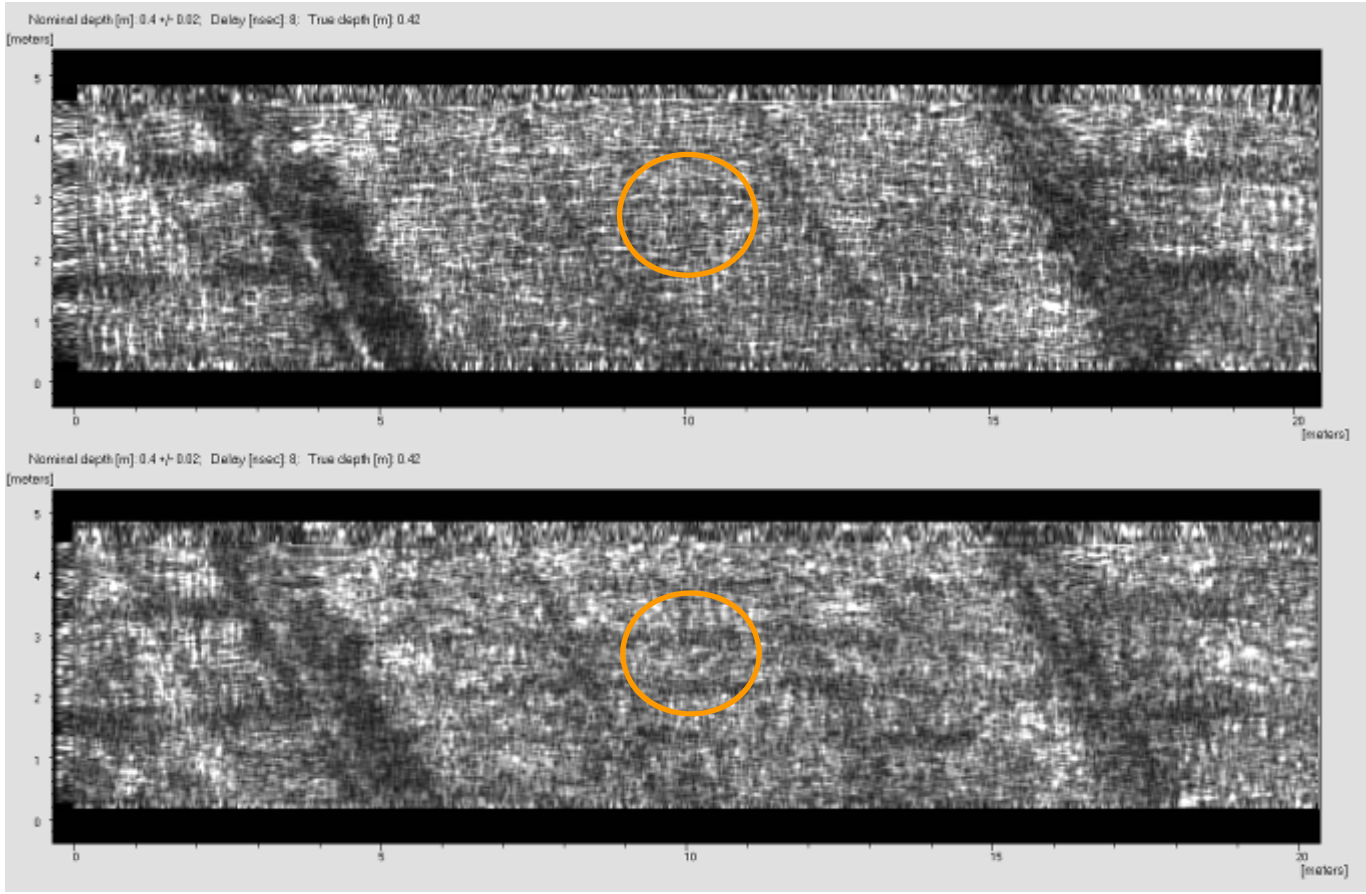
RIS Hi-BrigHT: tomography

Tomography: HH Polarization

Tomography: VV Polarization



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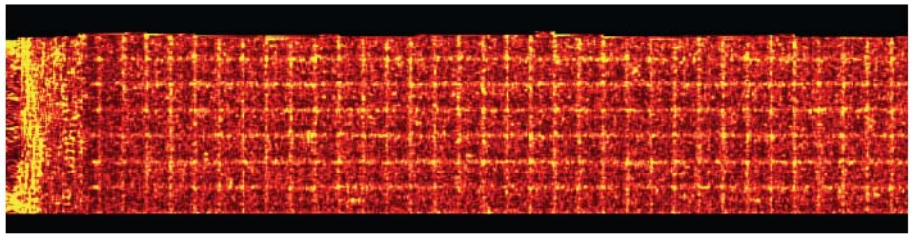
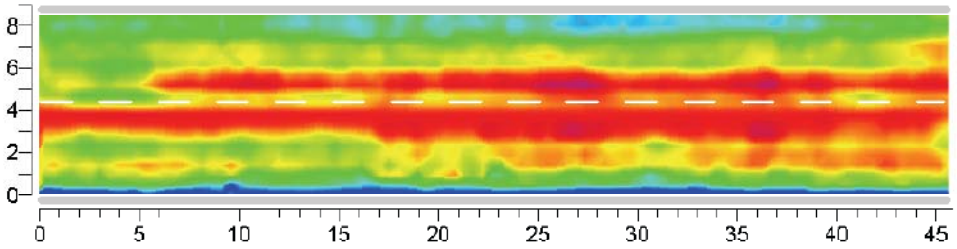
RIS Hi-BrigHT: processing

RIS Hi-BrigHT uses the new BridgeDoctor processing software by Roadscanners, a processing and interpretation tool dedicated to bridge analyses, featuring:

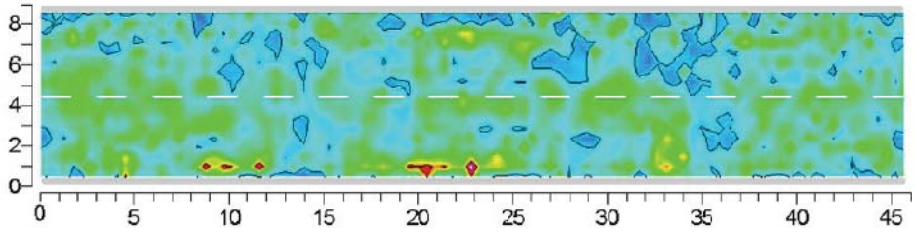
- 3D tomographic view
- Map of pavement and concrete thicknesses
- Map of moisture deteriorated zones
- Map and depth of reinforcement bars



Tomographic view of the reinforced cover.



Map of pavement thickness.



Identification of moisture zones. Blue spots locate moisture in concrete.

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ALADDIN

an advanced radar based sensor for Non-Destructive structural analysis

Civil engineering & Cultural heritage applications

- 3D imaging of shallow and deep rebars in concrete;
- Inspection of concrete for location of voids;
- Inspection of concrete thickness, integrity;
- 3D imaging of pre-tension and post-tension cables;
- Inspection and analysis of old structures and monuments;
- Inspection of walls and floors for the location of pipes, objects, caches, etc..

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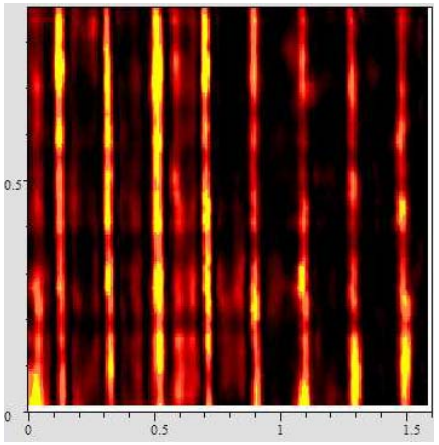
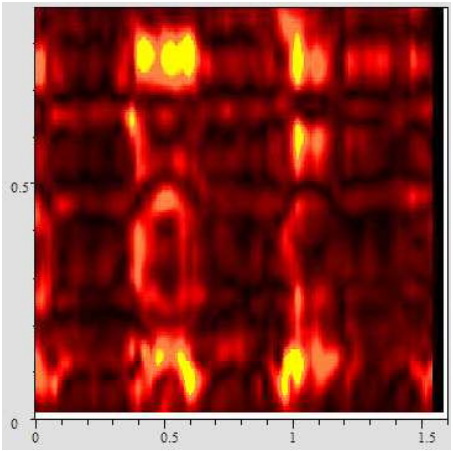
Standard Products

Depth: 0.10m



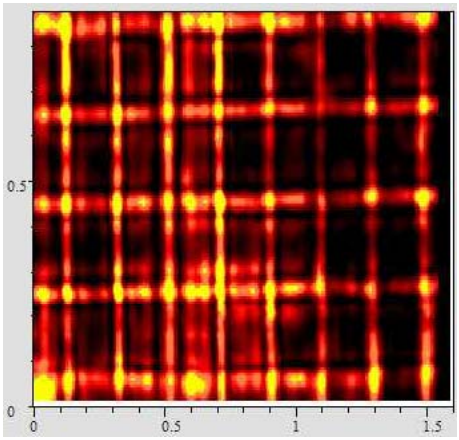
Depth: 0.40m



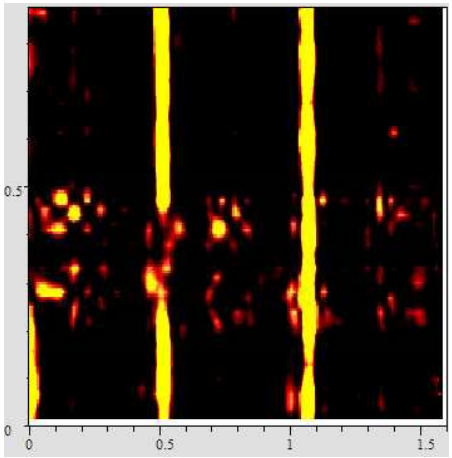
The standard antenna can read the shallow targets (rebars), but is not able to reveal the lower structures

ALADDIN

Depth: 0.10m

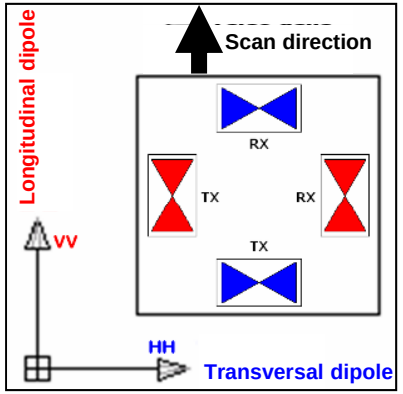


Depth: 0.40m



Instead, the FULL-POLAR antenna is able to identify both targets (shallow and deep) in just one scan.

The **SPECIAL FULL-POLAR** high-frequency (2 GHz) antenna combined with the **patented Pad Survey Guide (PSG)** permit joint orthogonally polarized scans to be acquired in a single pass, detecting shallow and deep structures and halving acquisition time compared to standard methods.



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RAILWAY ENGINEERING

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SafeRailSystem

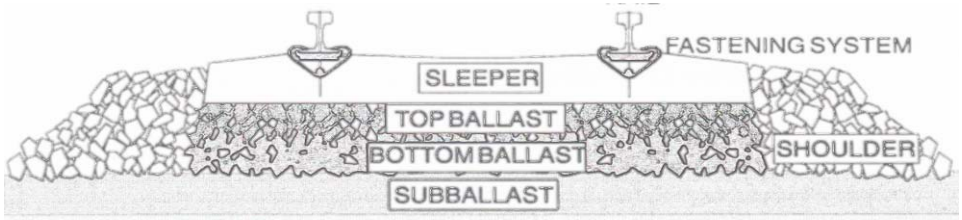
Track bed inspection by high speed radar

All rights reserved to IDS

IDS INGEGNERIA DEI SISTEMI

Expectations from the end-user

- Continuous Mapping of Ballast Thickness
- Locating Areas with Insufficient Bearing Capacity (e.g. Ballast Pockets)
- Differentiation Between Clean and Fouled Ballast
- Detection of Sections with Drainage Problems



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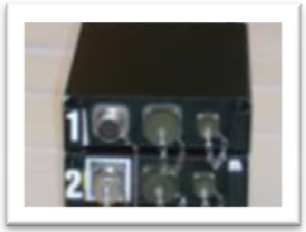
IDS INGEGNERIA DEI SISTEMI

Data Acquisition Unit

SafeRailSystem

Data Logger / Pc
(Panasonic CF30)

Qty2:
DAD MCh Fastwave



Qty1:
Synchro Unit

SRS 400 MHz antennas

Doppler Encoder

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IDS INGEGNERIA DEI SISTEMI

Data Acquisition Unit: unmatched features

- Interleaved multiplexing (up to 4 antennas ran simultaneously)
- Very fast collection speed
  - 150 Km/h @ 12 cm sampling step (512 samples per trace)
  - 190 Km/h @ 12 cm sampling step (384 samples per trace)
  - > 300 Km/h @ 60 cm sampling step (512 samples per trace)
- Video frame from the USB camera captured and stored at user-defined step (typ. 20 m)
- GPS information stored with radar data at user-defined step (typ. 20 m)
- Unlimited length of the collected profile for avoiding stop on tracks (data are automatically stored every 10 Km and reformatted at the end of the survey)

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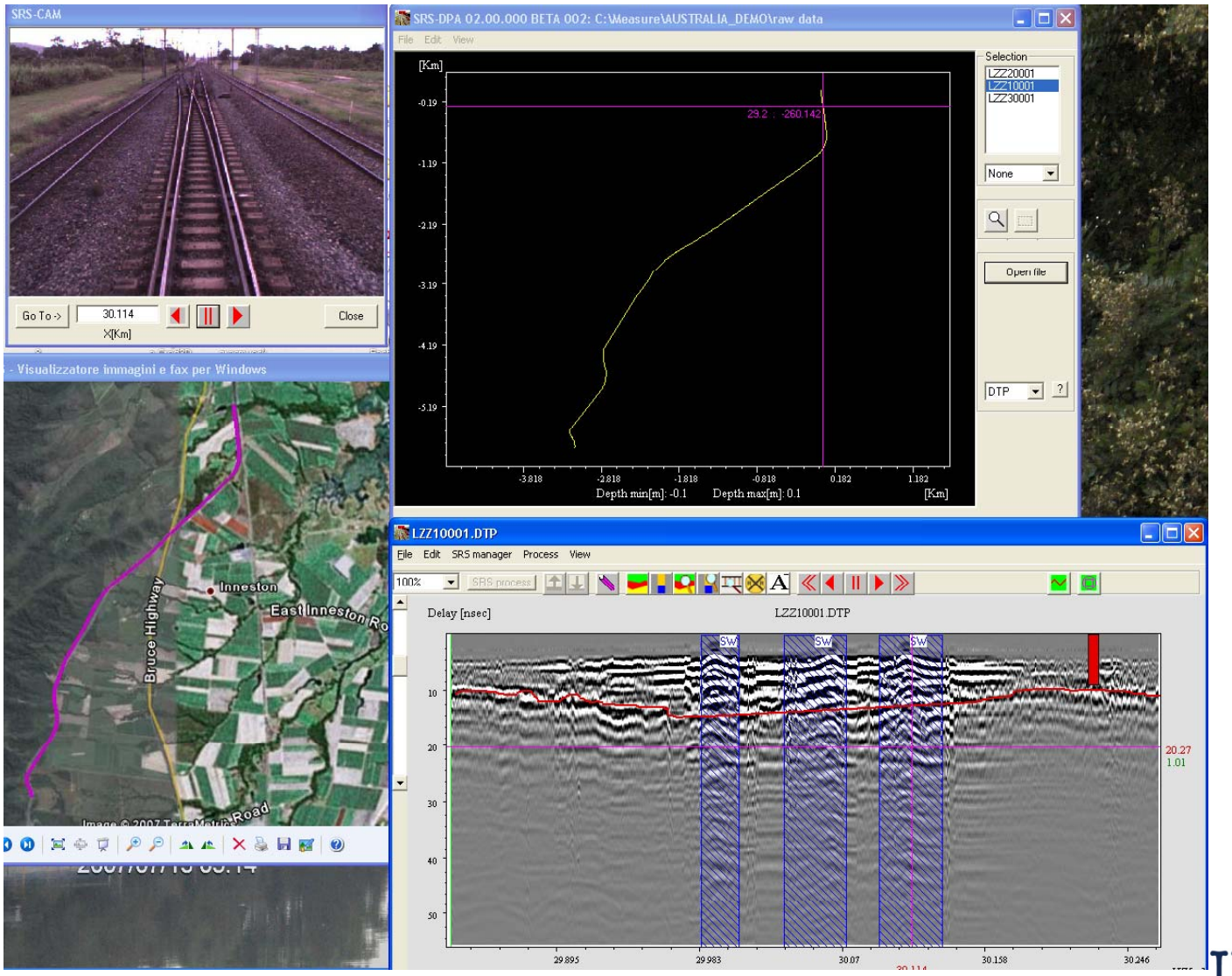
Data Analysis Software: data selection



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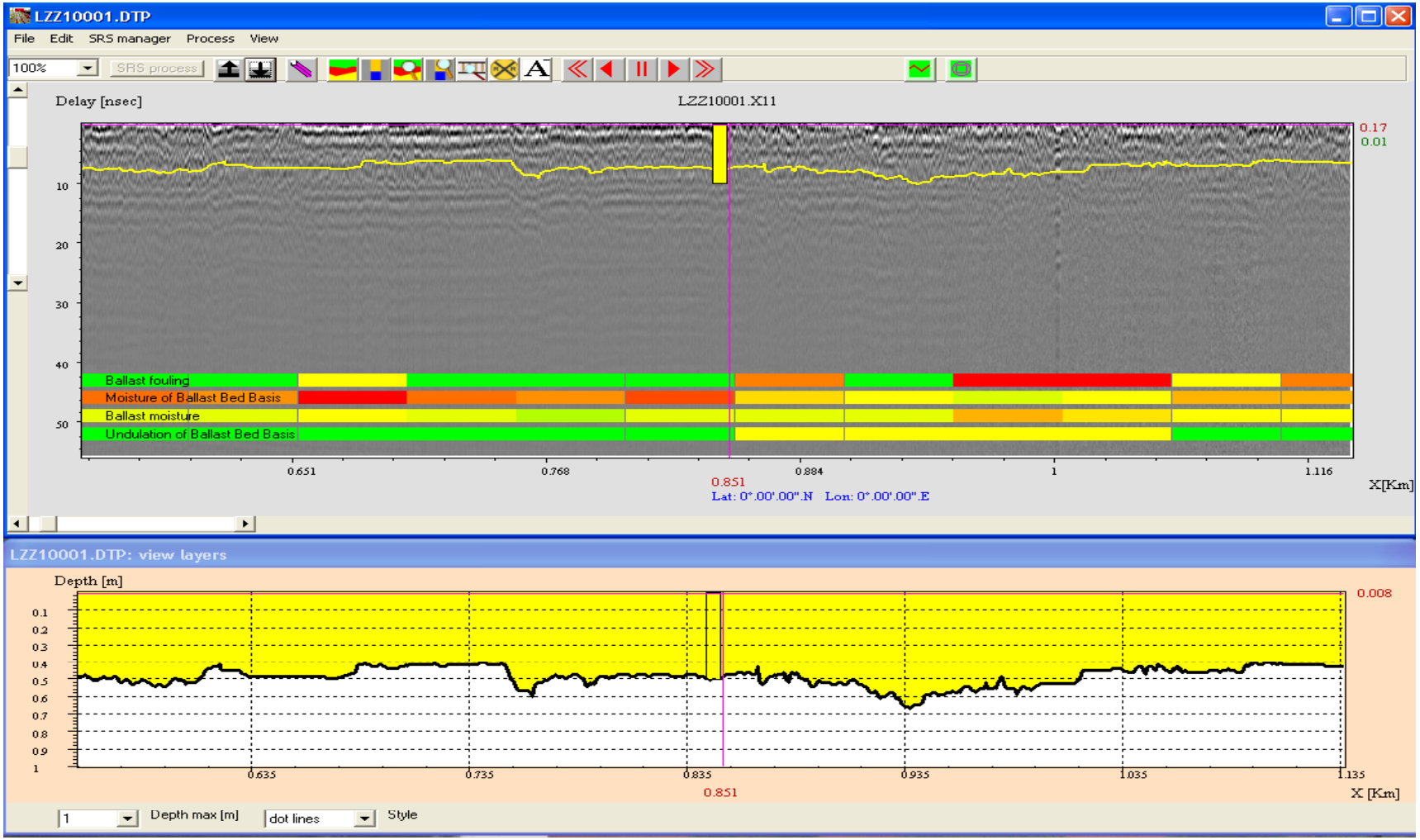
Automatic analysis of ballast



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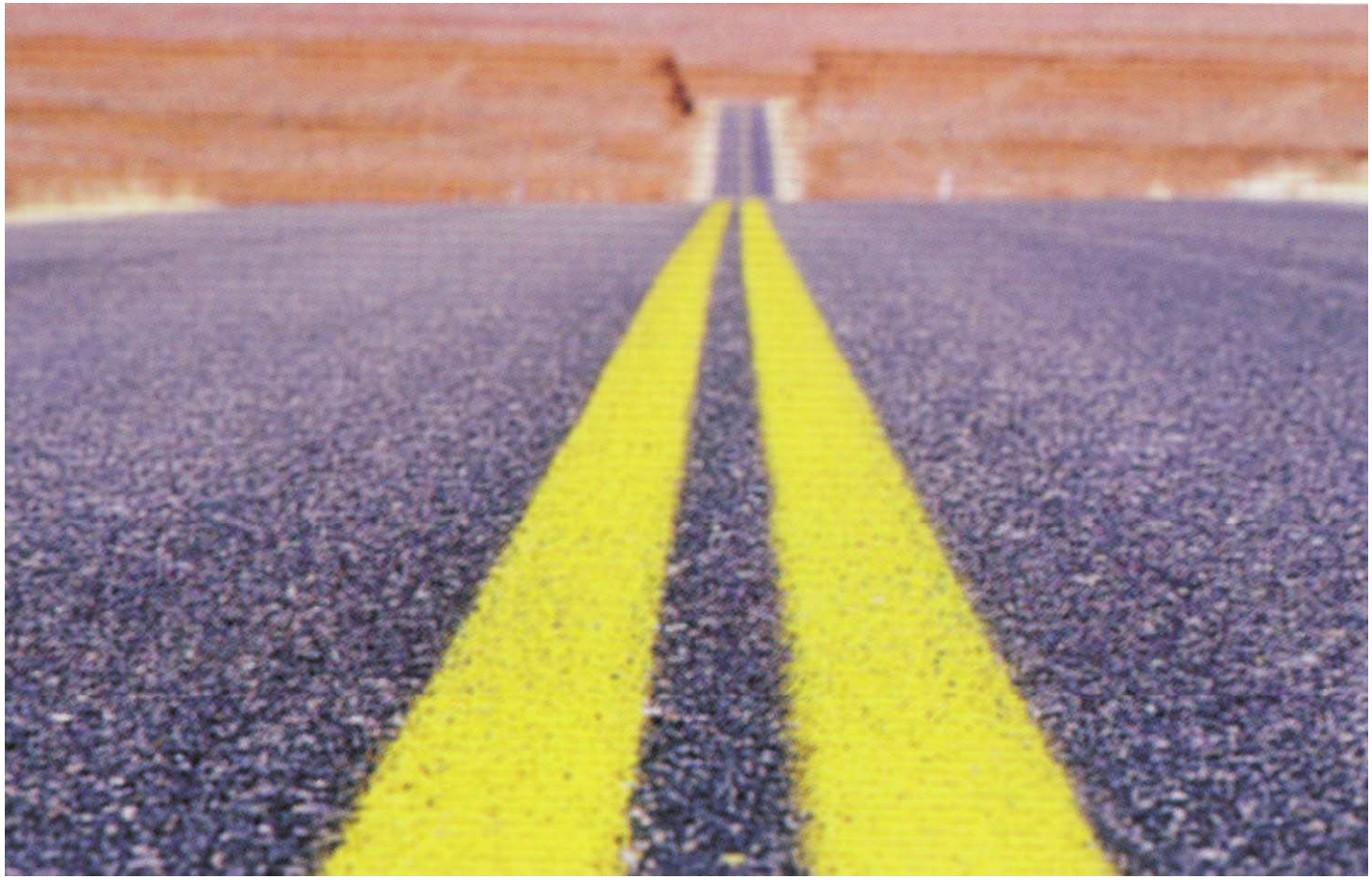

ROAD ENGINEERING

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RIS Hi-Pave: architectures

DAD MCh Fastwave

Data Logger

GPS antenna + Video Camera (option)

Dedicated encoder fixed on the car wheel

Horn antenna 1000 MHz

Mechanical Kit for can be connected to any car or van with drag-hook

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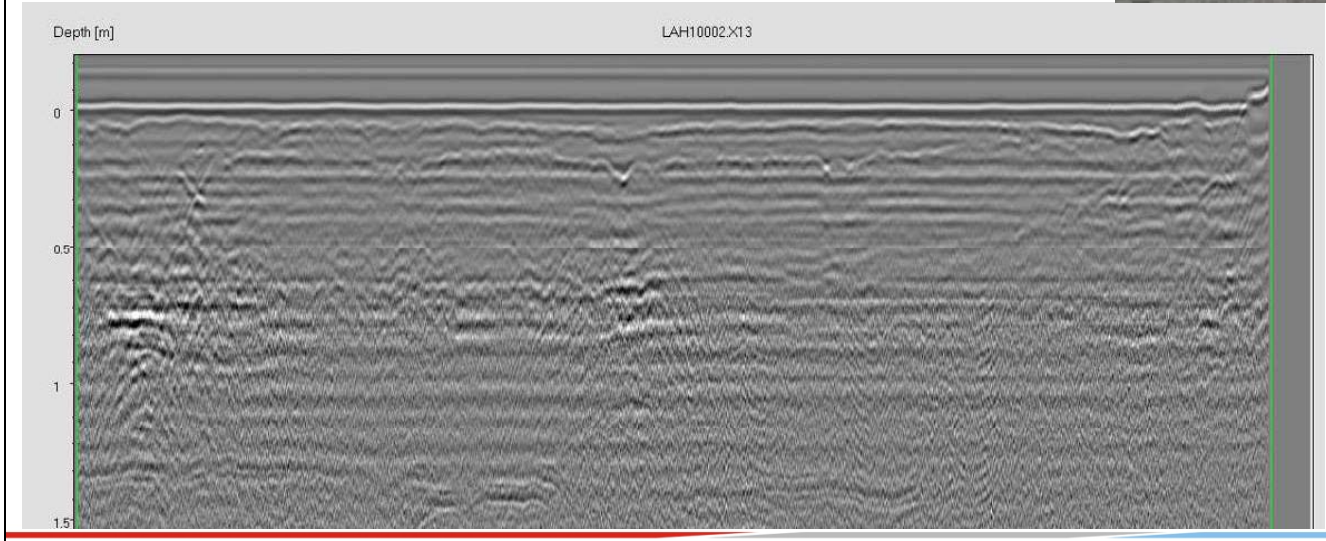
IDS INGEGNERIA DEI SISTEMI

RIS Hi-Pave: available Horn antennas

IDS Horn antennas :

- **TR 1000 (1000 MHz)**
- **TR2000 (2000 MHz)**



Radar map with 1000 MHz Horn antenna.

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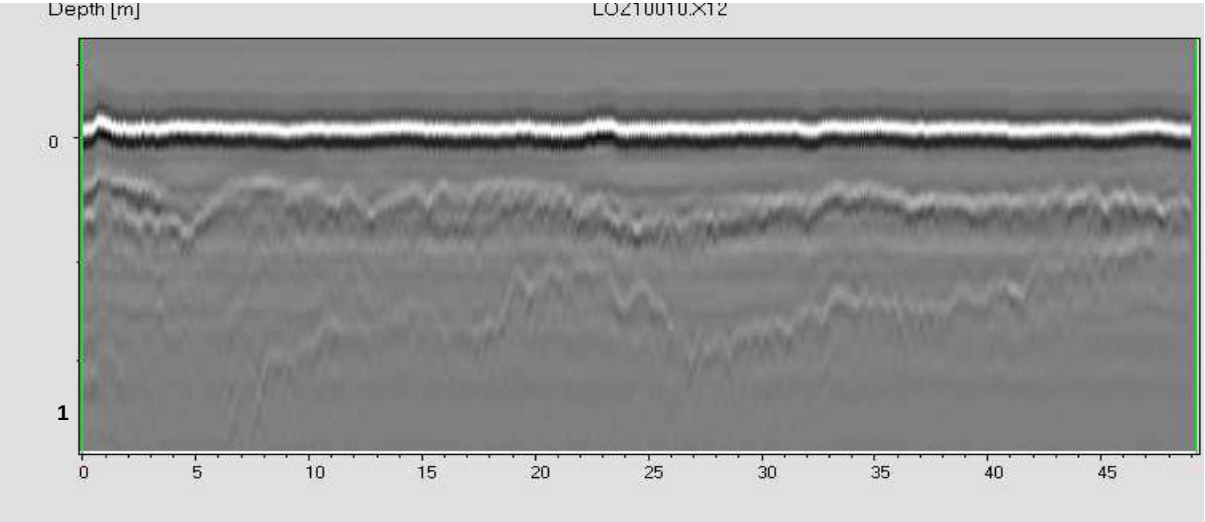
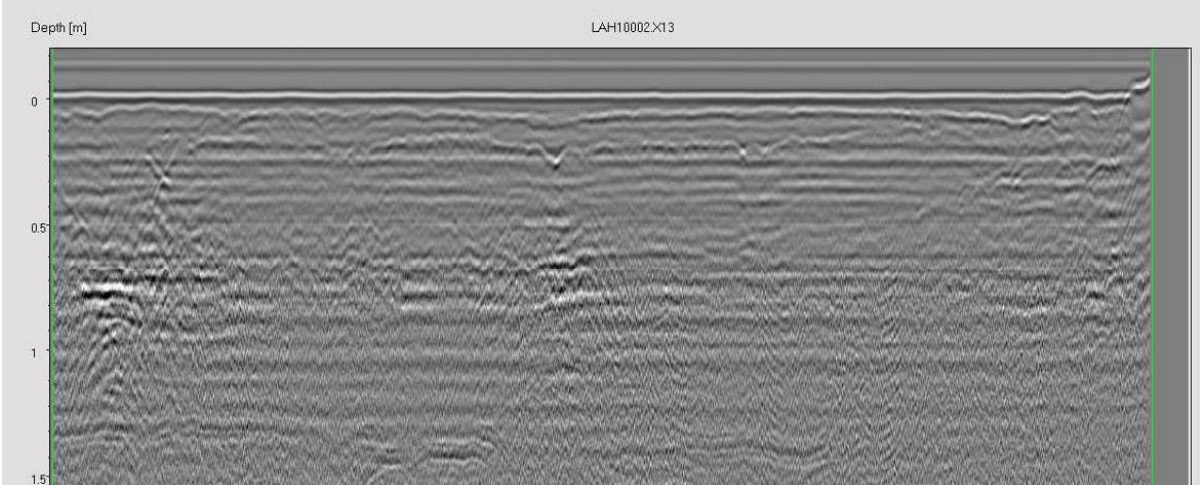
Horn antennas: radar maps



Radar map with 2000 MHz Horn antenna.



Radar map with 1000 MHz Horn antenna.

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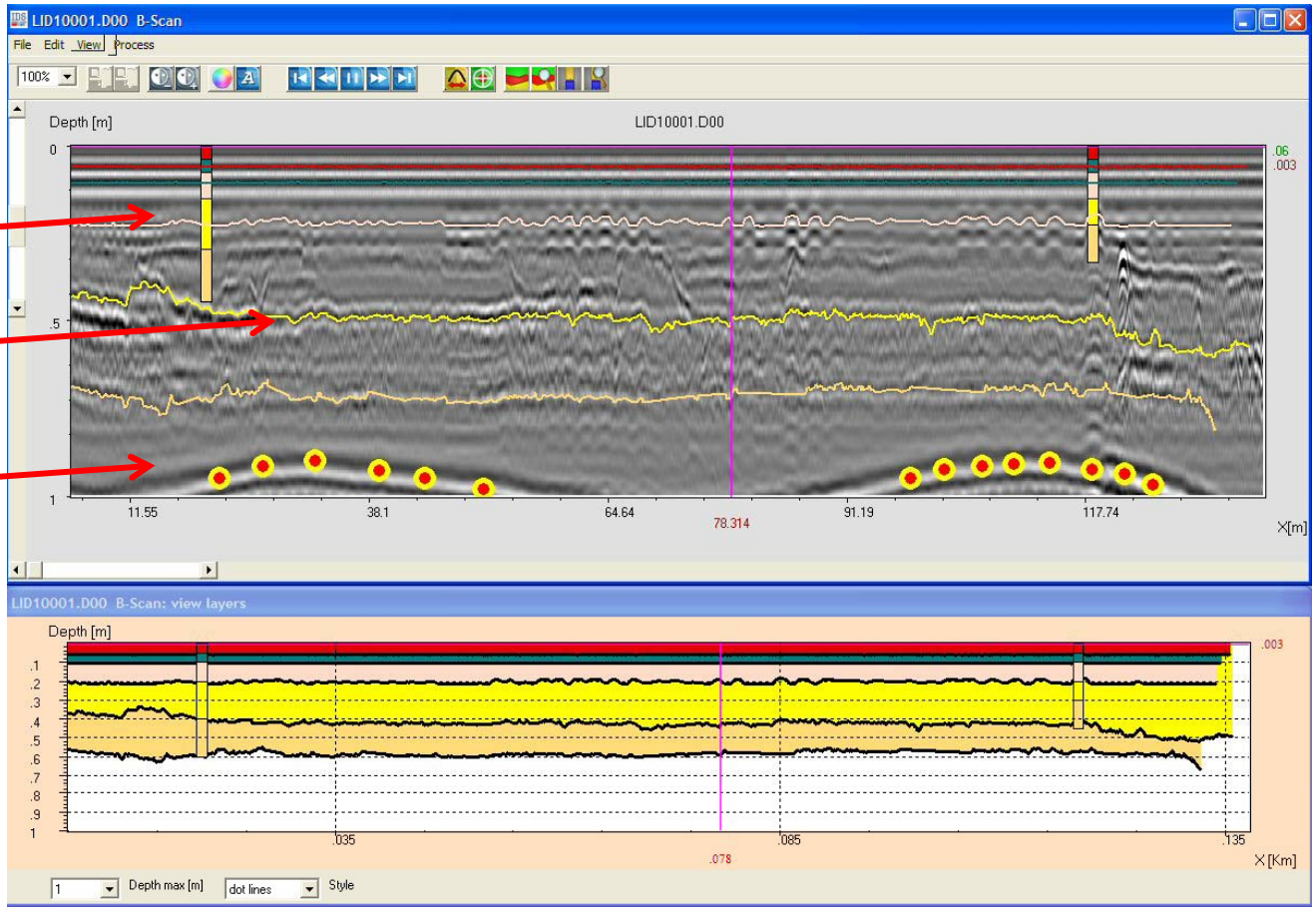
RIS Hi-Pave: data analysis software for asphalt layers

Core test

Stratigraphic levels

Cavities



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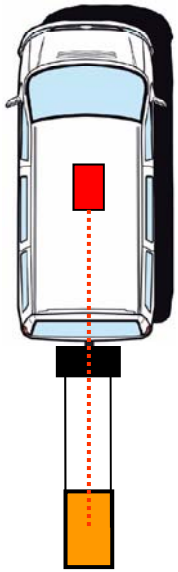
RIS Hi-Pave: possible configurations

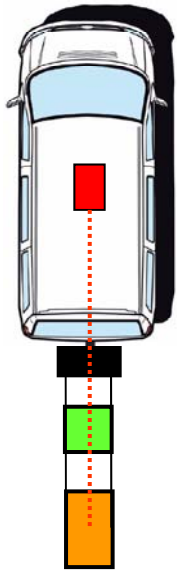
DAD
Cable
TR600
HORN



RIS Hi-Pave HR1

The single-antenna, entry-level configuration for road and runaway pavement evaluation:
- 1 DAD FastWave control unit

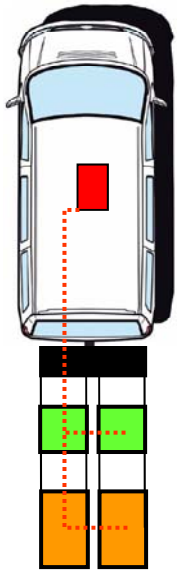
- 1 HR2000 antenna (2 GHz horn) for road survey
or
1 HR1000 antenna (1 GHz horn) for runaway survey



RIS Hi-Pave HT2

The double-antenna configuration for complete road and runaway evaluation (pavement, grade, subgrade):
- 1 DAD FastWave control unit

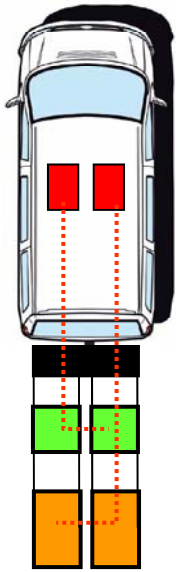
-1 HR2000 antenna (2 GHz horn) for road pavement survey
or
- 1 HR1000 antenna (1 GHz horn) for runaway survey
-1 TR600 antenna (600 MHz) for grade and subgrade evaluations



RIS Hi-Pave HT4

The four-antenna configuration for complete and wide road and runaway evaluation:
- 1 DAD FastWave control unit

-2 HR2000 antennas (2 GHz horn) for road survey
- 2 HR1000 antenna (1 GHz horn) for runaway survey
-2 TR600 antennas (600 MHz) for grade and subgrade evaluations



RIS Hi-Pave HT4 HS
or
RIS Hi-Pave HT2 HS

The same as the HT4 or HT2 configuration but with 2 synchronised DAD control units for maximum speed (over 200 Km/h) or very dense sampling (5 cm. at 125 km/h)

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IDS INGEGNERIA DEI SISTEMI

Geology and Environment

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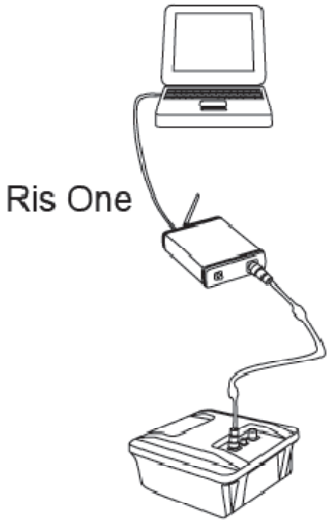
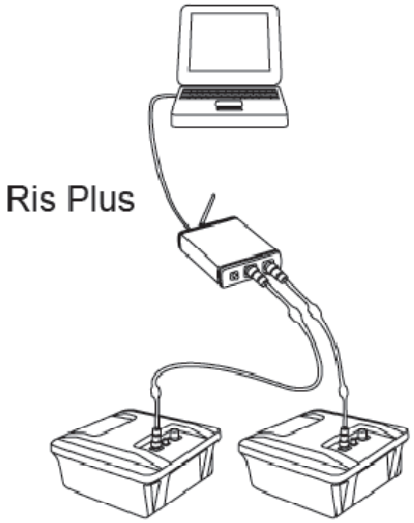
RIS One and RIS Plus:

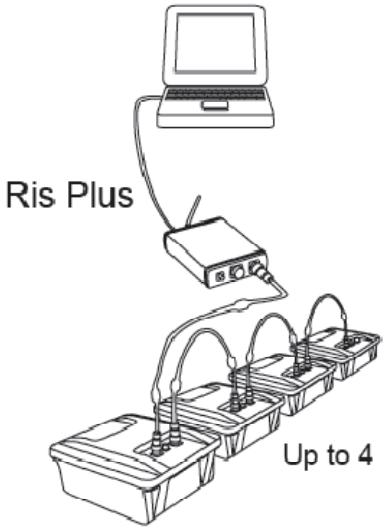
a comprehensive set of products covering the needs of geology and environment applications



Single channel configuration (also available with 1 dual frequency antenna)



Multi-channel configuration with two single frequency antennas



Multi-channels configuration comprising a chain connection with up to 4 dual frequency antennas

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IDS INGEGNERIA DEI SISTEMI

IDS available antennas

TYPOLOGY	MODEL	FREQUENCY (MHz)	WEIGHT (Kg)	DIMENSIONS (Cm)
UNSHIELDED	TR 25	25	18	400x120x55
	TR 40	40	18	274x120x55
SHIELDED	TR 80	80	23	140x70x30
	TR 100	100	23	140x70x30
	TR 200	200	6	43x37x20
	TR 400	400	5.5	43x37x20
	TR 600 H	600	5.5	43x37x20
	TR 600 V	600	3	20x26x20
	TR 900	900	3	20x26x20
	TR HF	2000	1.3	13x12x8
BOREHOLE	BH 150	150	1	160; Ø 40
	BH 300	300	1.5	100; Ø 40
HORN ANTENNAS	HR 1000	1000	7	51x46x23
	HR 2000	2000	7	51x46x23

TYPOLOGY	MODEL	FREQUENCY (MHz)	WEIGHT (Kg)	DIMENSIONS (Cm)
DUAL FREQUENCY ANTENNAS	DUAL F (200-600) Fastwave	1 x 200	6	43x37x20
		1 x 600		
	DUAL F (400-900) Fastwave	1 x 400	6	43x37x20
		1 x 900		
	TR-AL	1 x 600	5	43x37x20
		1 x 2000		
SPECIAL HF ANTENNAS	HIRESS	4 x 2000	3	45x15x17
	FULL POLAR	2 x 2000	1.5	12x12x18
ANTENNA ARRAY	DML 200	200	32	98x37x18
	DML 600	600	30	98x37x18

Main features:

- Wide number of model at different frequency
- Compact and lightweight
- Better performances

21 models available

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IDS INGEGNERIA DEI SISTEMI

Low-frequency antennas for deep surveys

25 MHz antenna

- Unshielded 25 MHz and 40 MHz antennas.

  Single Tx/Rx module with replaceable antenna modules

80/100 MHz antenna

- Shielded 80 MHz and 100 MHz antennas.

  Separated Tx and Rx modules for bistatic and

  CMP investigations

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IDS INGEGNERIA DEI SISTEMI

BOREHOLE antennas for deep surveys

Available models/frequency antennas :

- BA150 MHz,
- BA 300 MHz
- BA 1000 MHz (prototype)

- Borehole antenna cable (40 m) (BAC 4000)
- Antenna Type: Unshielded Dipole
- Nominal Frequency: 150 or 300 MHz
- Operation Mode: Single hole reflection, Cross-hole tomography
- Length: 1.6 or 1.0 meter
- Diameter: 40 mm
- Weight: 1.5 Kg
- Water-proof: up to 5 bar

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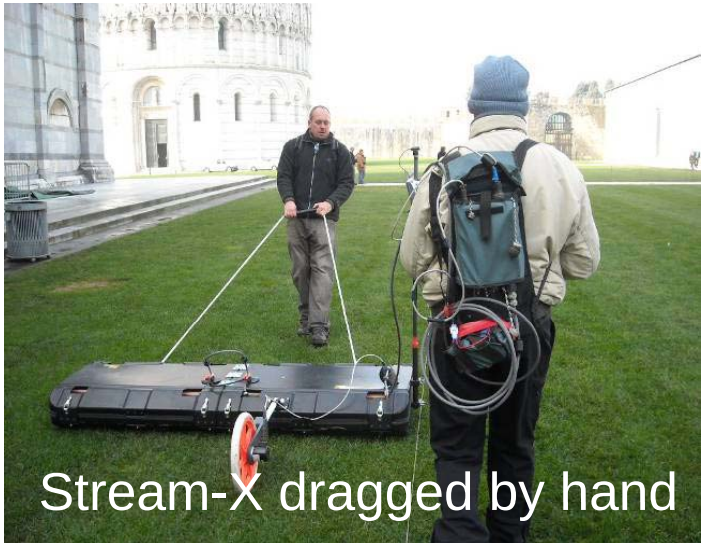
IDS INGEGNERIA DEI SISTEMI

STREAM-X: the massive array solution for archaeology and environment survey

Stream-X towed by quad



Stream-X dragged by hand

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IDS INGEGNERIA DEI SISTEMI

STREAM-X: main benefits

- GPR solution towed by a vehicle (speed > **15** Km/h).
- Suitable for working on rough terrain
- Can be dragged by hand or towed by a vehicle
- Positioning: survey wheel, GPS or Total station
- High productivity: 1 hectare/hour
- High detection capability thanks to the following data spacing:
  - up 12 cm @200 MHz
  - up to 4 cm @ 600 MHz
- Higher investigation depth thanks to the high stacking factor and high performance low frequency antennas
- Real time Navigator for a fast and complete area coverage
- Dedicated post processing software with automated transfer to CAD/GIS

Stream X System: complete configuration with an array of 200 or 600 MHz antennas

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IDS INGEGNERIA DEI SISTEMI

STREAM-X: modularity and array architectures

1x200 MHz DML array for detecting main target underground (12 cm transversal sampling; VV polarization)

GPS or Total Station

Radar Control Unit

Electric motor

Cart to be towed by a van or a quad

Stream X: the DML array can be dragged by hand for archeology or environment surveys.

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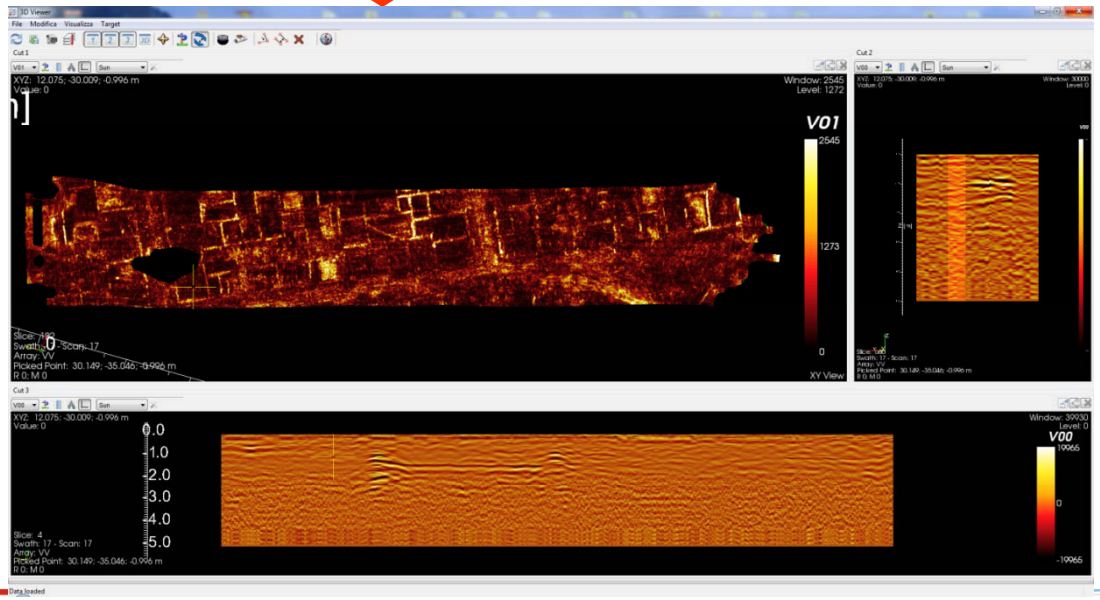
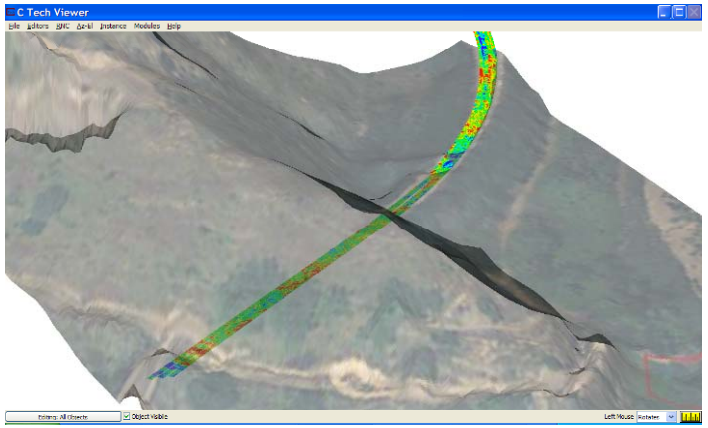
STREAM-X: Work Flow

1. Data acquisition

2. Data processing (office)



3. 3D view
in CAD/GIS environment



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IDS INGEGNERIA DEI SISTEMI

Forensic & Security

FoRad System

Forensic Solutions

Radar technology is exploited

for public security & law enforcement applications

to locate tunnels, weapons, caches and hidden persons

composed by

a specialized Surface Penetrating Radar

and

an innovative TWR Detector

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IDS INGEGNERIA DEI SISTEMI

Available Configurations

Sila System

Forensic Radar

Shallow Antenna (HF)

Medium-Deep Antenna (MF-LF)

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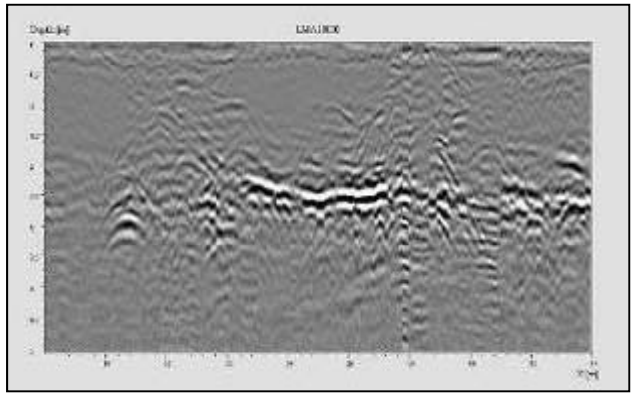
IDS INGEGNERIA DEI SISTEMI

Sila - MF/LF

200/600 MHz Antennas
for subsoil investigations

Fast Surveys & deeper
investigations



Locates tunnels, caches
and cavities where people
and weapons are
supposed to be hiding

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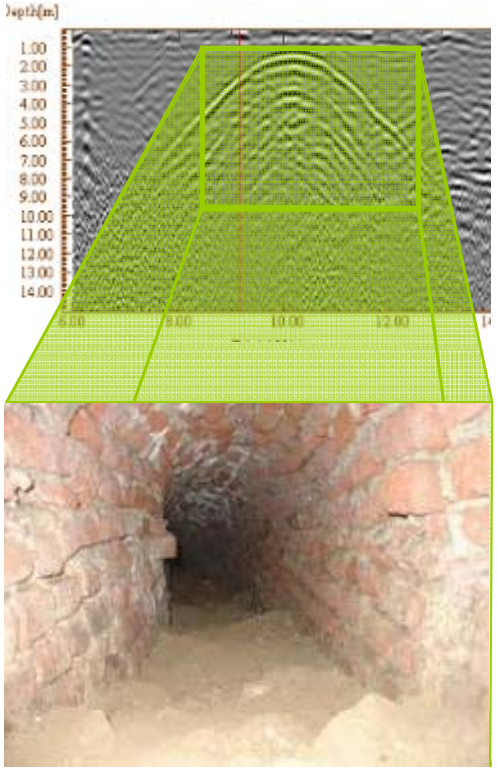
IDS INGEGNERIA DEI SISTEMI

Sila - MF/LF



Quickly reveals buried constructions, buildings and booties by the use of 200 MHz antenna (low frequency)

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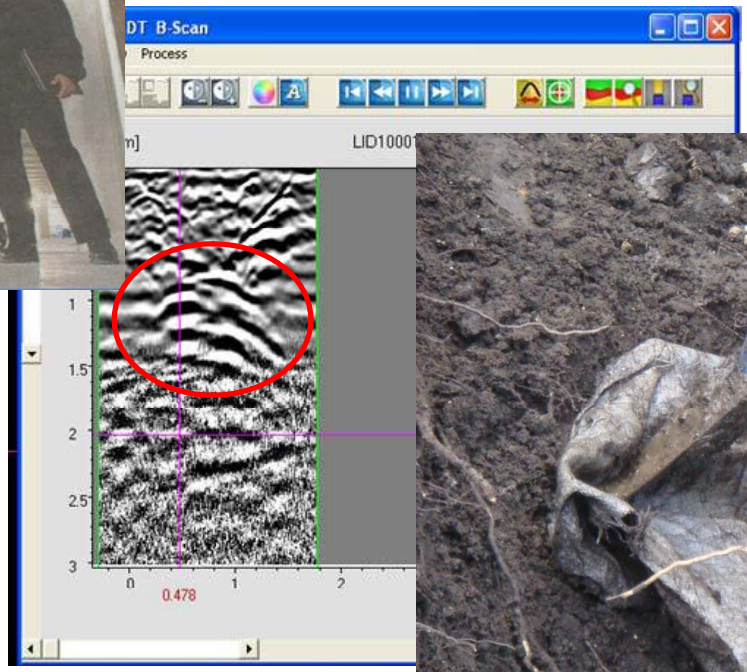
IDS INGEGNERIA DEI SISTEMI

Sila – MF/LF



Carabinieri research and discover of buried bodies, thanks to Sila system

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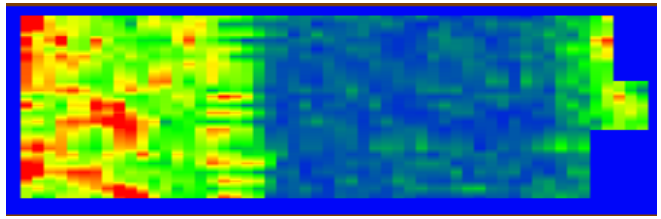
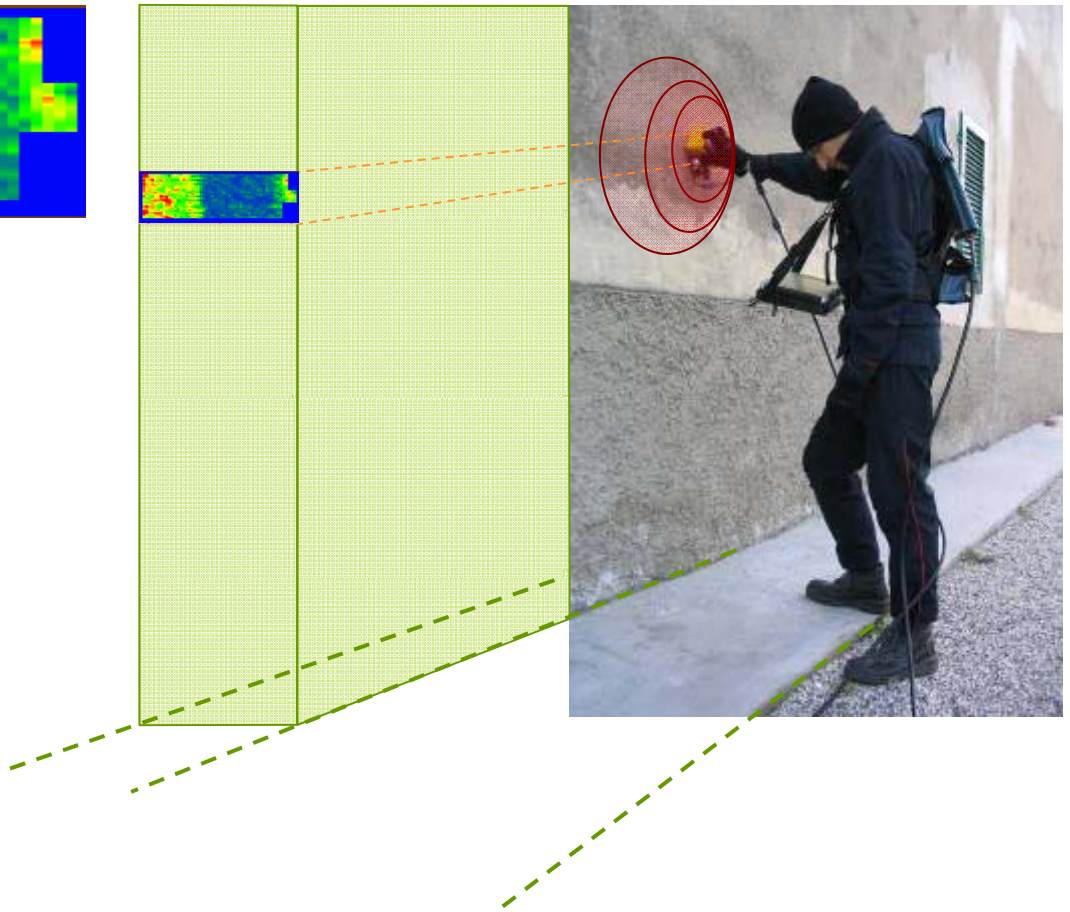
IDS INGEGNERIA DEI SISTEMI

Sila-HF





2 GHz antennas for wall and floor investigations

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IDS TWR

IDS Through Wall Radar device for ISR missions

(Intelligence, Surveillance & Reconnaissance)

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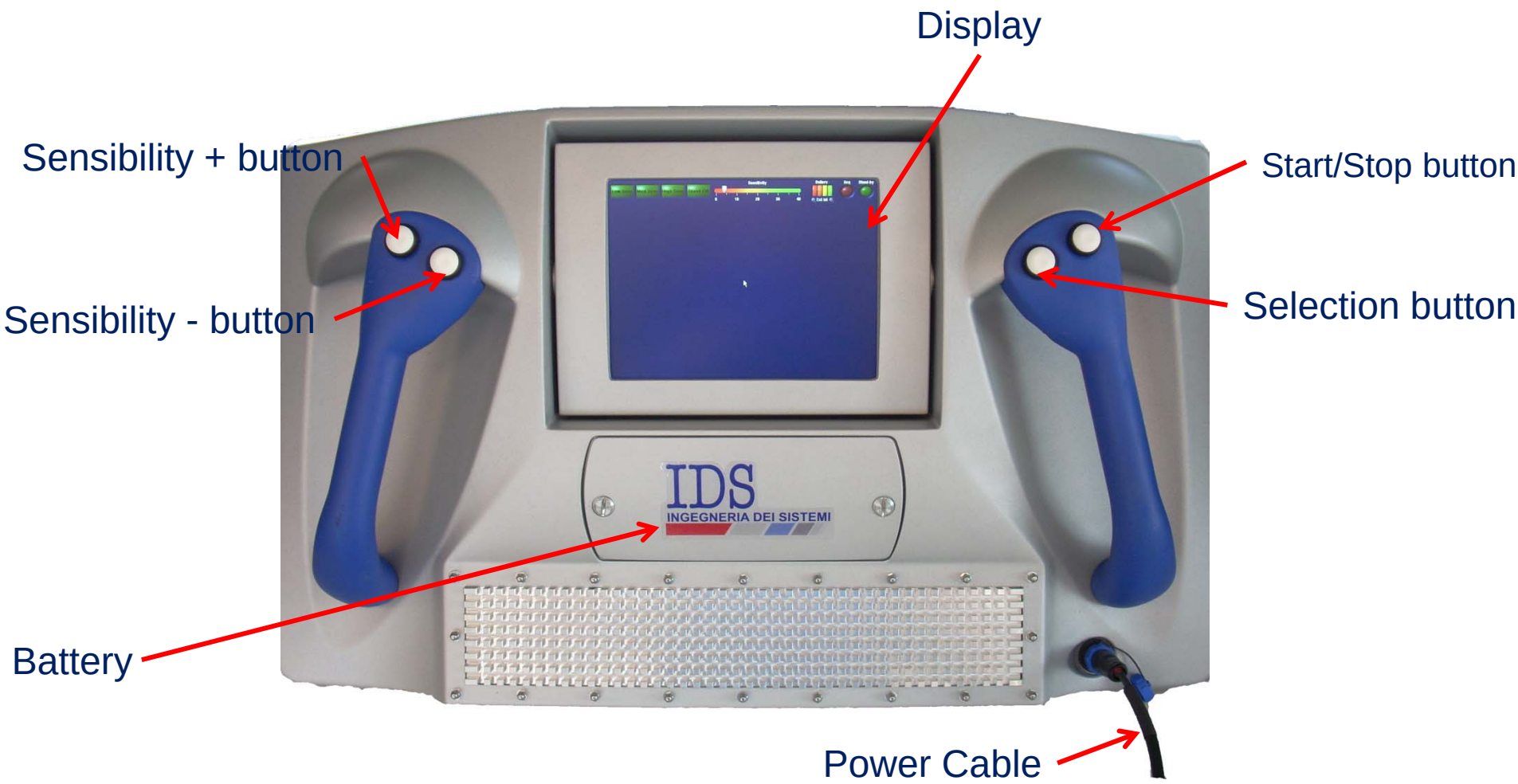
IDS TWR- Composition



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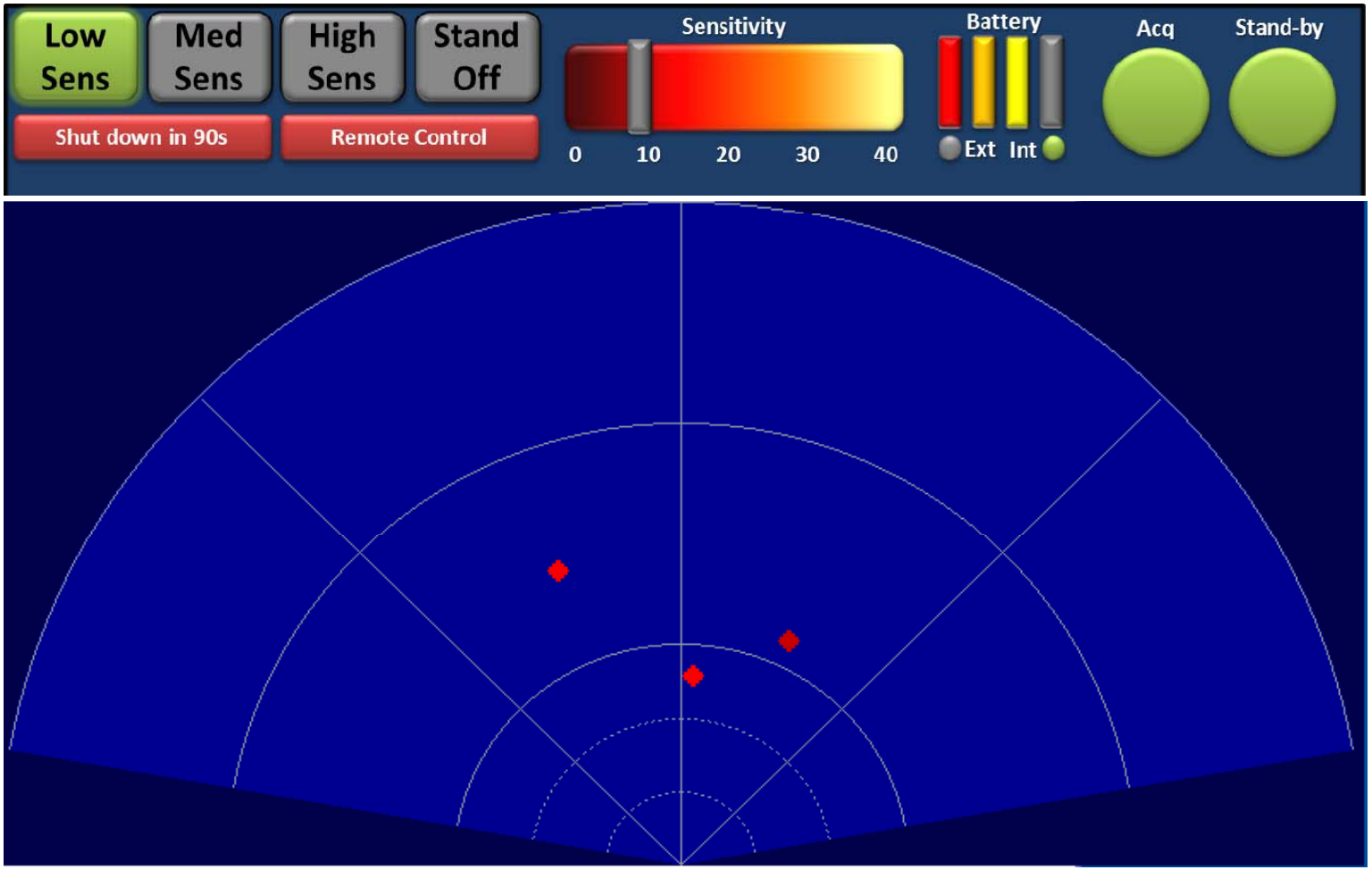
IDS TWR - Handheld Through the Wall Radar



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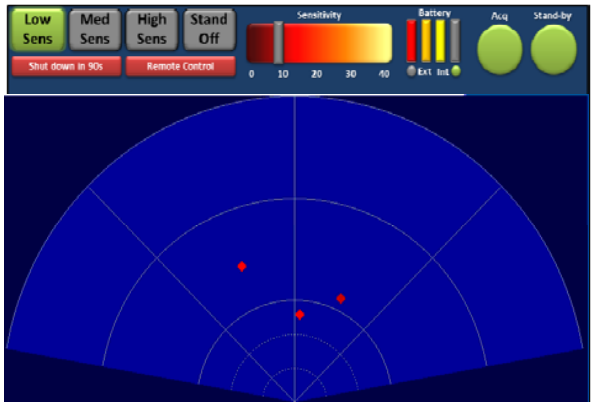
IDS TWR- Handheld Through the Wall Radar



Technical Features

Frequency: 2 GHz to 2,5 GHz

Display mode: 2D plain view, 1.5D (range with time history)

Display type: Colour, tilt-able, ultra bright

Weight: 5,5 Kg

Size: 60x32x12 cm

Ultra light materials: carbon & glass fibre

Survey Range: 15m (depending on obstacle type)

walking person > 12 m

standing, still breathing >3 m

Data Processing: Real time, 47 frame/sec

Wireless connection: available

Power Supply: battery 15 V or power line

Batteries operating time: Rechargeable batteries < 4hours

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IDS TWR- Handheld Through the Wall Radar

Main Features:

- High sensibility: Breathing and heart beat detection capability
- Compact and lightweight for tactical operations
- User friendly: 2D imaging capability for intuitive image interpretation
- Detection through different types of wall: concrete, full-bricks, empty-bricks, stone, adobe, wood
- Friendly HMI: controls directly available by the handles

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IBIS
Image by Interferometric Survey

A comprehensive family of ground-based Radar Interferometers for the measurement of displacements and vibrations

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IBIS: ground-based interferometric radars

IDS present the IBIS family:

an innovative range of advanced “geodetic” instruments based on ground-based radar interferometry aimed at providing accurate measurement of movements over wide areas.

IBIS products have been designed to address the specific needs of the civil engineering, geotechnical and mining markets

This revolutionary approach provides the IBIS users with accurate remote measurements without requiring any contact with the target and in almost all weather conditions.

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IBIS product range

PRODUCTS

IBIS - L

IBIS - M

IBIS - S

APPLICATIONS

LANDSLIDE & DAM MONITORING

SLOPE STABILITY IN MINING

STRUCTURE MOVEMENTS

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IDS INGEGNERIA DEI SISTEMI

IBIS-S: system & application fields

IBIS-S

BRIDGE TESTING

CULTURAL HERITAGES

INDUSTRIAL FACILITIES

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IBIS-L: system & application fields

IBIS-L

LANDSLIDE MONITORING

DAM MONITORING

GROUND SETTLEMENTS MONITORING

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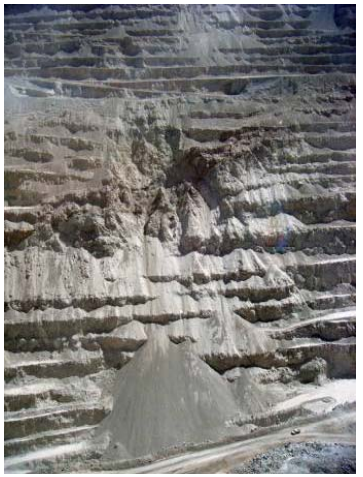
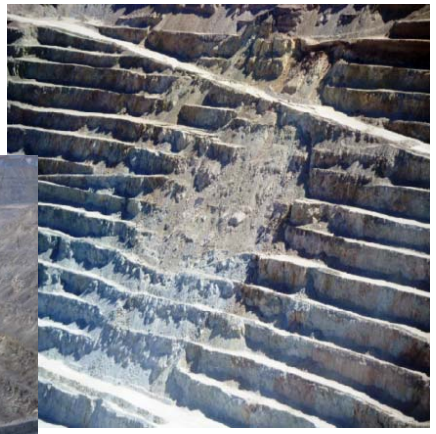
IDS INGEGNERIA DEI SISTEMI

IBIS-M: system & application field

IBIS-M





SLOPE MOVEMENT MONITORING WITHIn OPEN PITS MINES

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Techniques behind the IBIS systems

The IBIS products are based on four well-known radar techniques:

1. Stepped-Frequency Continuous Wave (SF-CW) technique resolves the scenario in the range direction, detecting the position in range of different targets placed along the radar's line of sight;
2. Synthetic Aperture Radar (SAR) allows to obtain 2D high-resolution radar images by adding to the range resolution (fro the SF-CW), the cross-range angular resolution
3. Interferometric technique, computes the displacement of each pixels by comparing the phase information of the radar signal collected at different times.
4. Persistent Scatterers algorithm (PSInSAR) selects among the whole image the high quality pixels and estimates the atmospheric artefacts in an automatic and robust way

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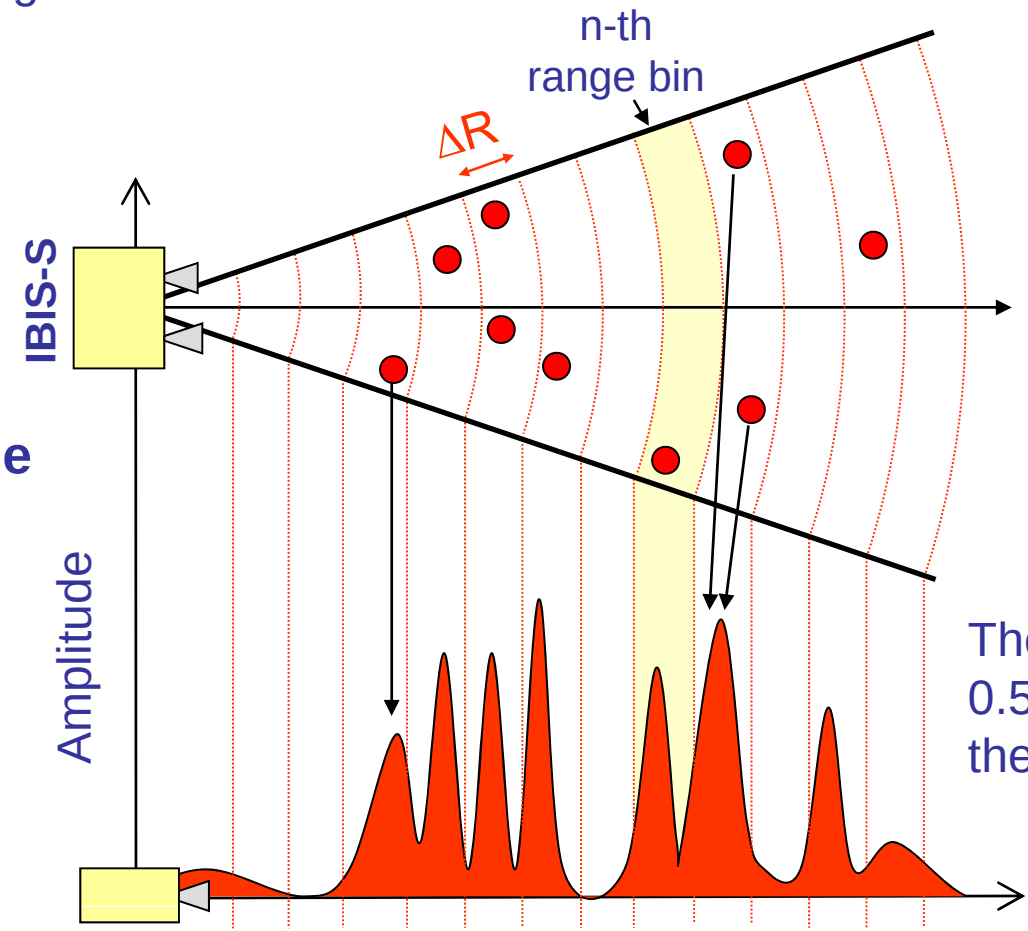
Stepped Frequency-Continuous Wave

The SFCW radar detects the position in range of different targets placed along the radar's line of sight



Range profile

The range resolution of 0.5 m, independent from the distance.

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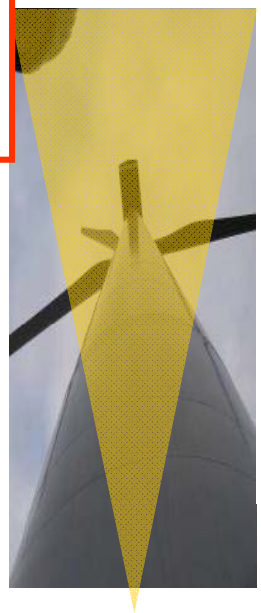
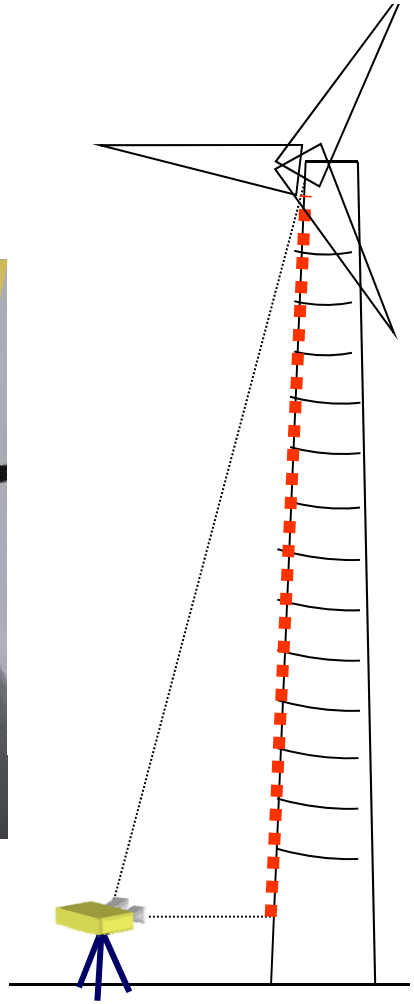
IBIS-S: 1-dimensional range profiles

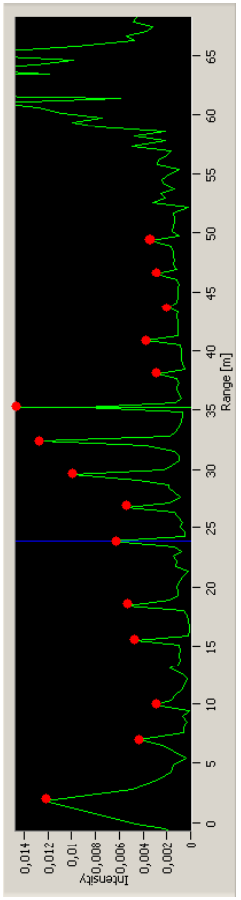
Range Profile: one dimensional image with 0.5m range resolution

Welding lines are good reflective points

IBIS-S installed at the turbine pillar base (height 60m)







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IBIS-L & IBIS-M: Synthetic Aperture Radar (SAR)

SAR technique enables the system to provide high cross range resolution exploiting the movement of the physical antenna along a straight trajectory (linear scanner)

Using 2 m rail
IBIS-L system obtains
4.38mrad (=0.25deg)
angle resolution

The SAR process of the data, collected during the movement of the sensor head on the 2 meter track, allows the IBIS-L and M systems to synthesize a 2m antenna whose azimuth beam width is:

$$\Delta\varphi = \frac{\lambda}{2 \cdot L} = 4.38 mrad$$

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IBIS-L & IBIS-M: SAR 2-dimensional images

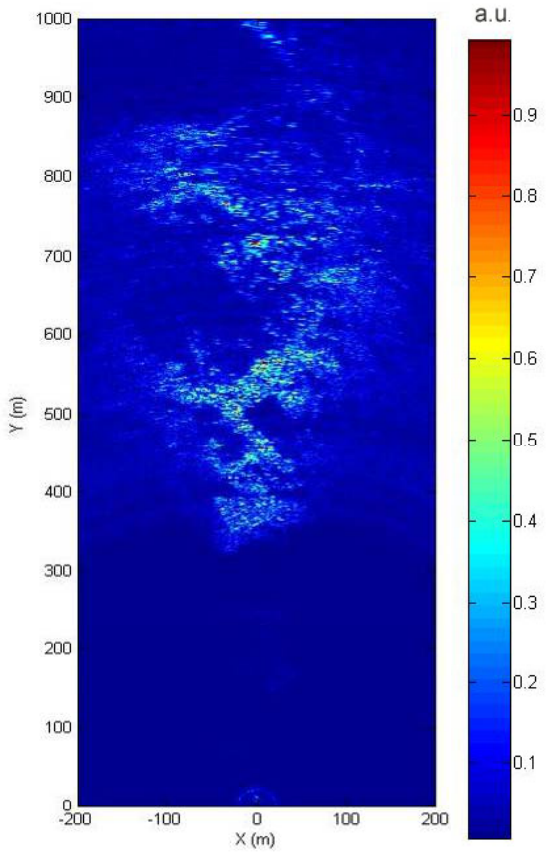
The combination of SAR and SF-CW techniques allows the system to resolve the scenario into two dimensional pixels

Pixel dimension:

- 0.5m in range;
- 1.35m – 4.05m cross range for 300 - 900m range

Optical Image

Power Map



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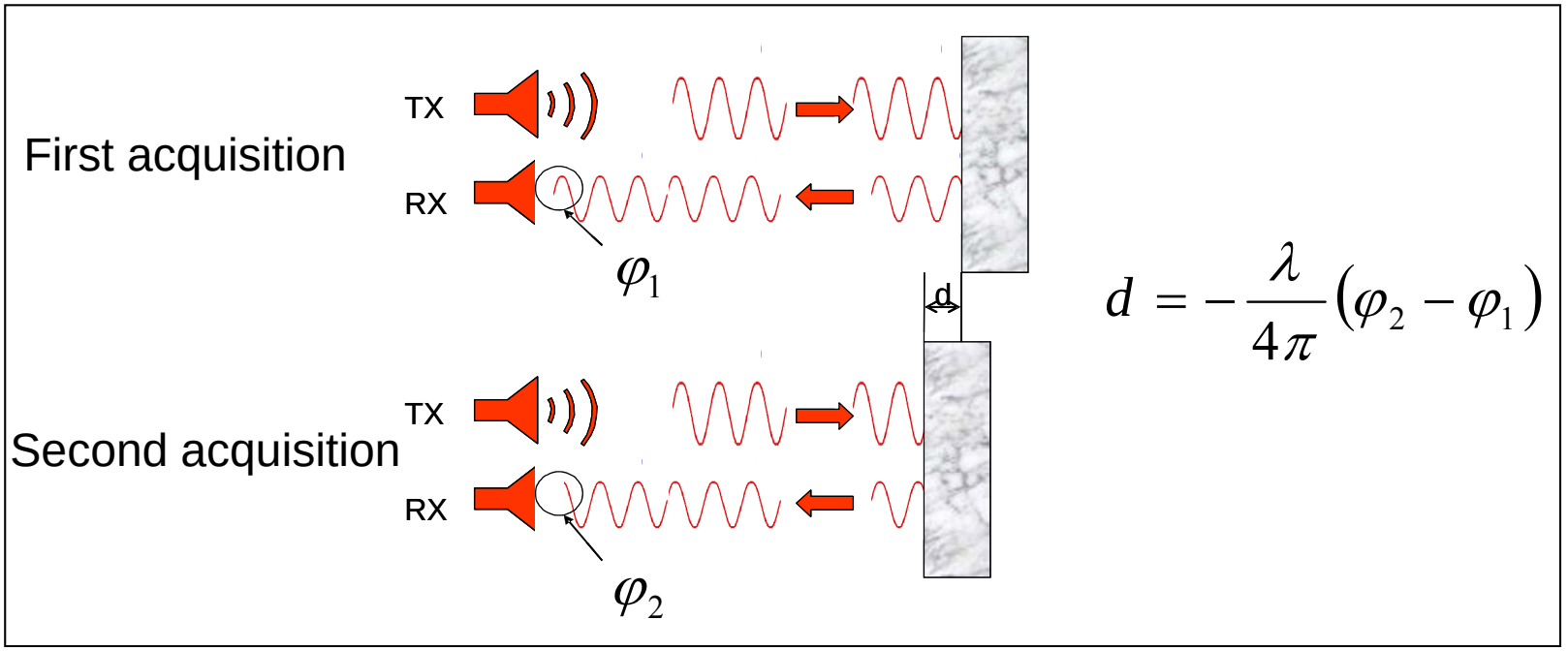
Interferometric capability

The **interferometric analysis** provides data on object displacement by comparing phase information, collected in different time periods, of reflected waves from the object, providing a measure of the displacement with an accuracy of less than 0.01mm (intrinsic radar accuracy in the order of 0.001 mm.)



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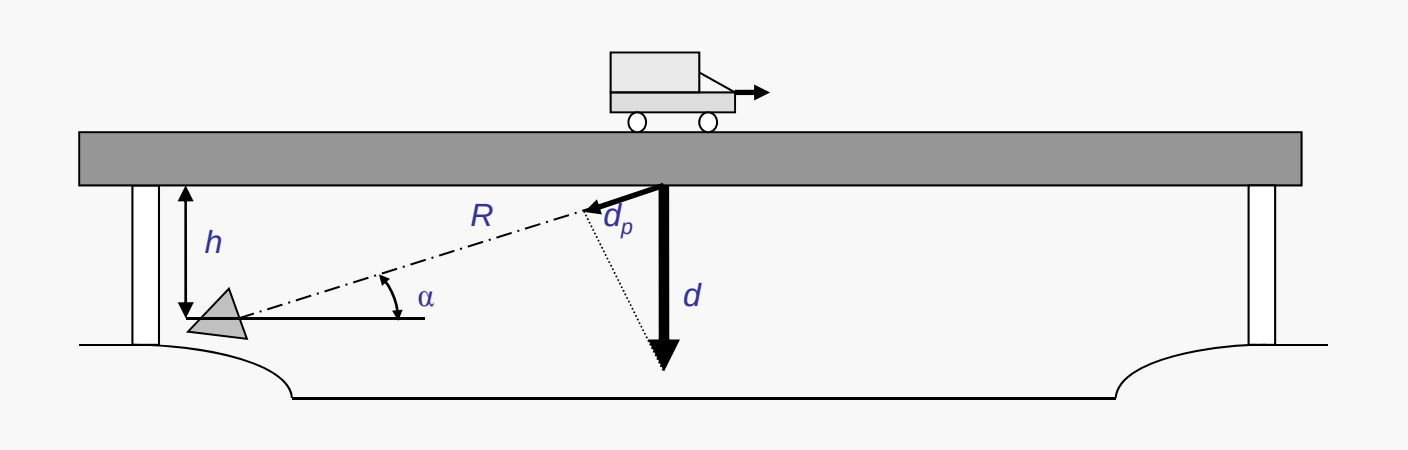
Interferometric capability

The displacement is measured in the direction of the line of sight of the system.

To calculate the real displacement is needed to know the acquisition geometry



$$d = \frac{d_p}{\sin(\alpha)} \quad \Rightarrow \quad \sin(\alpha) = \frac{h}{R} \quad \Rightarrow \quad d = d_p \cdot \frac{R}{h}$$

*The distance **R** is measured by IBIS-S*

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IBIS main advantages

The main advantages of the use of IBIS for monitoring are:

- possibility to carry out the survey without accessing the land/structure but installing the IBIS system in its proximity

- obtain information from all the area illuminated by the antenna beam: the radar measures the local displacement of the scenario by resolving it into pixels of a few square meters

- high displacement measurement accuracy, up to 1/10 mm

- day-night continuous operation

- completely autonomous operation not requiring human intervention

- acquisition frequency of the order minutes for IBIS-L, msec for IBIS-S

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Landslide monitoring

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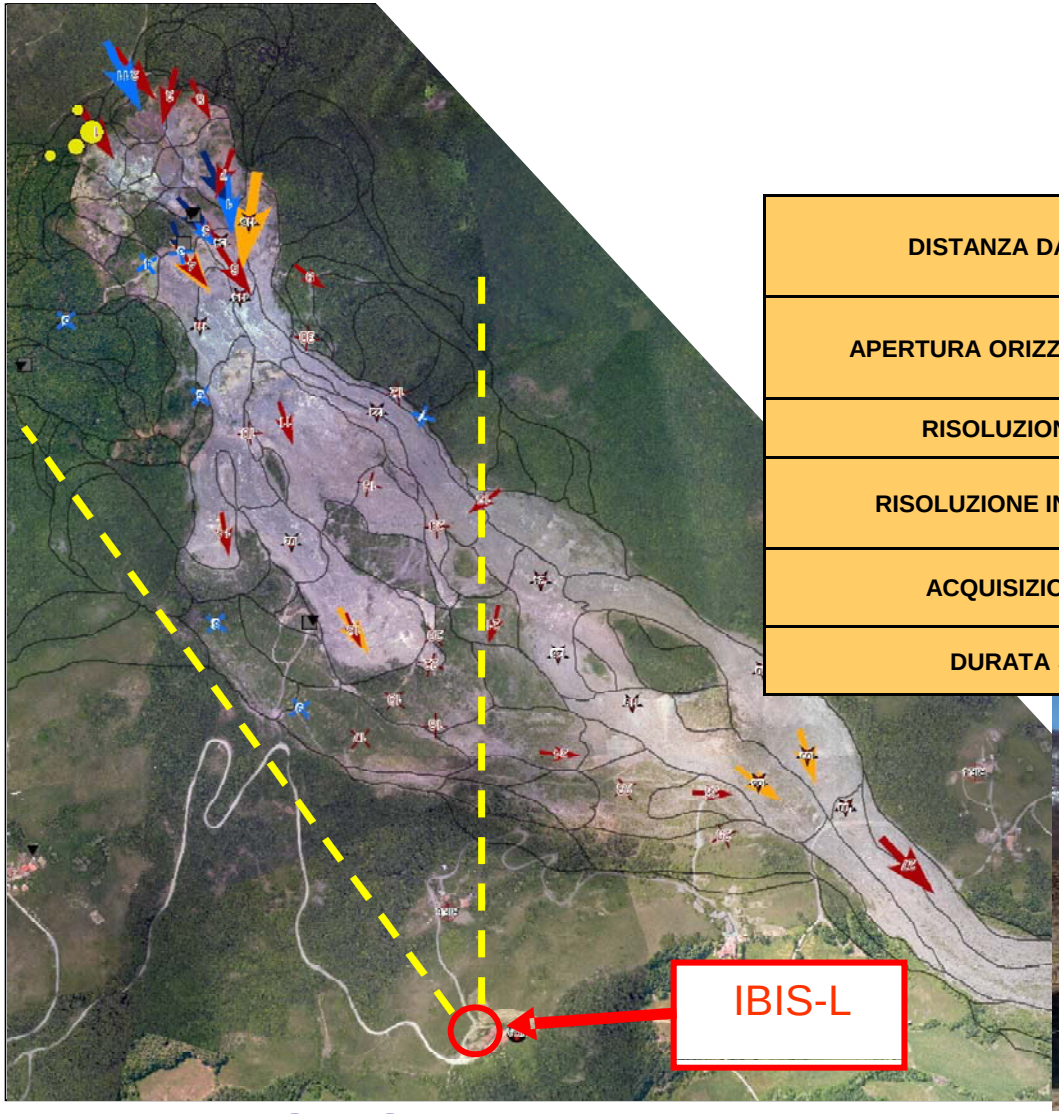
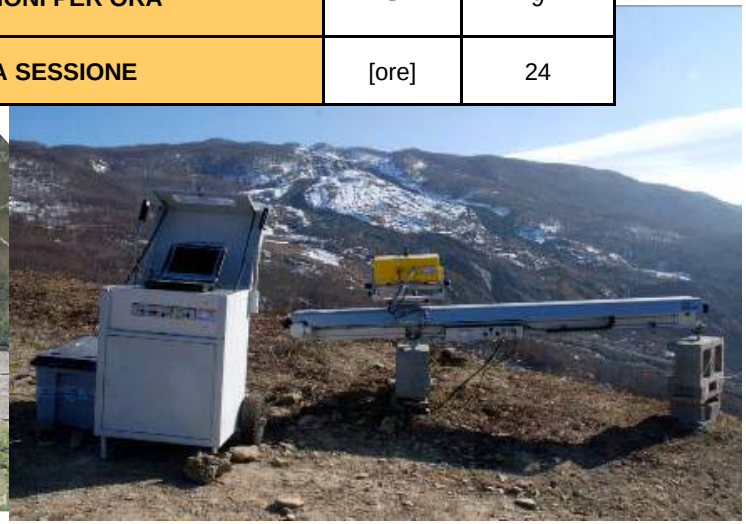
Landslide monitoring



IBIS-L System set-up

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



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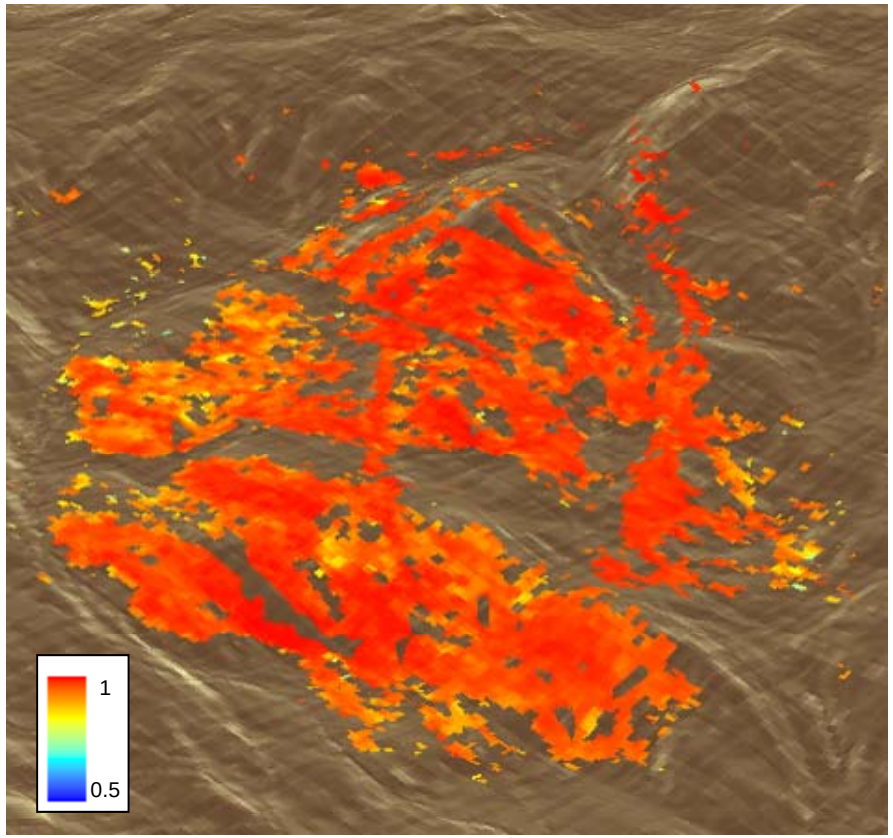
Landslide monitoring



Geocoded quality map

Picture taken from the radar location

More than 40.000 measurement points are identified on the quality map

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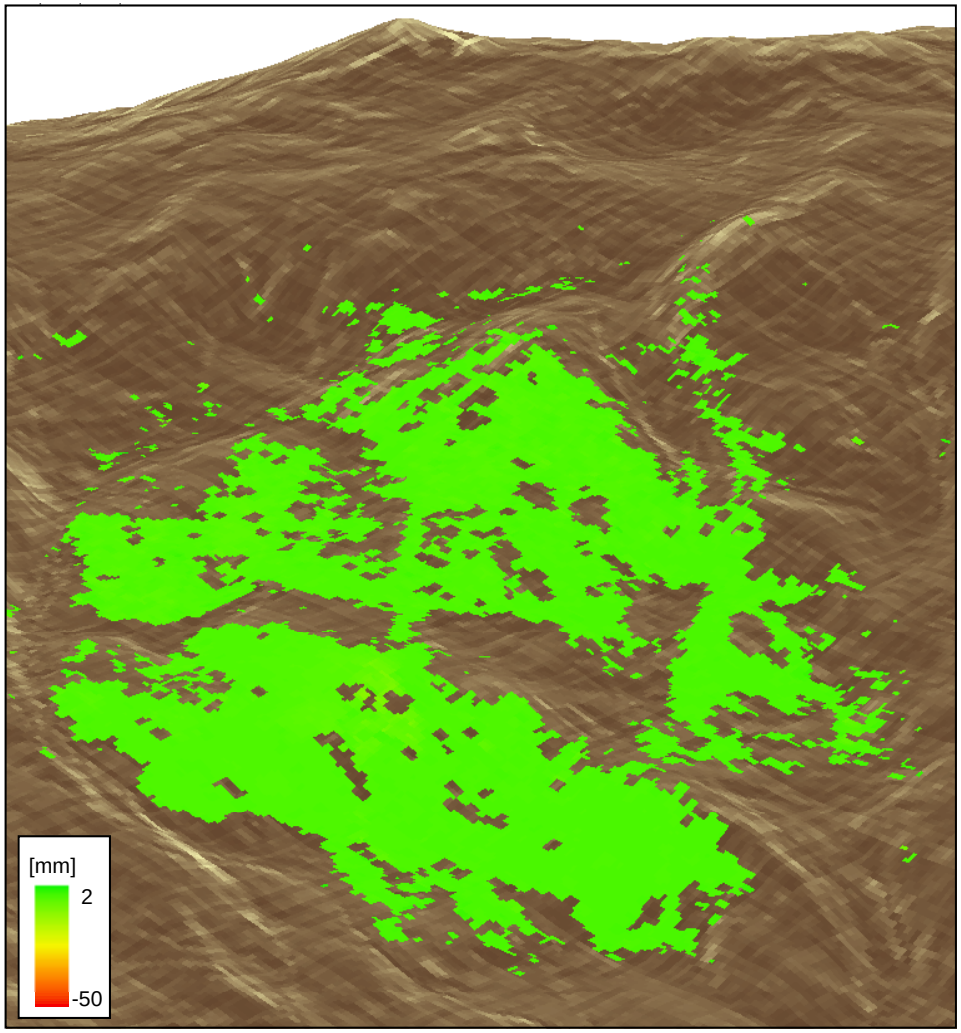
IDS INGEGNERIA DEI SISTEMI

Geocoded cumulative displacement map (1 h)

Geocoded Line Of Sight Displacement Map



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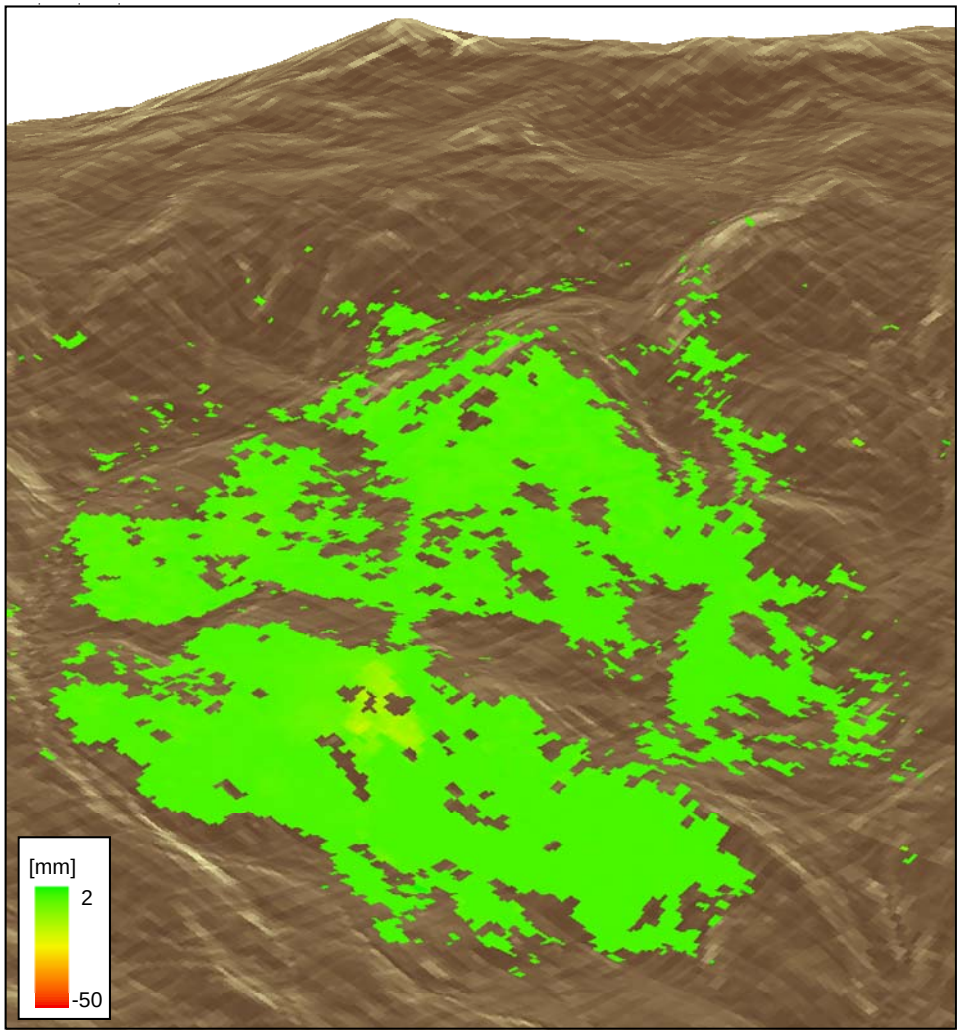
Geocoded cumulative displacement map (2 h)

Geocoded Line Of Sight Displacement Map



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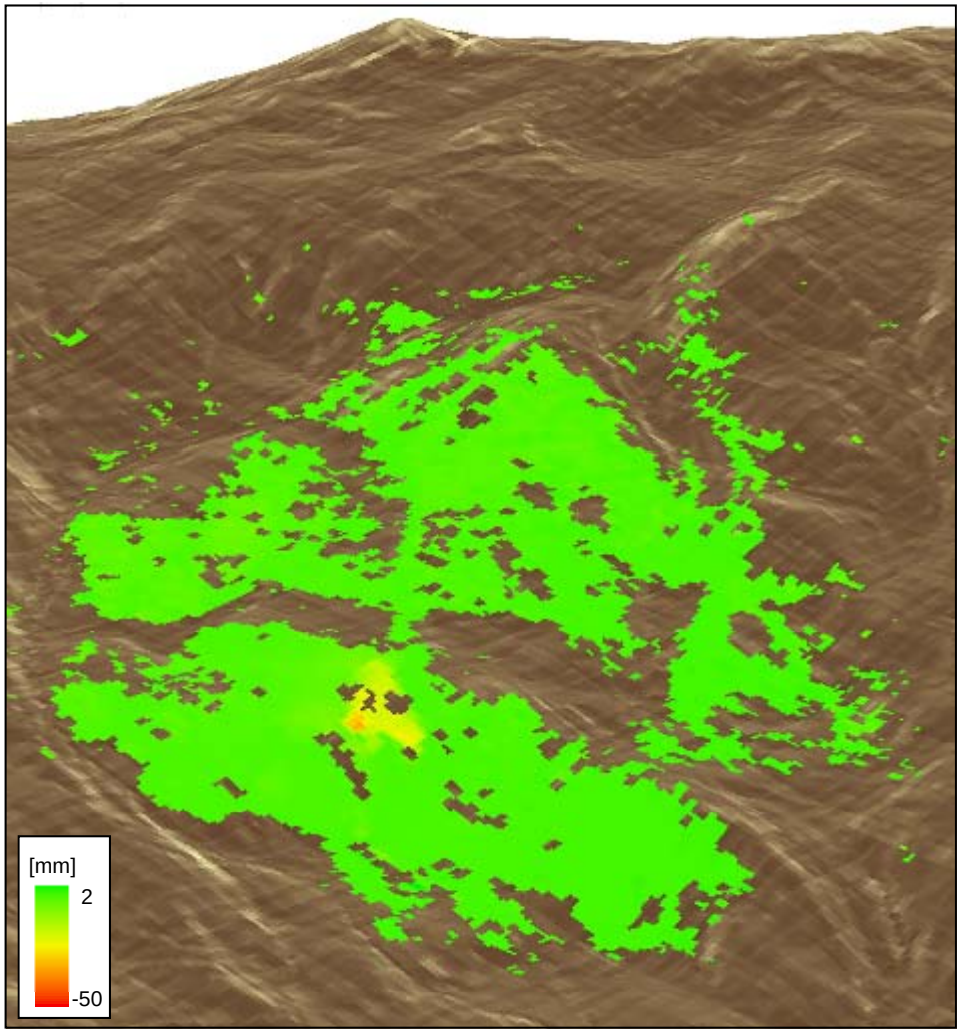
Geocoded cumulative displacement map (3 h)

Geocoded Line Of Sight Displacement Map



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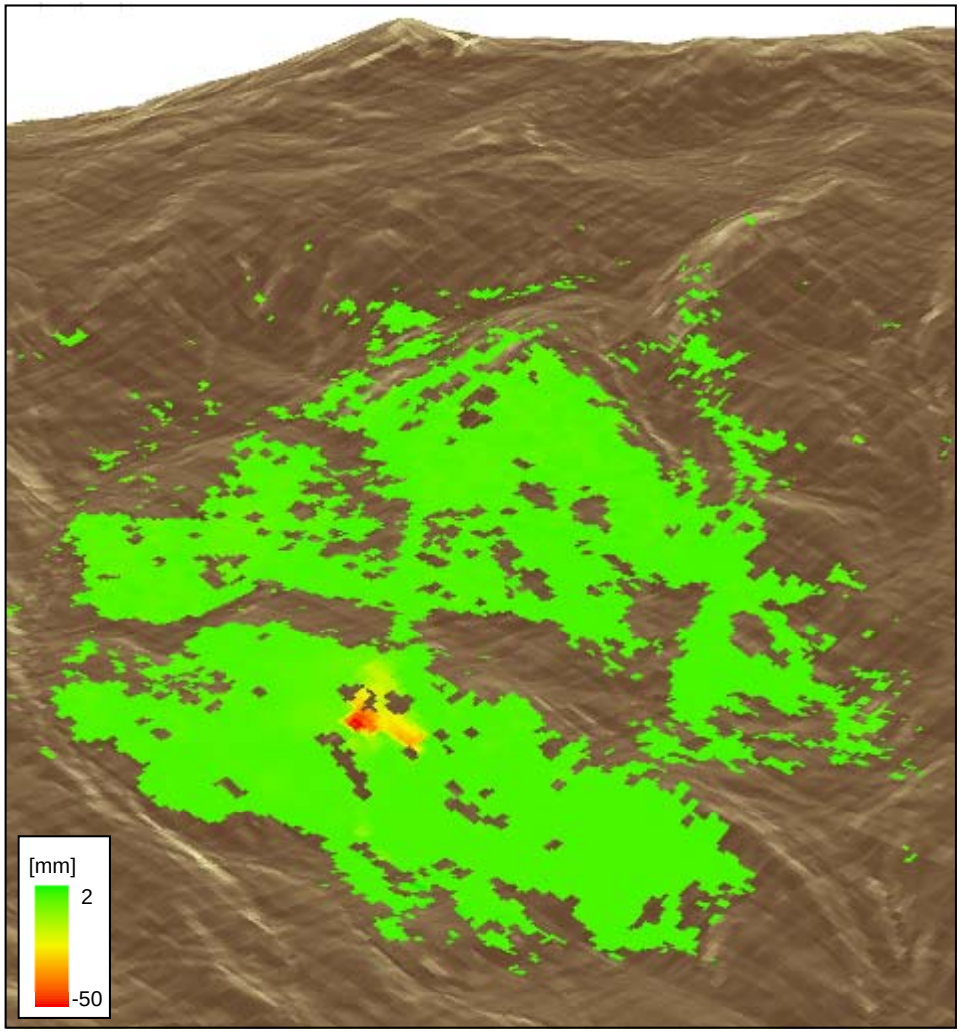
Geocoded cumulative displacement map (4 h)

Geocoded Line Of Sight Displacement Map



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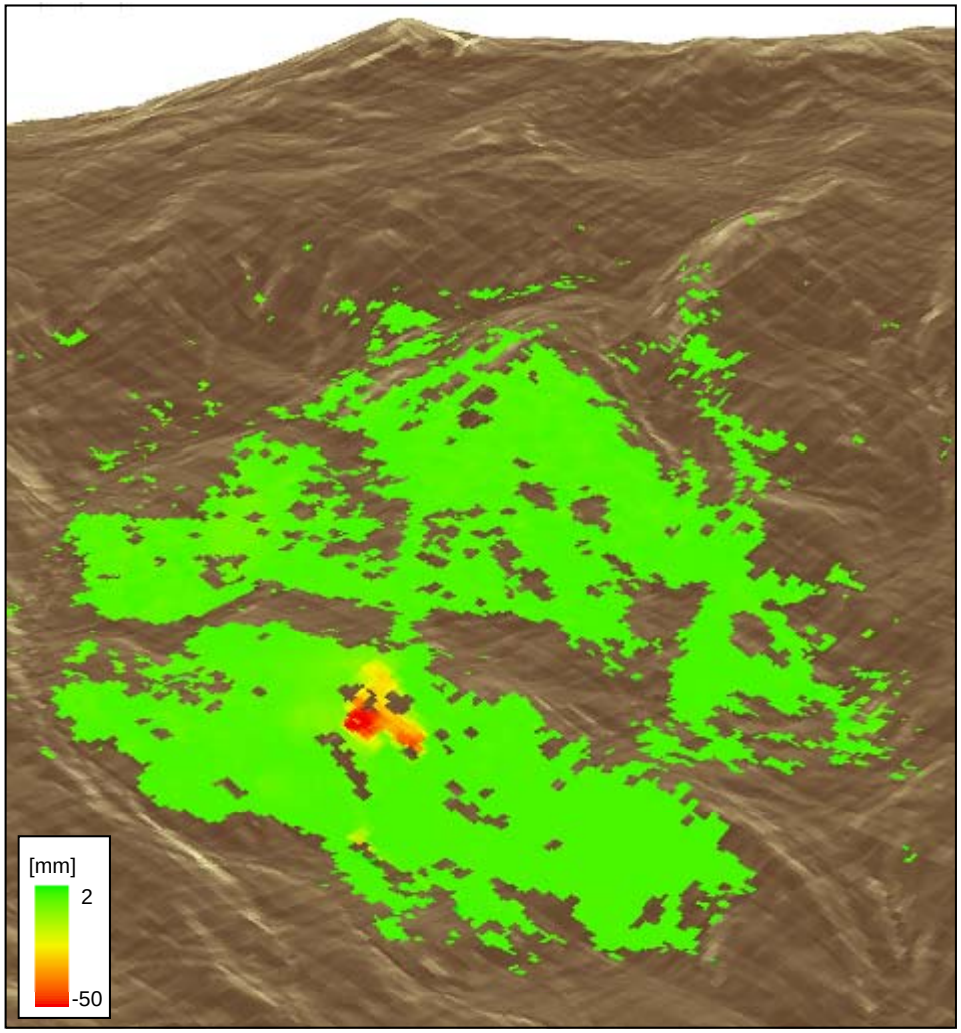
Geocoded cumulative displacement map (5 h)

Geocoded Line Of Sight Displacement Map



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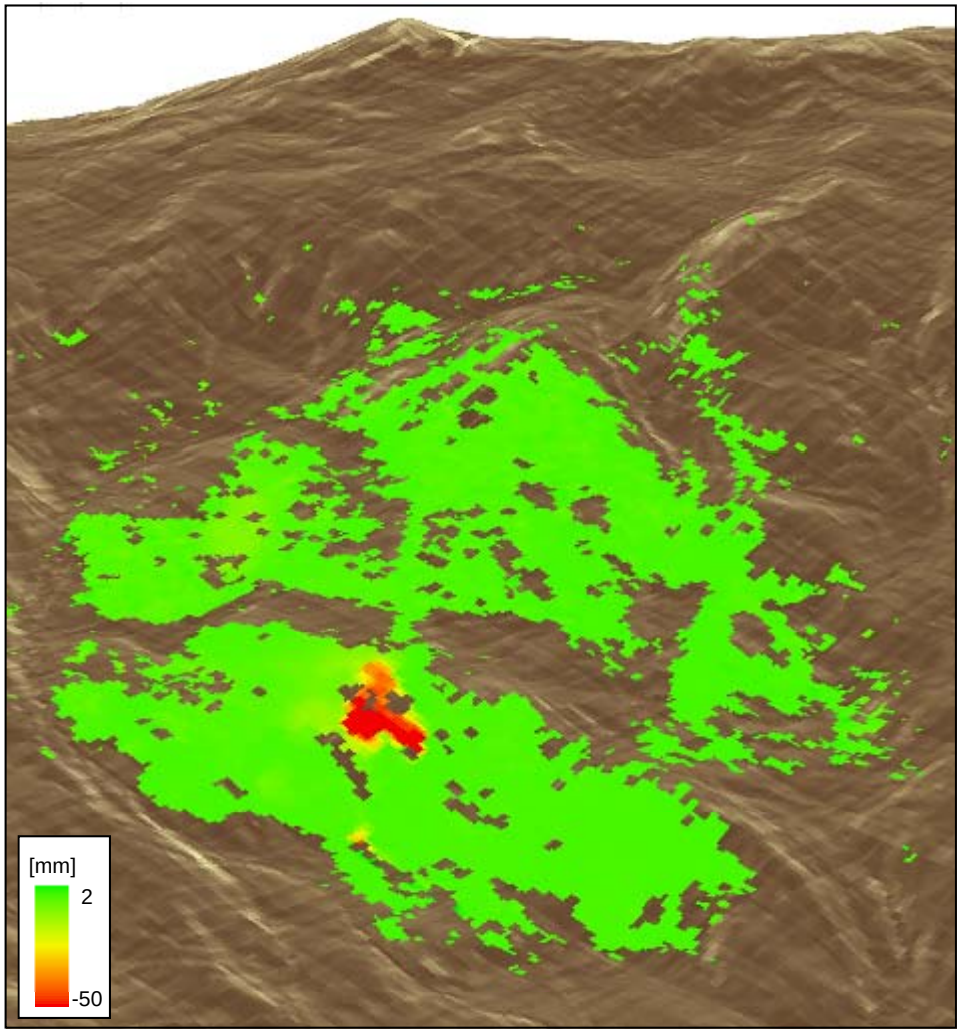
Geocoded cumulative displacement map (6 h)

Geocoded Line Of Sight Displacement Map



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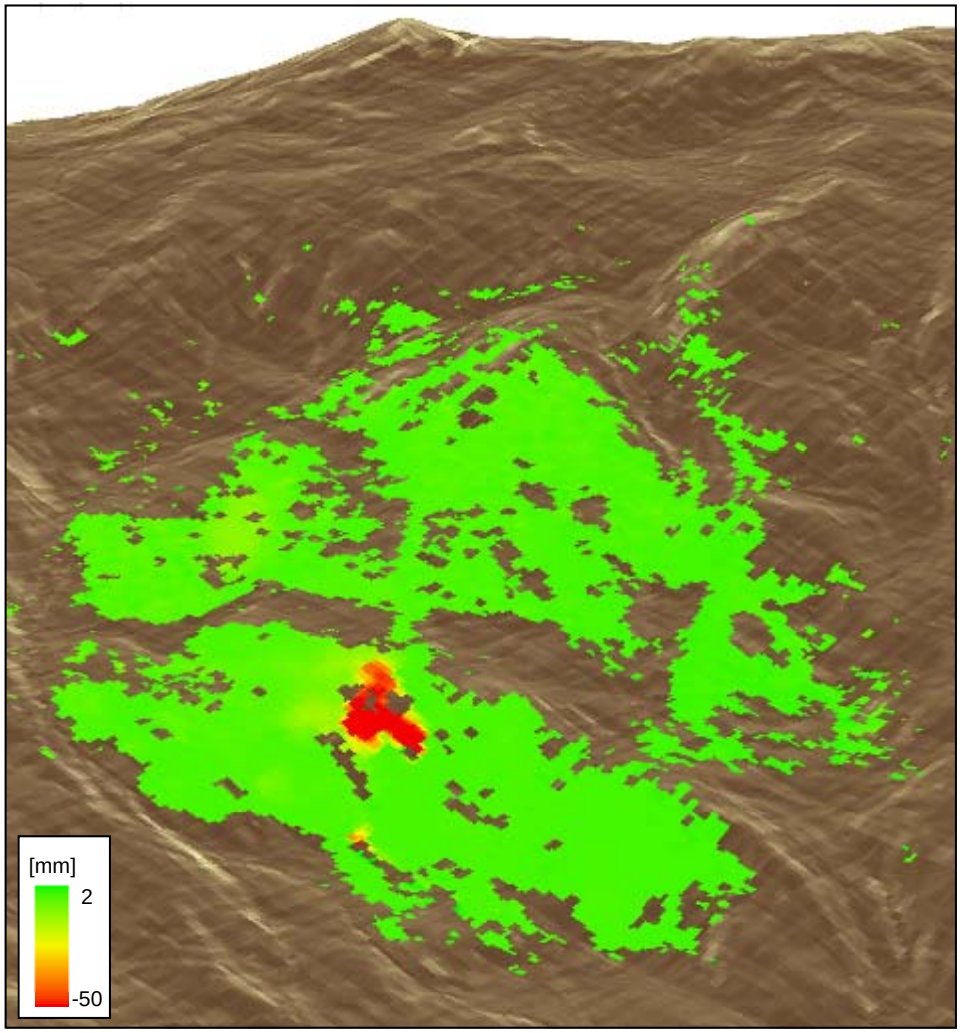
Geocoded cumulative displacement map (7 h)

Geocoded Line Of Sight Displacement Map



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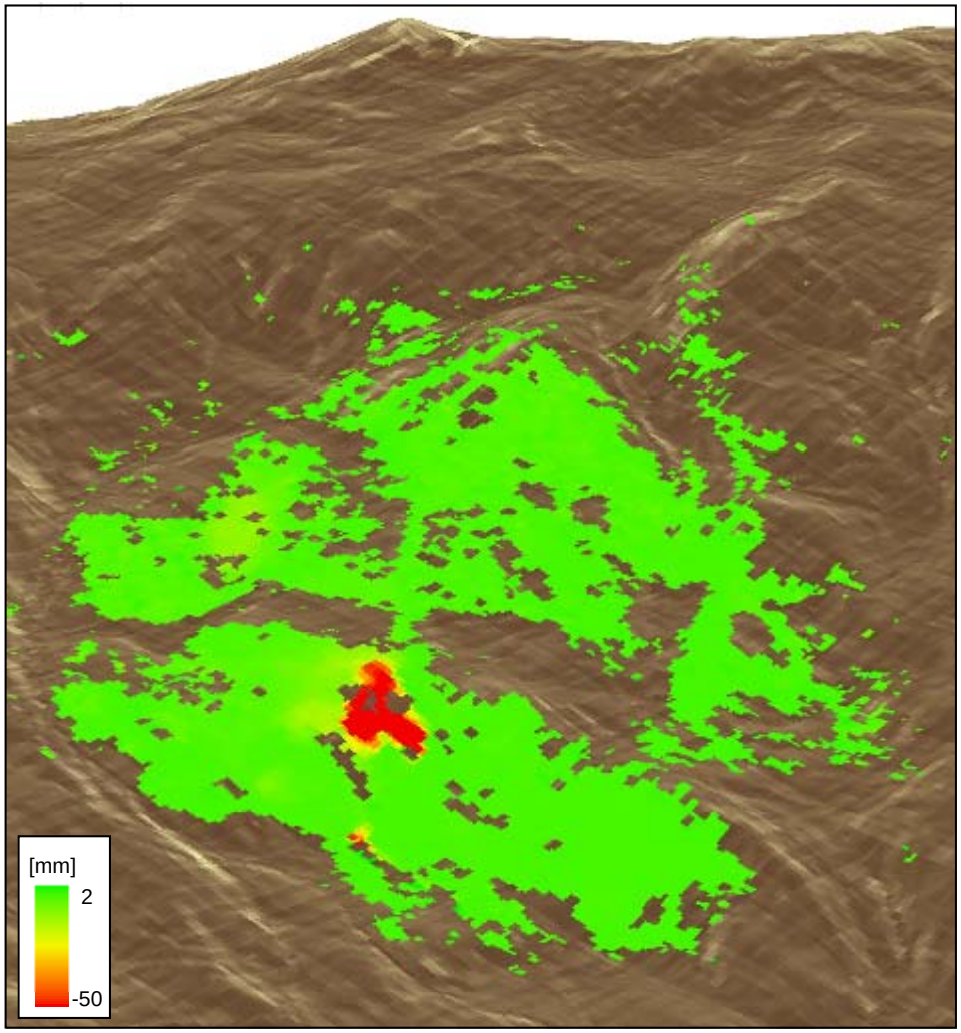
Geocoded cumulative displacement map (8 h)

Geocoded Line Of Sight Displacement Map



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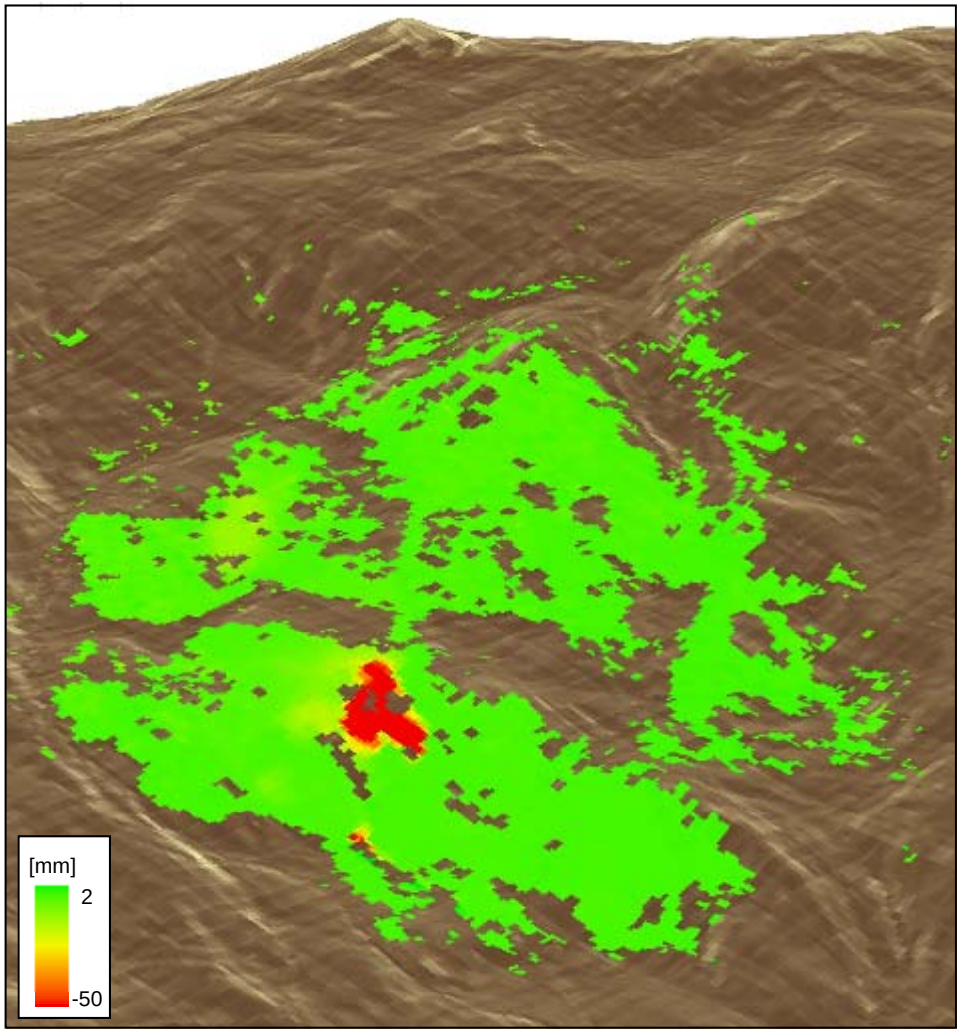
Geocoded cumulative displacement map (9 h)

Geocoded Line Of Sight Displacement Map



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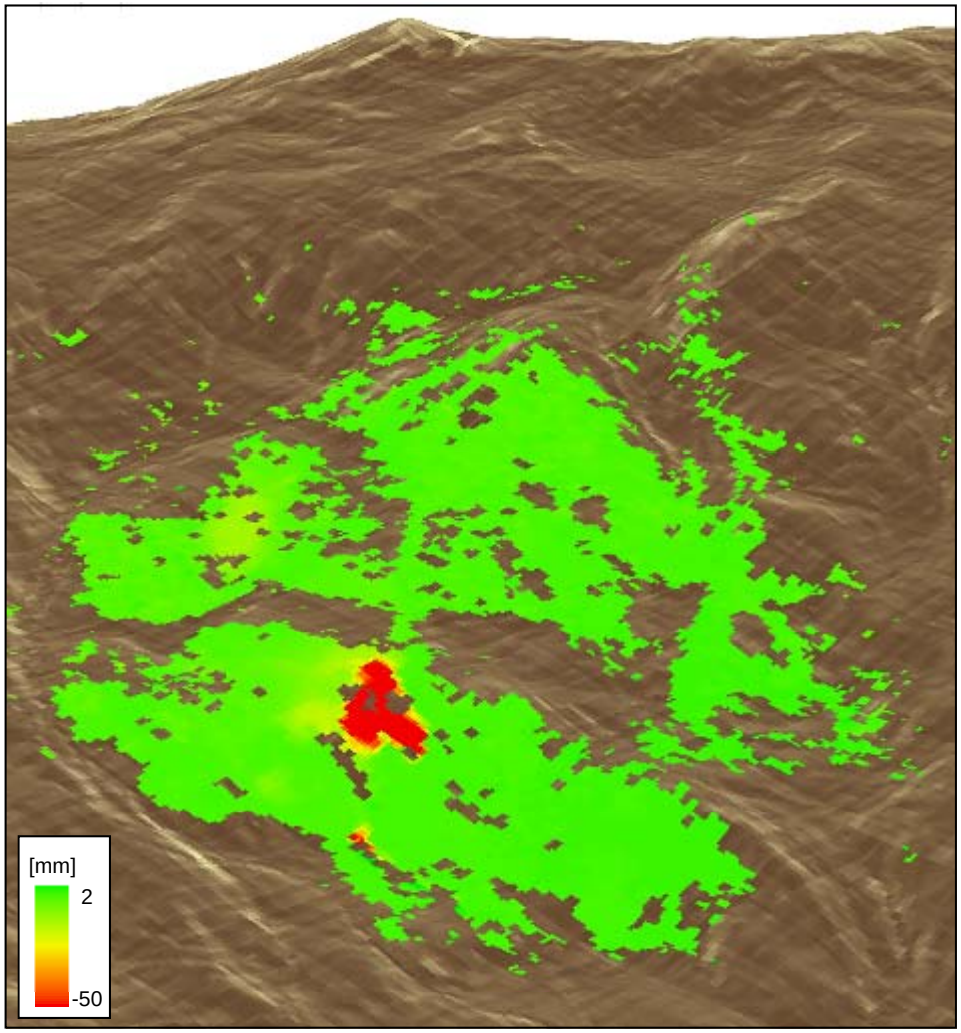
Geocoded cumulative displacement map (10 h)

Geocoded Line Of Sight Displacement Map



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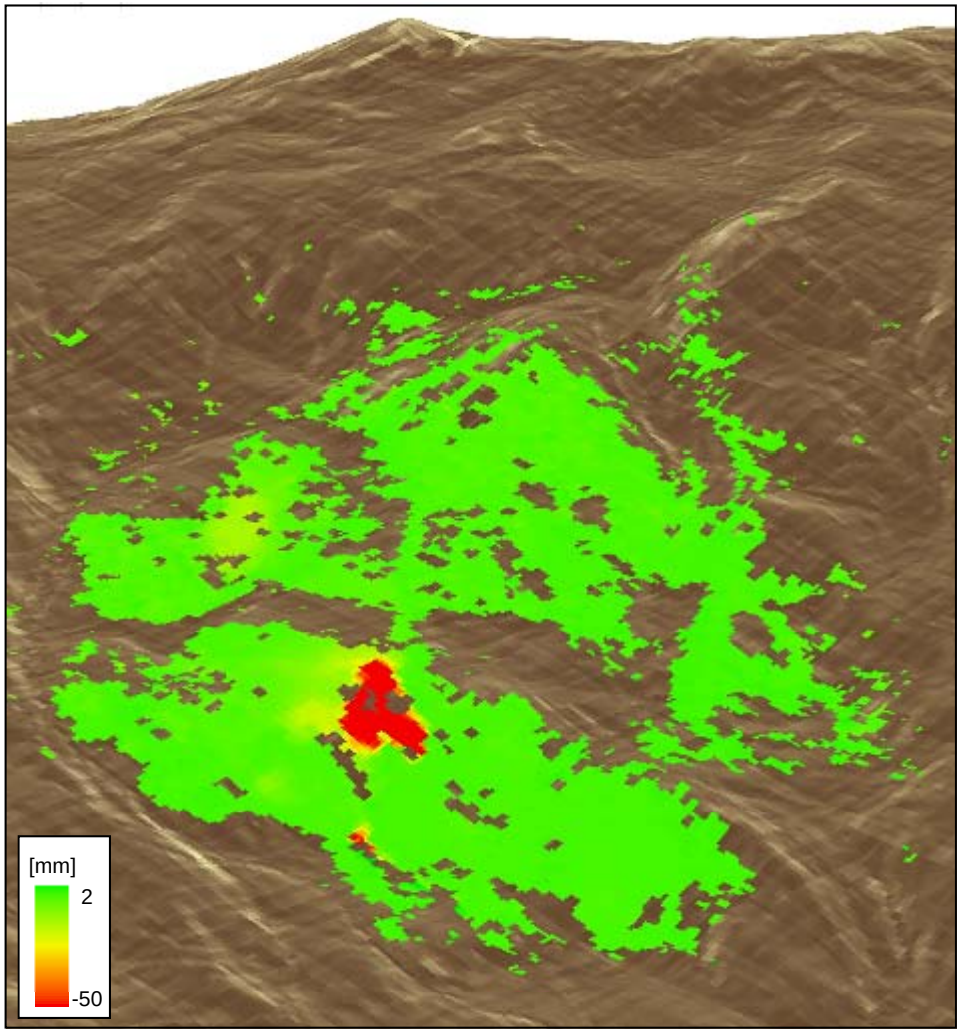
Geocoded cumulative displacement map (11 h)

Geocoded Line Of Sight Displacement Map



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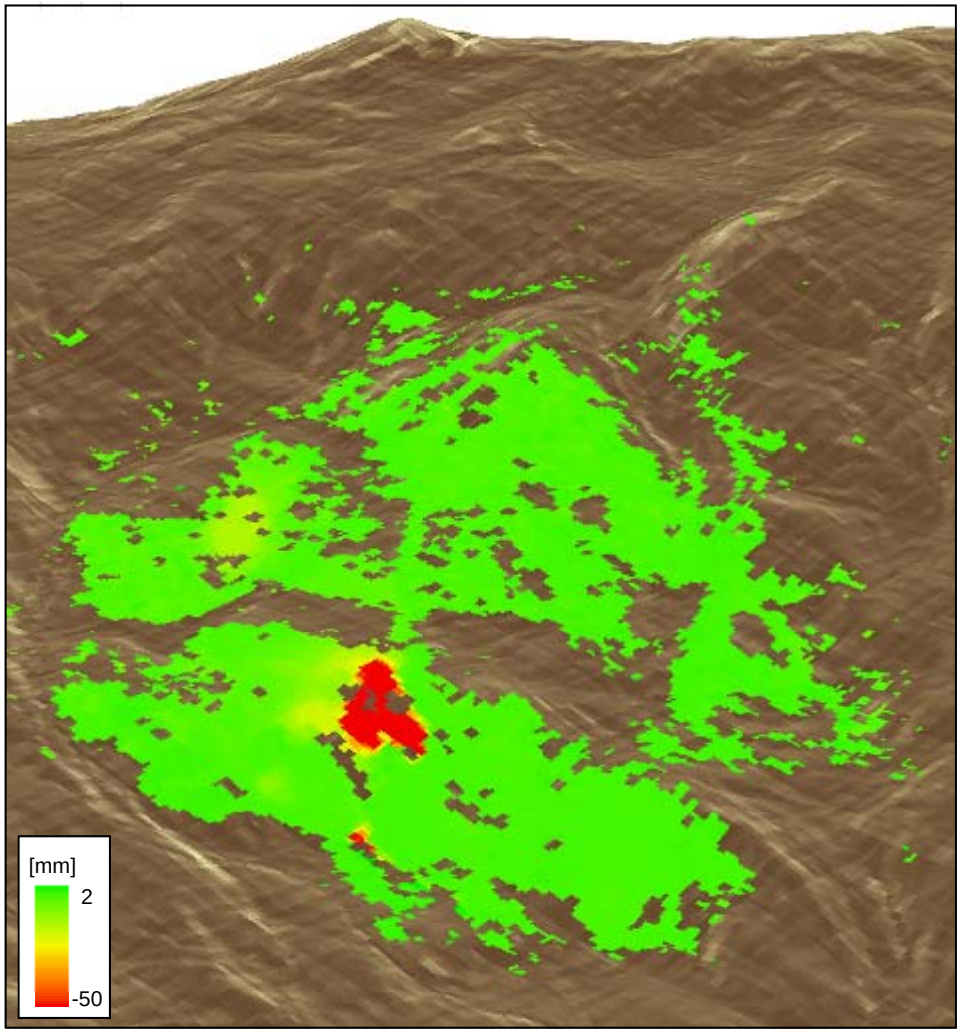
Geocoded cumulative displacement map (12 h)

Geocoded Line Of Sight Displacement Map



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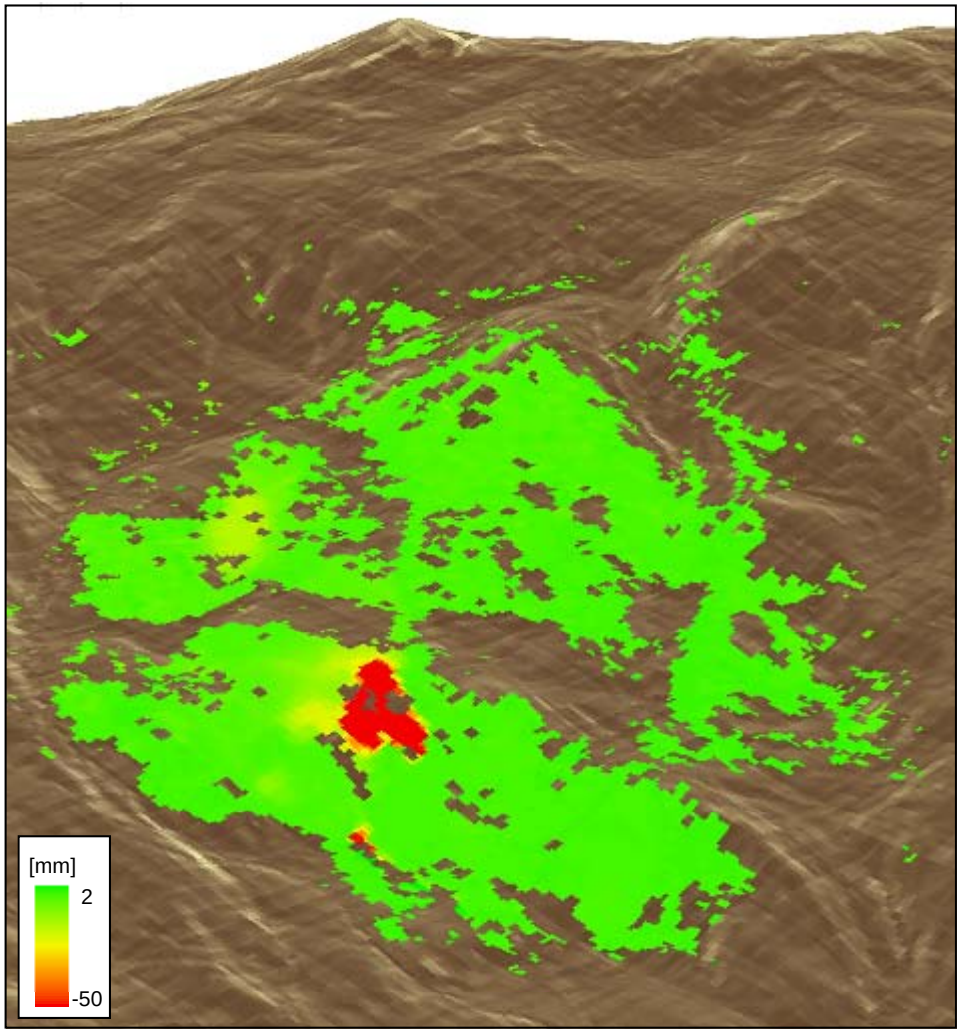
Geocoded cumulative displacement map (13 h)

Geocoded Line Of Sight Displacement Map



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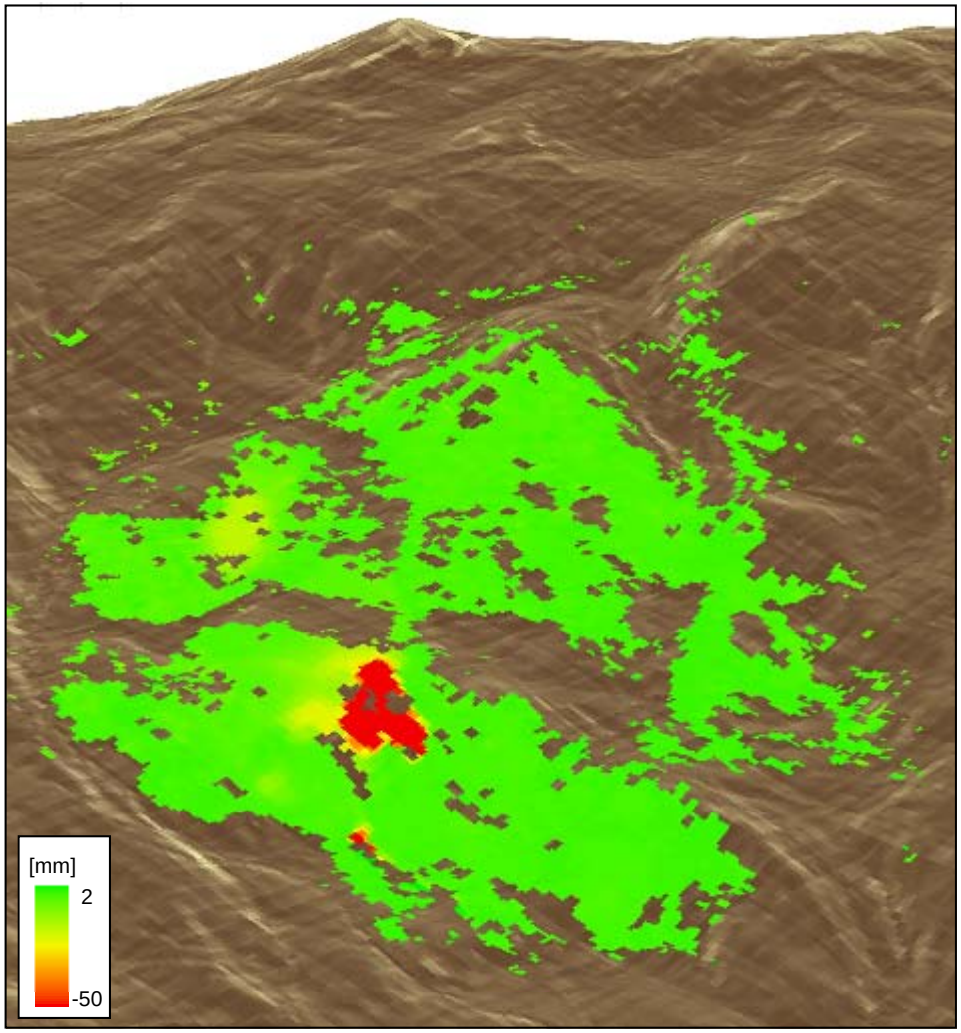
Geocoded cumulative displacement map (14 h)

Geocoded Line Of Sight Displacement Map



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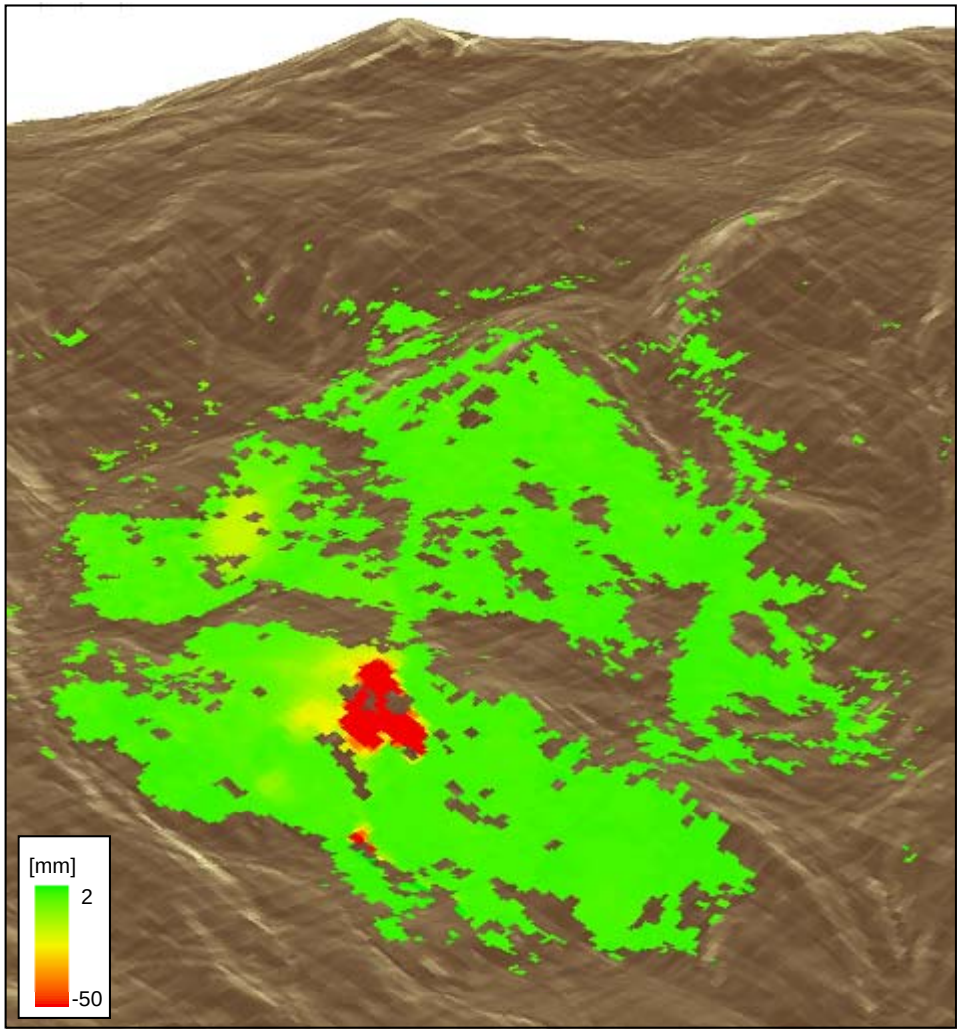
Geocoded cumulative displacement map (15 h)

Geocoded Line Of Sight Displacement Map



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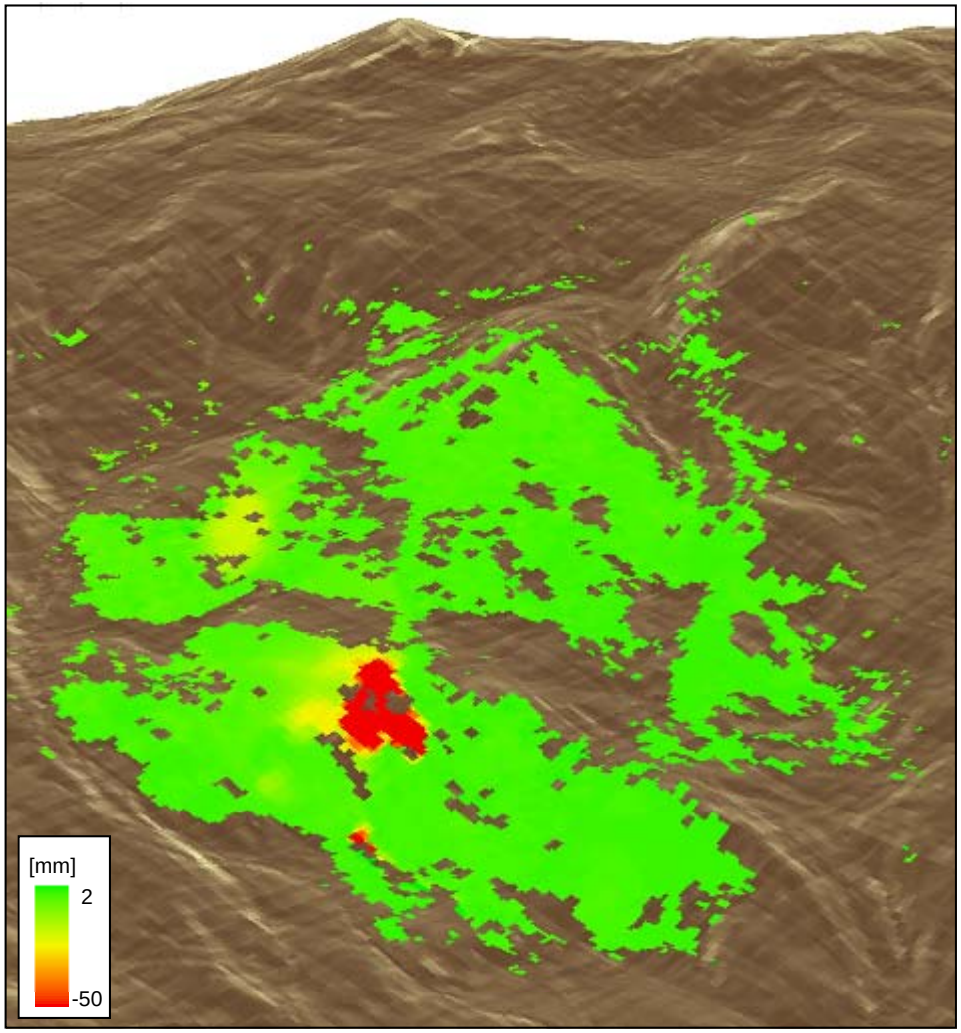
Geocoded cumulative displacement map (16 h)

Geocoded Line Of Sight Displacement Map



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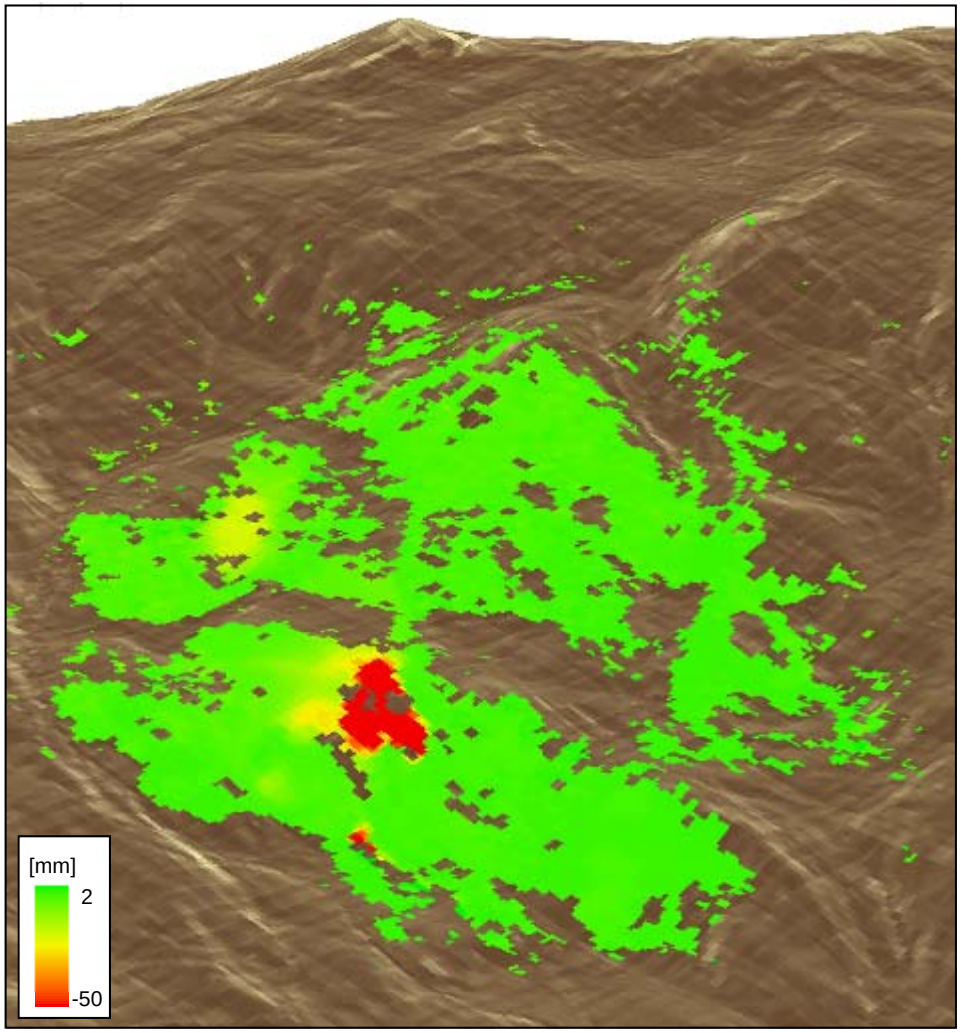
Geocoded cumulative displacement map (17 h)

Geocoded Line Of Sight Displacement Map



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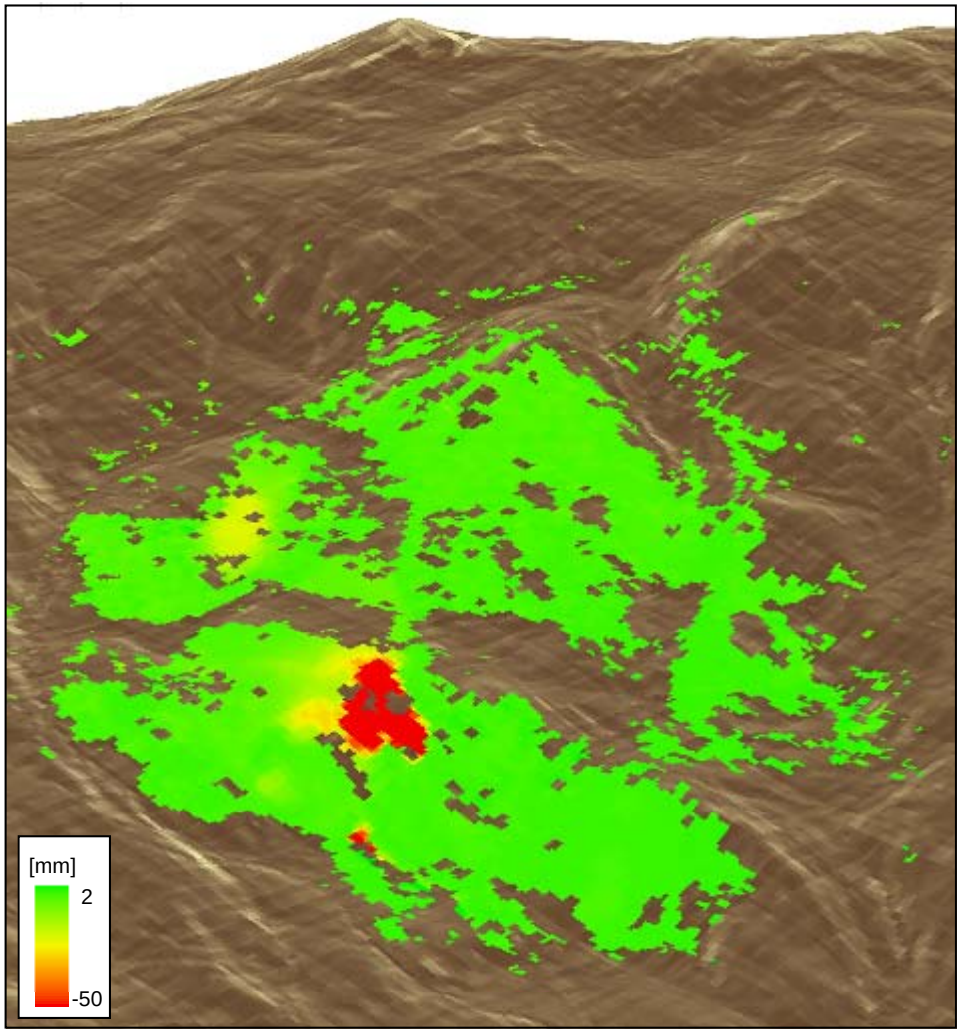
Geocoded cumulative displacement map (18 h)

Geocoded Line Of Sight Displacement Map



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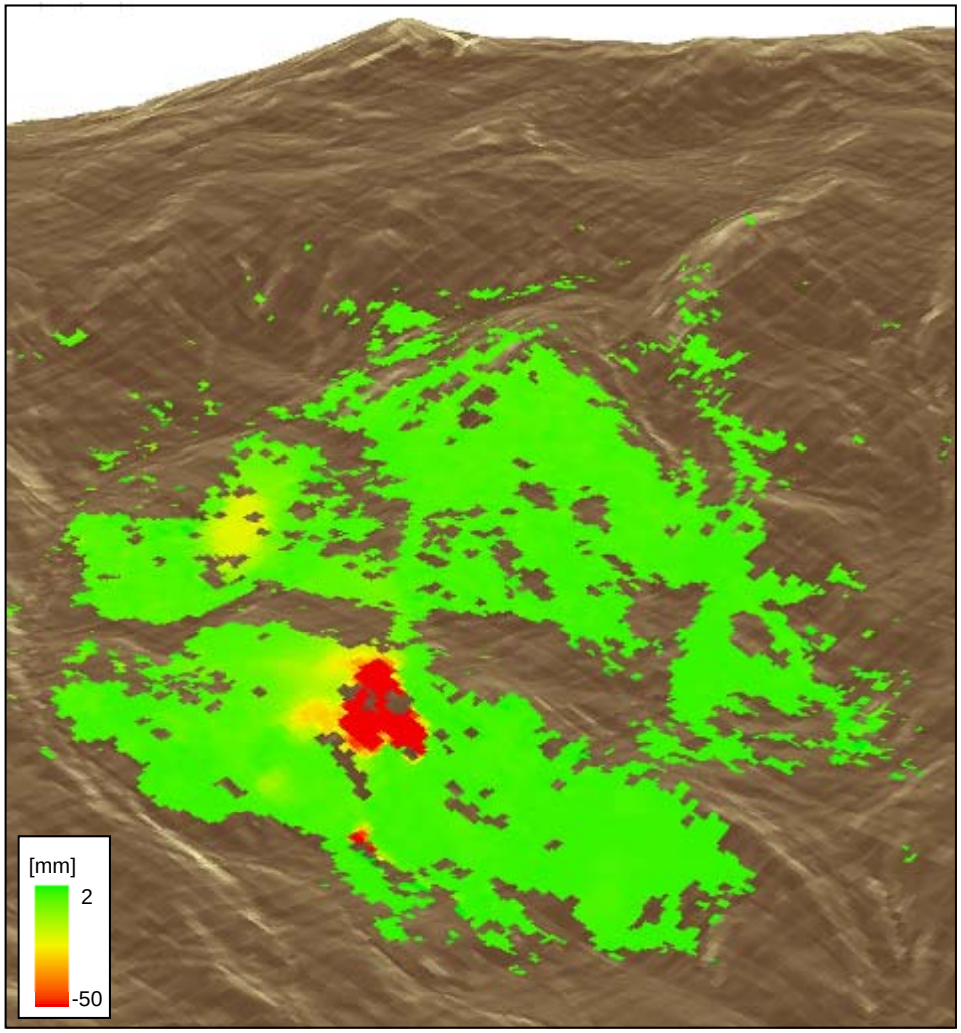
Geocoded cumulative displacement map (19 h)

Geocoded Line Of Sight Displacement Map



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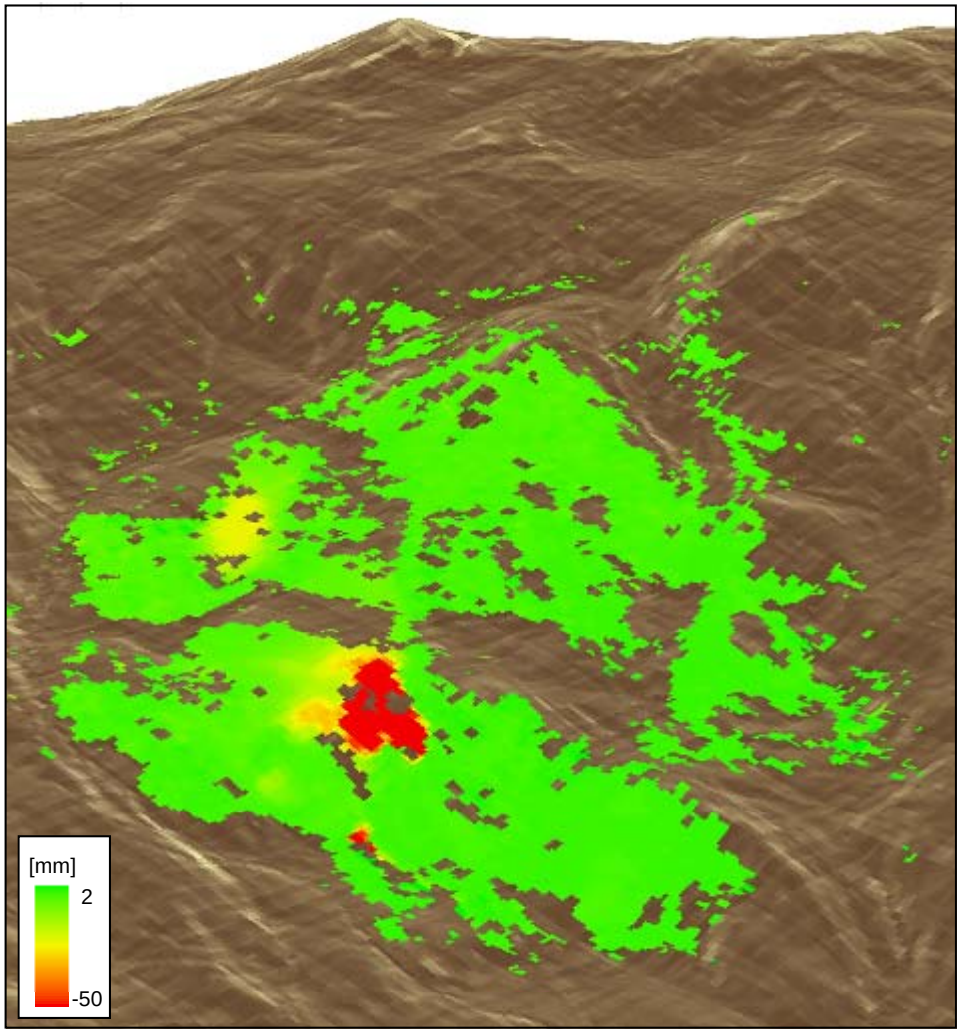
Geocoded cumulative displacement map (20 h)

Geocoded Line Of Sight Displacement Map



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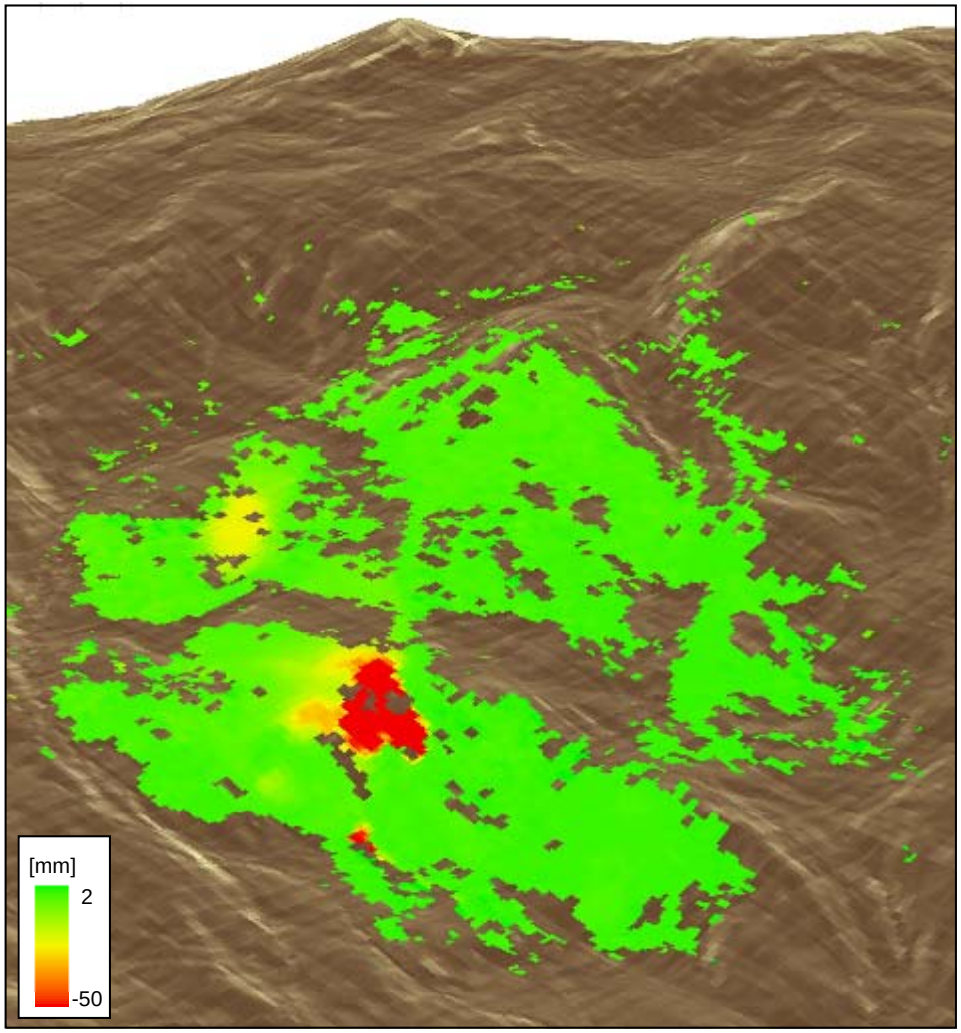
IDS INGEGNERIA DEI SISTEMI

Geocoded cumulative displacement map (21 h)

Geocoded Line Of Sight Displacement Map



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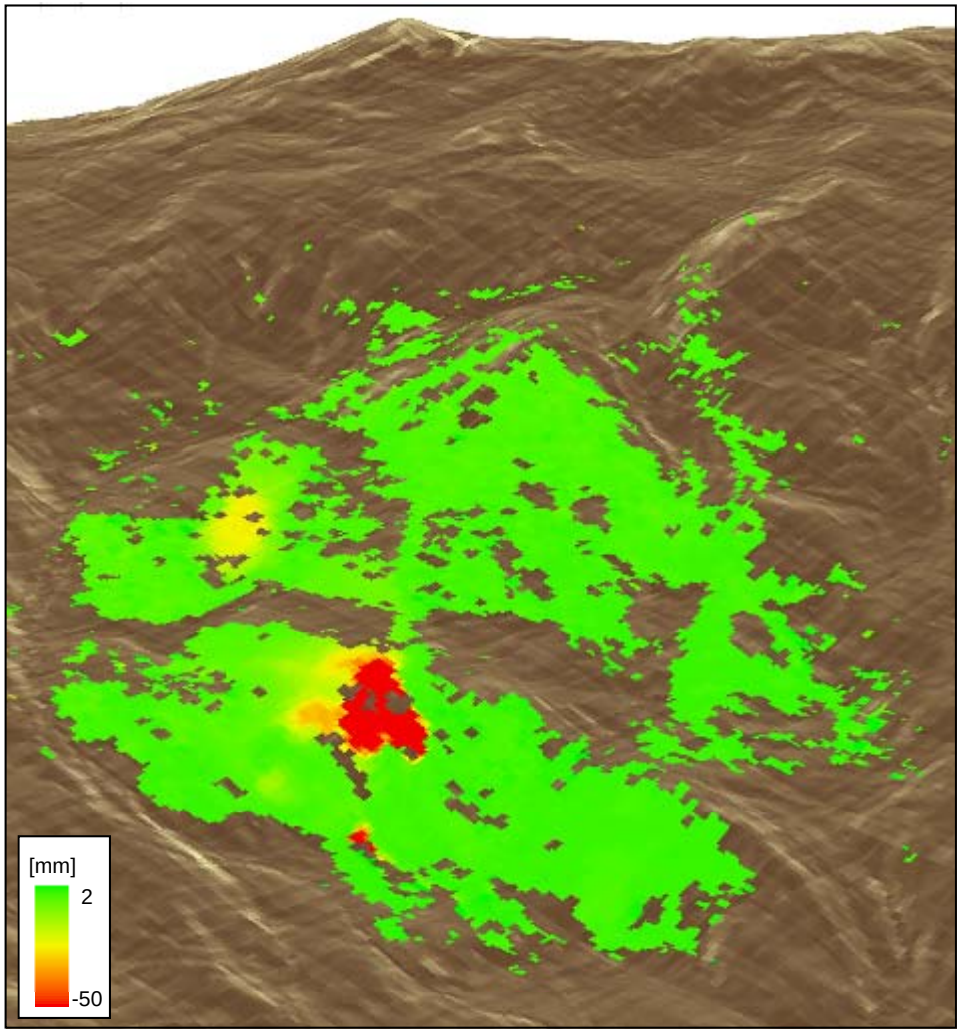
Geocoded cumulative displacement map (22 h)

Geocoded Line Of Sight Displacement Map



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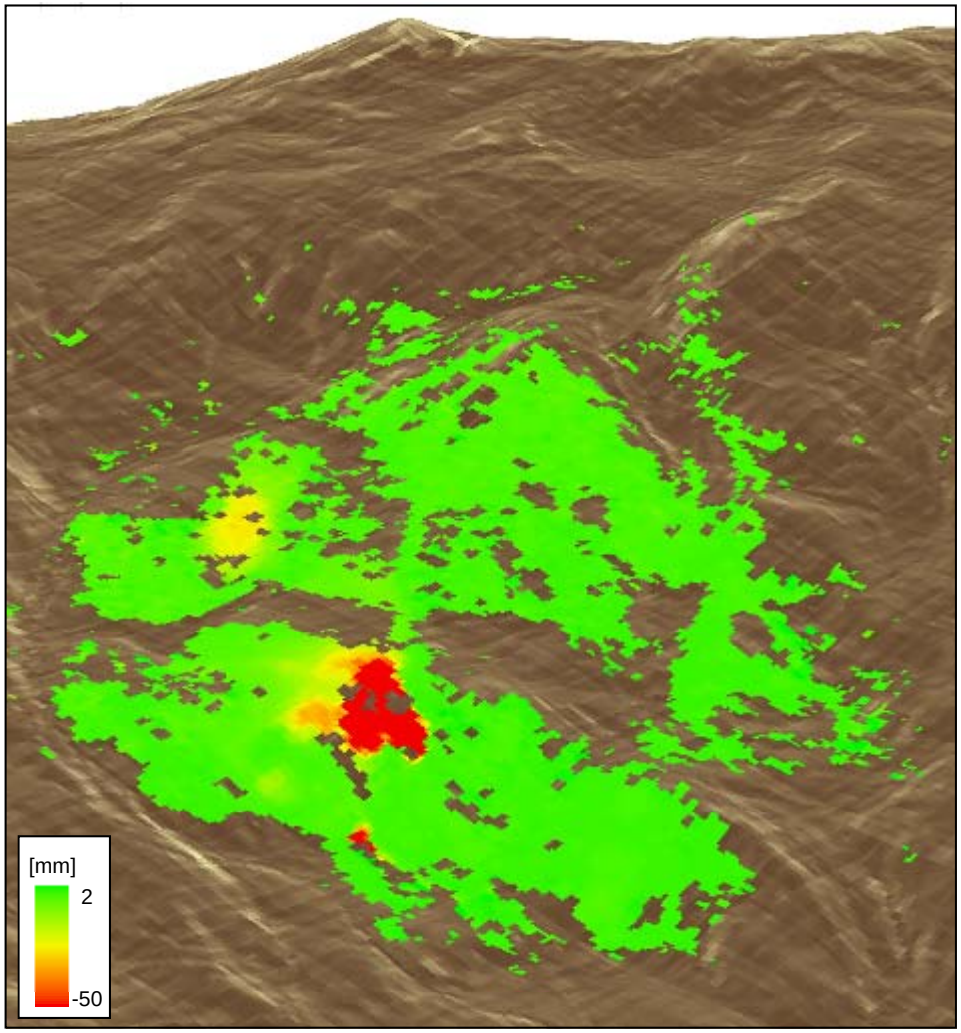
Geocoded cumulative displacement map (23 h)

Geocoded Line Of Sight Displacement Map



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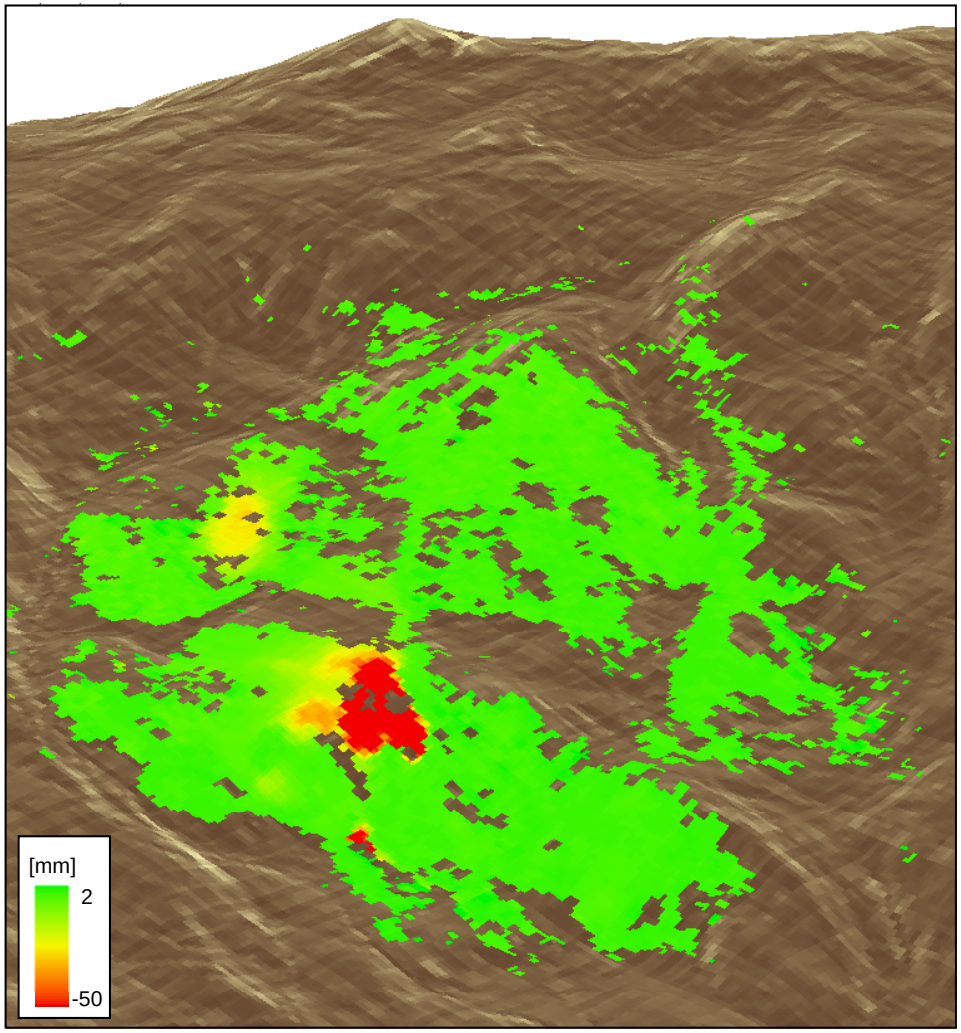
Geocoded cumulative displacement map (24 h)

Geocoded Line Of Sight Displacement Map



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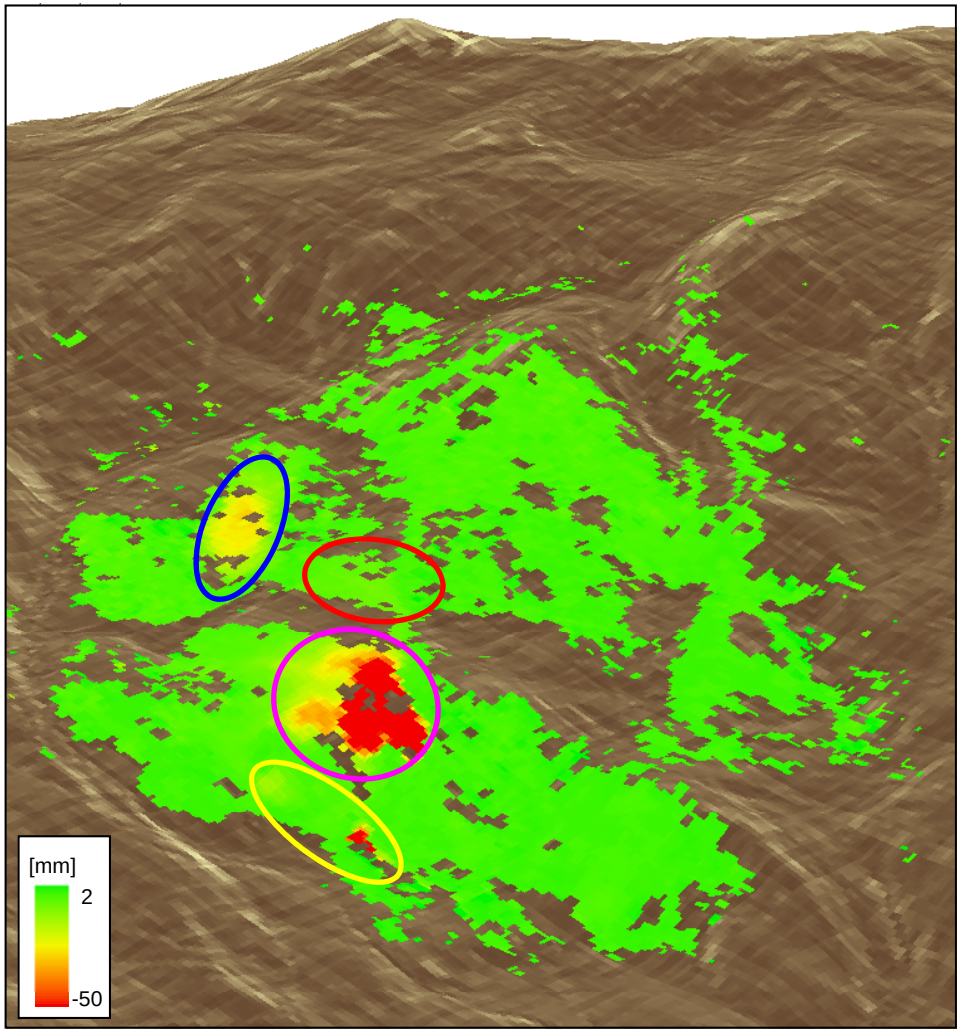
Identification of moving portions of the slope

Zona A	
Zona B	
Zona C	
Zona D	

Geocoded Line Of Sight Displacement Map



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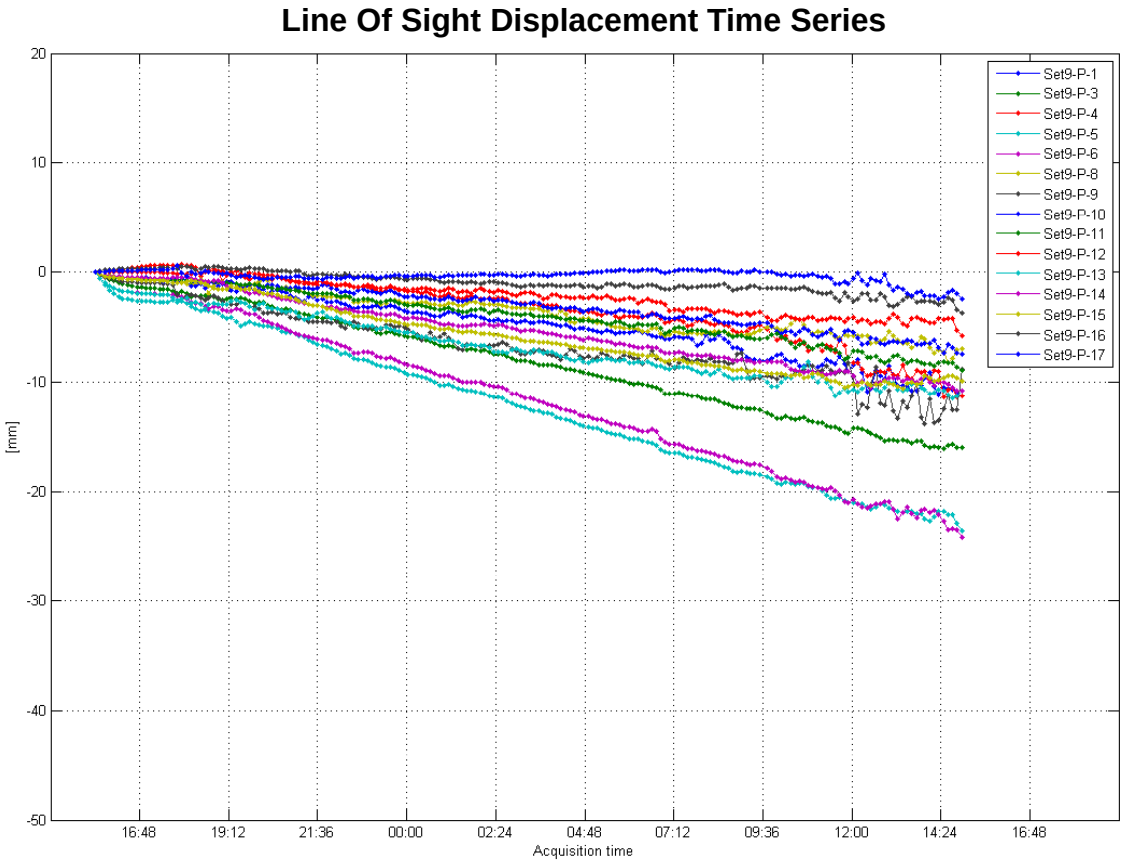
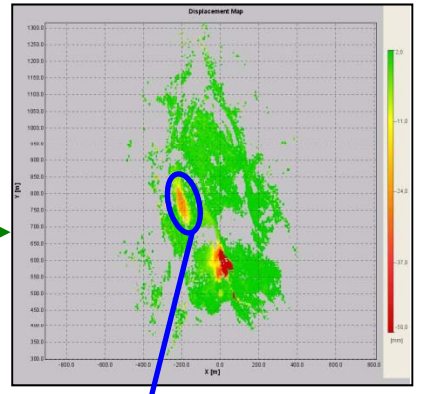
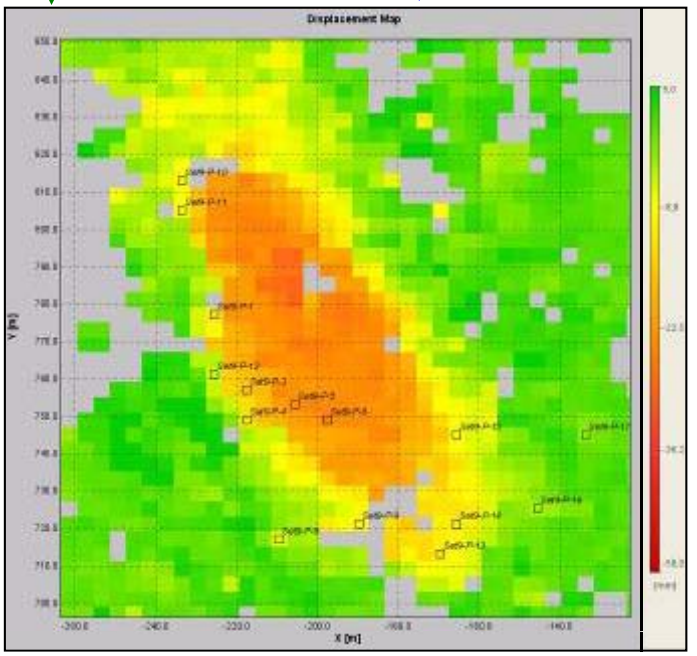
Displacement time series

ZONA A - movimento di alcuni punti di misura selezionati



Mappe di spostamento cumulato dopo 24 ore





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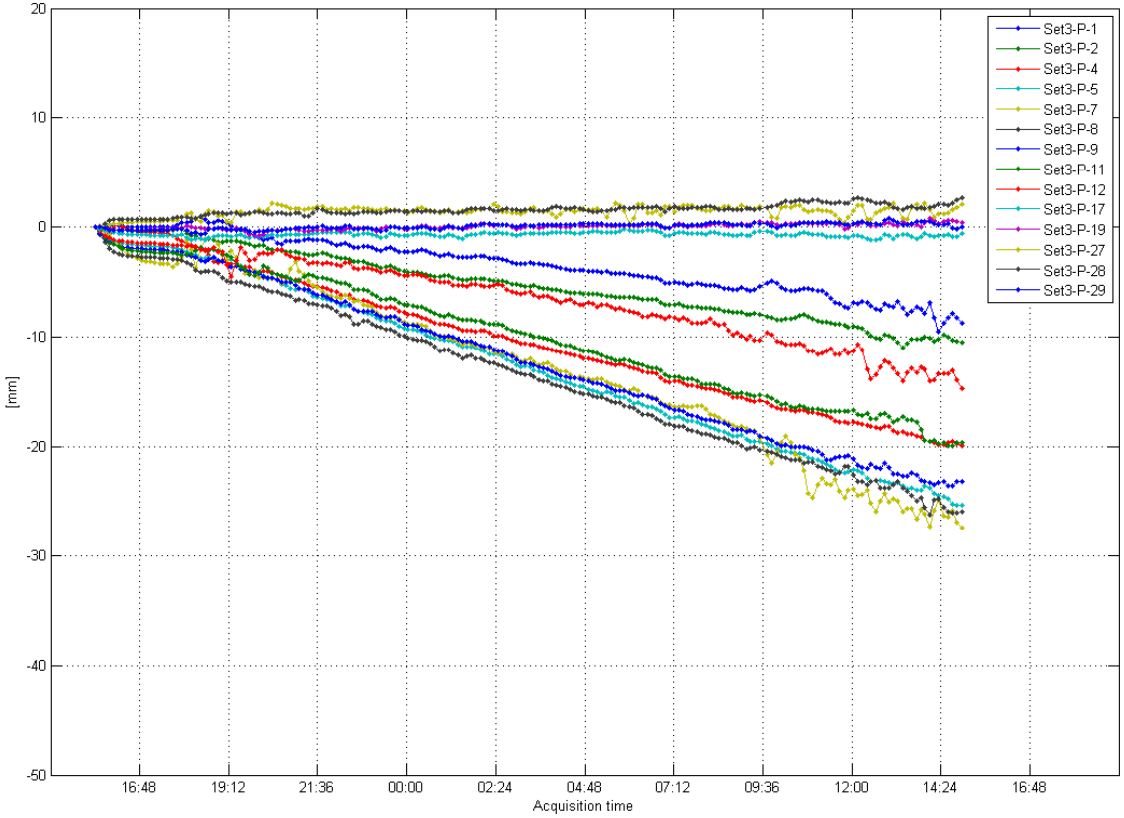
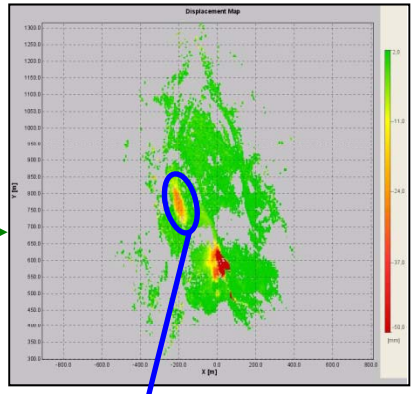
Displacement time series

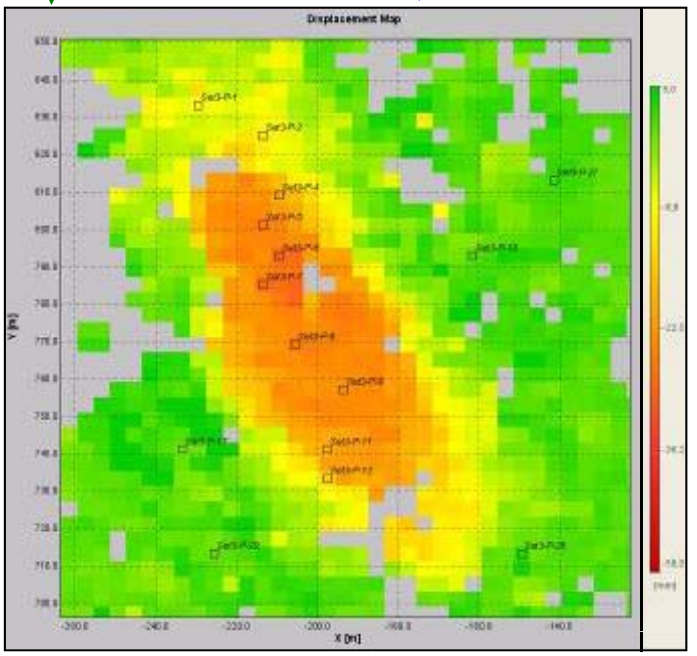
ZONE A - displacement of a few points

Line Of Sight Displacement Time Series



Mappe di spostamento cumulato dopo 24 ore





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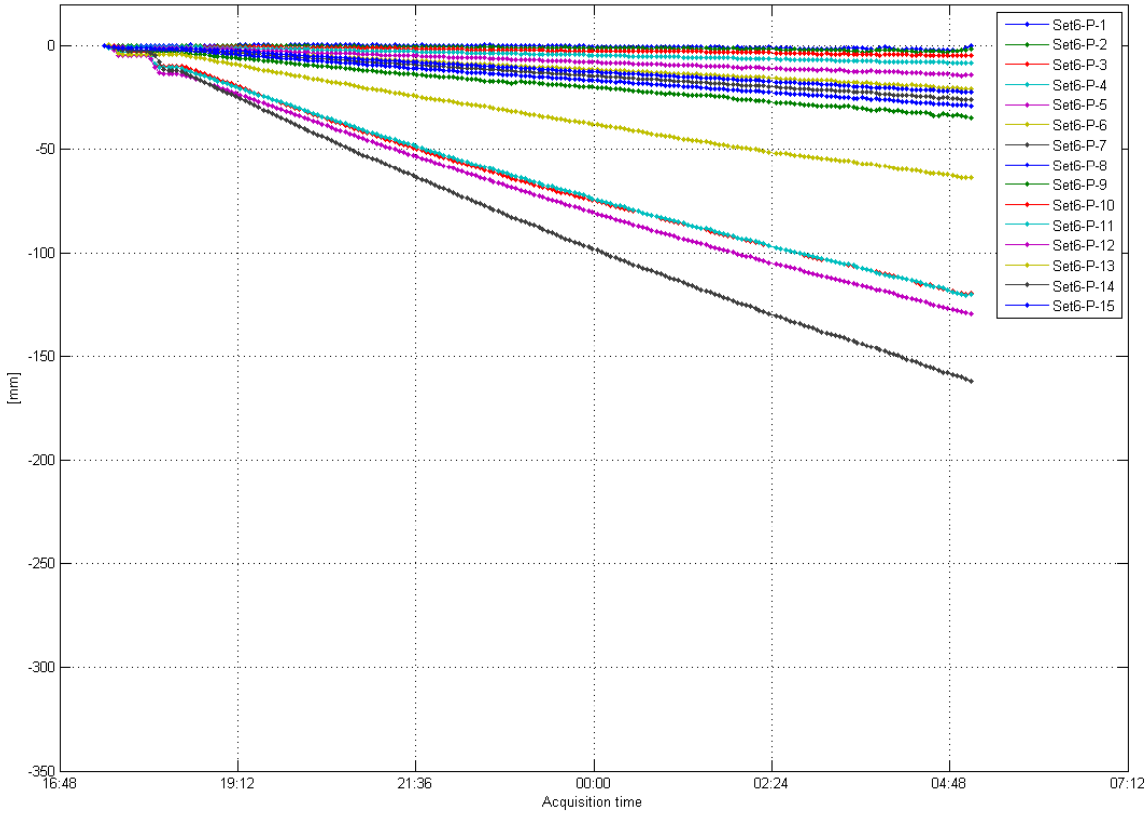
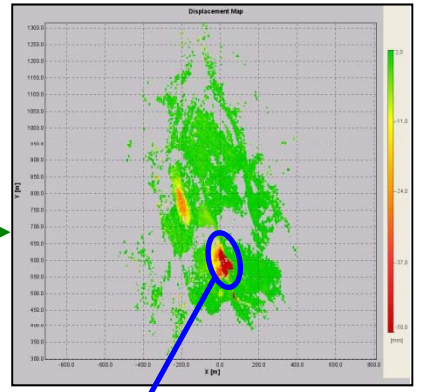
Displacement time series

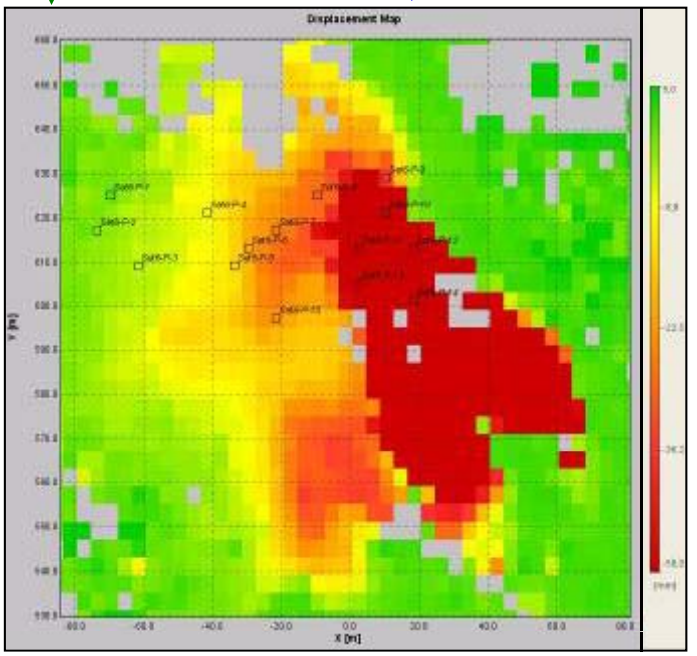
ZONE B - displacement of a few points

Line Of Sight Displacement Time Series



Mappe di spostamento cumulato dopo 24 ore





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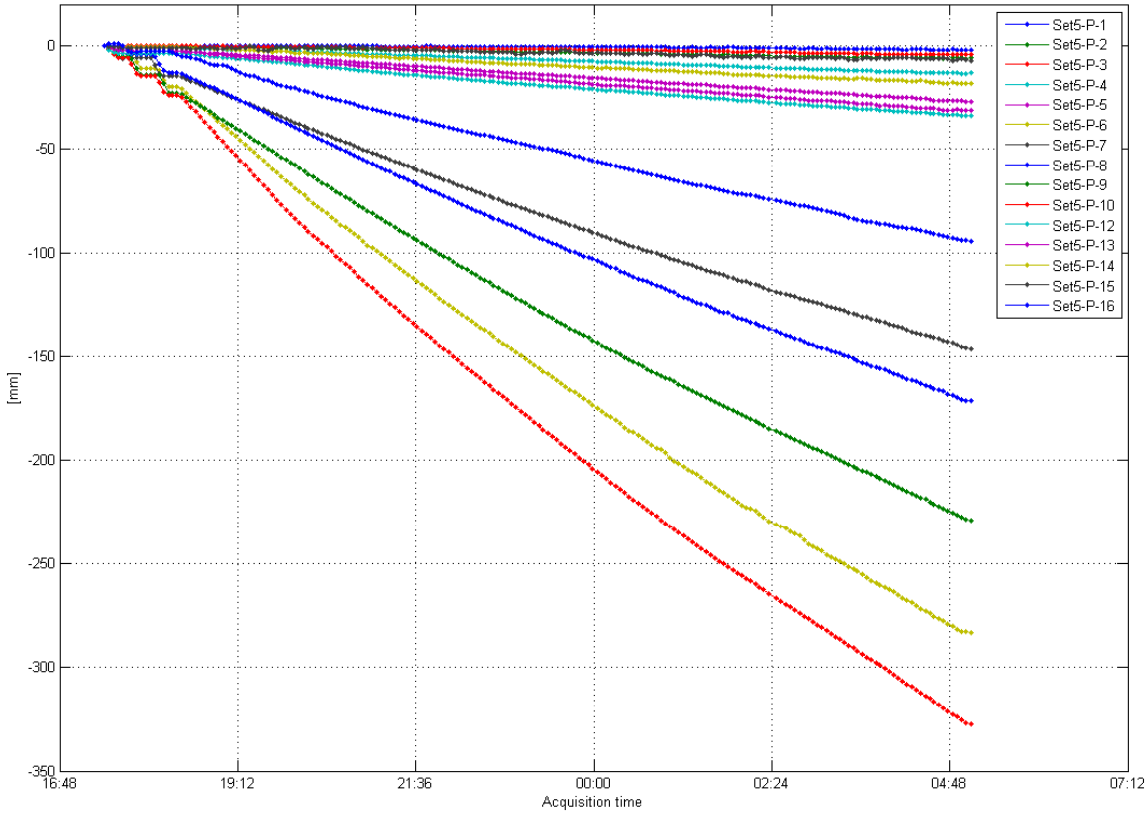
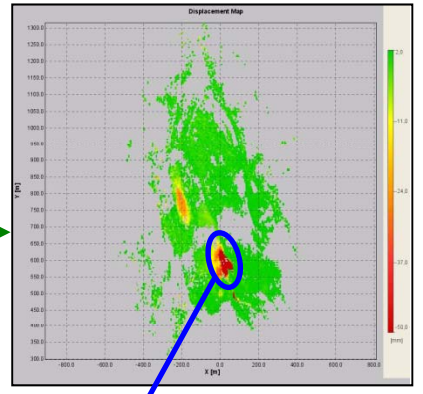
Displacement time series

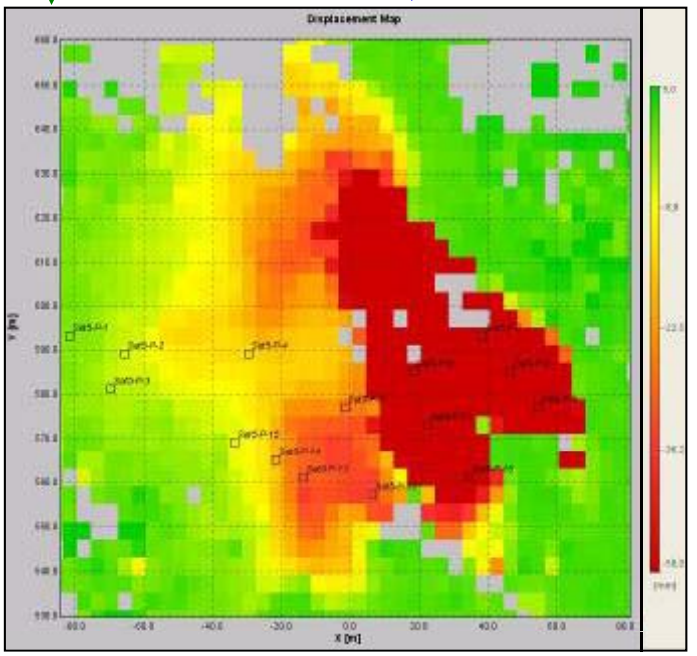
ZONE C - displacement of a few points

Line Of Sight Displacement Time Series



Mappe di spostamento cumulato dopo 24 ore





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IDS INGEGNERIA DEI SISTEMI

IBIS-M for open-pit mines

Following a 80,000 ton slip occurred in late 2009 and the consequent closure of operations, an IBIS-M unit was deployed in January 2010 at the Pipeline pit in Cortez, Nevada, owned by Barrick.

The IBIS-M system was aimed at providing early warnings and support for geotechnical evaluation purposes.

After 7 months of rental of the equipment, in July 2010, the IBIS-M unit was purchased by Barrick.

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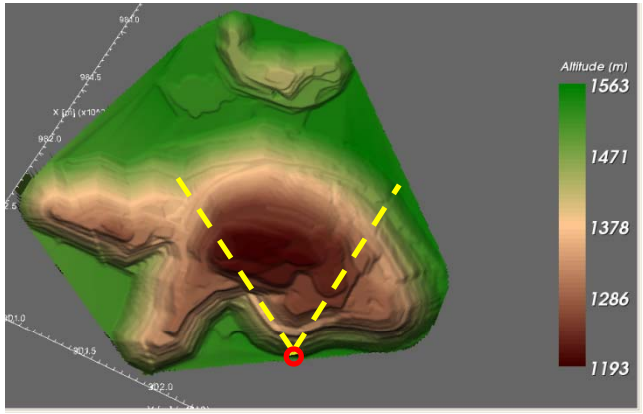
IBIS-M for open-pit mines



DISTANCE FROM THE SLOPE	[m]	800 – 1500
ANTENNA BEAM WIDTH	[deg]	68
NUMBER OF POINTS	-	90.000
RANGE RESOLUTION	[m]	0.5 (1.64 ft)
CROSS-RANGE RESOLUTION	[mrad]	4.5
SCANNING TIME	[min]	5

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IBIS-M set-up

Shelter (pit rim)
IBIS-M basic configuration unit
Fully enclosed (HVAC, WiFi)
Mine grid power supply
Backup power (1 day with genset)
IBIS Controller Software
24/7 functioning

Wireless link
+/- 200-300KB
every 6-7 mins

Dispatch Room
Guardian Software
24/7 monitoring for alarms
Status alarms/emails
Geotechnical alarms/emails

VPN, VNC
connections

Engineer's laptop

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IBIS-M set-up

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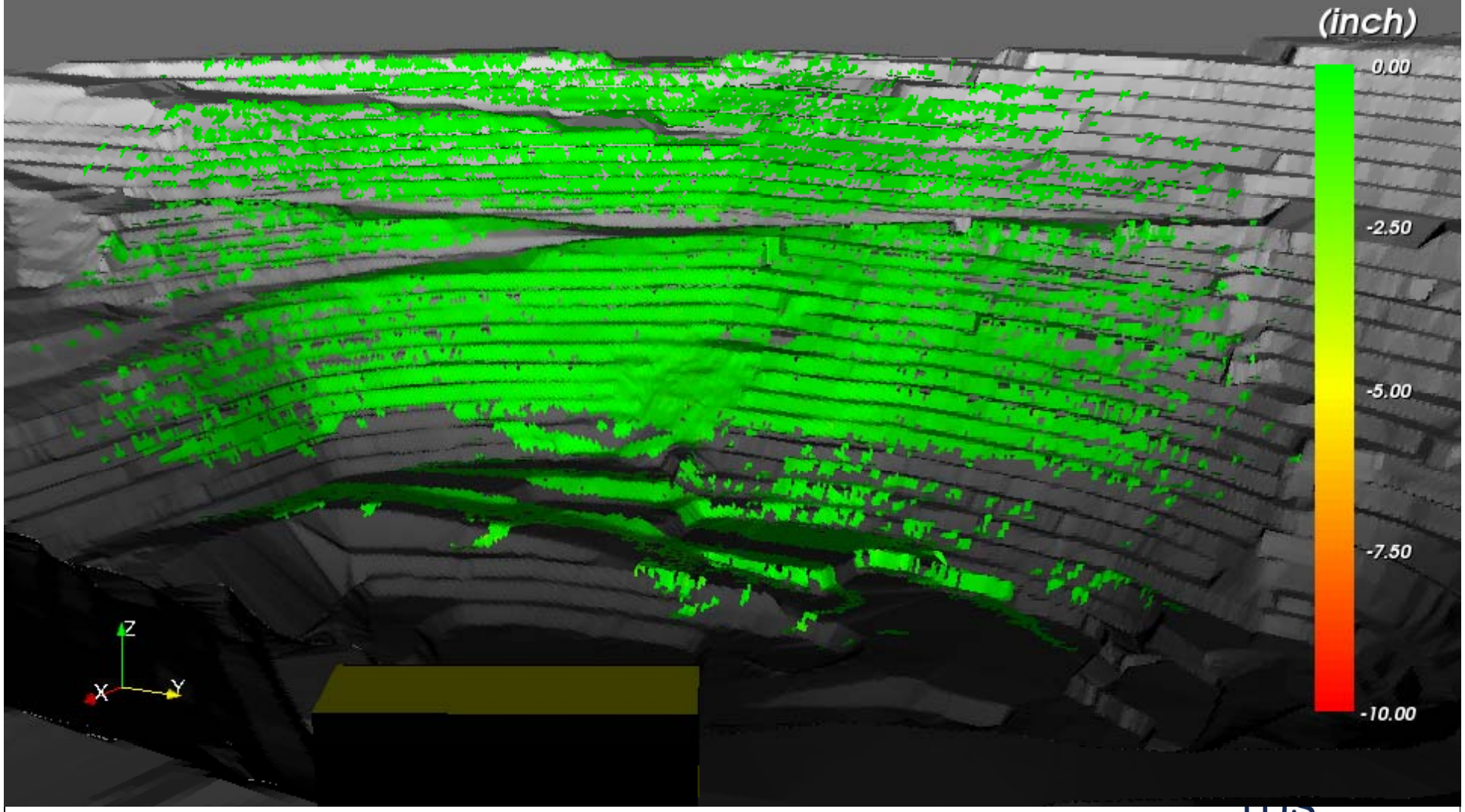
Start Time: 15:33 03/02/10
Stop Time: 14:36 18/02/10

Cumulative displacement from 03/02 to 18/02



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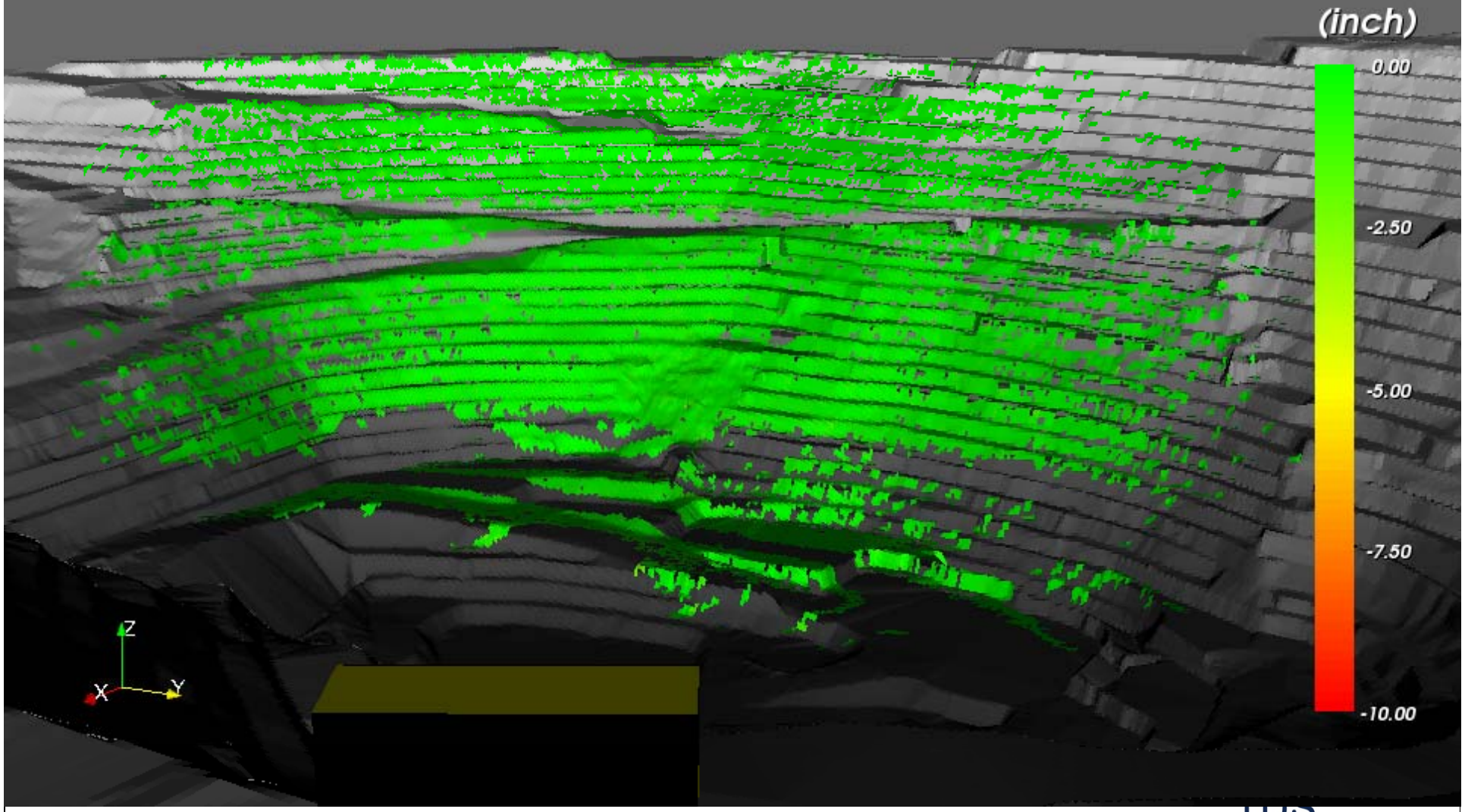
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 10:56 25/02/10

Cumulative displacement from 03/02 to 25/02



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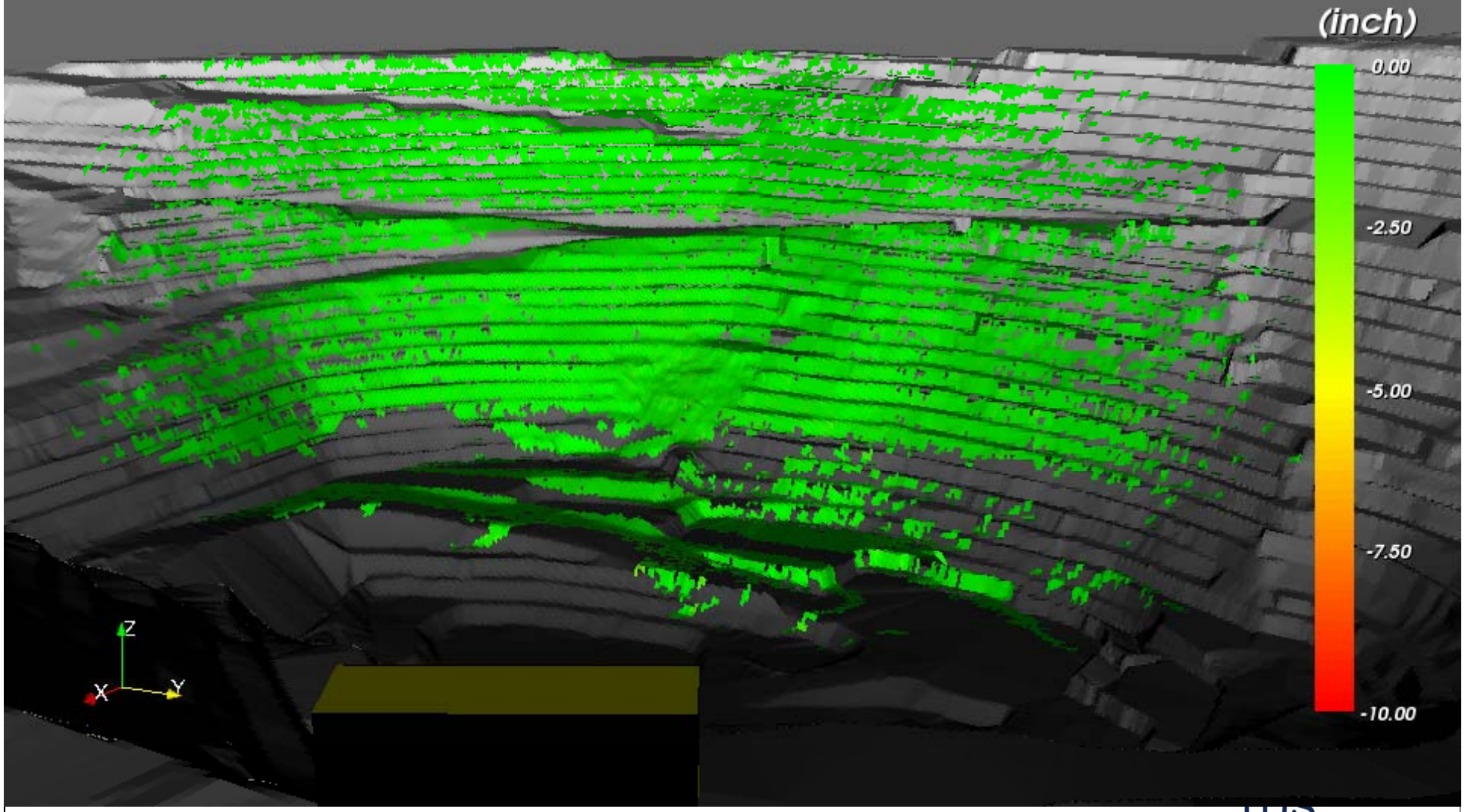
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 17:20 07/03/10

Cumulative displacement from 03/02 to 07/03



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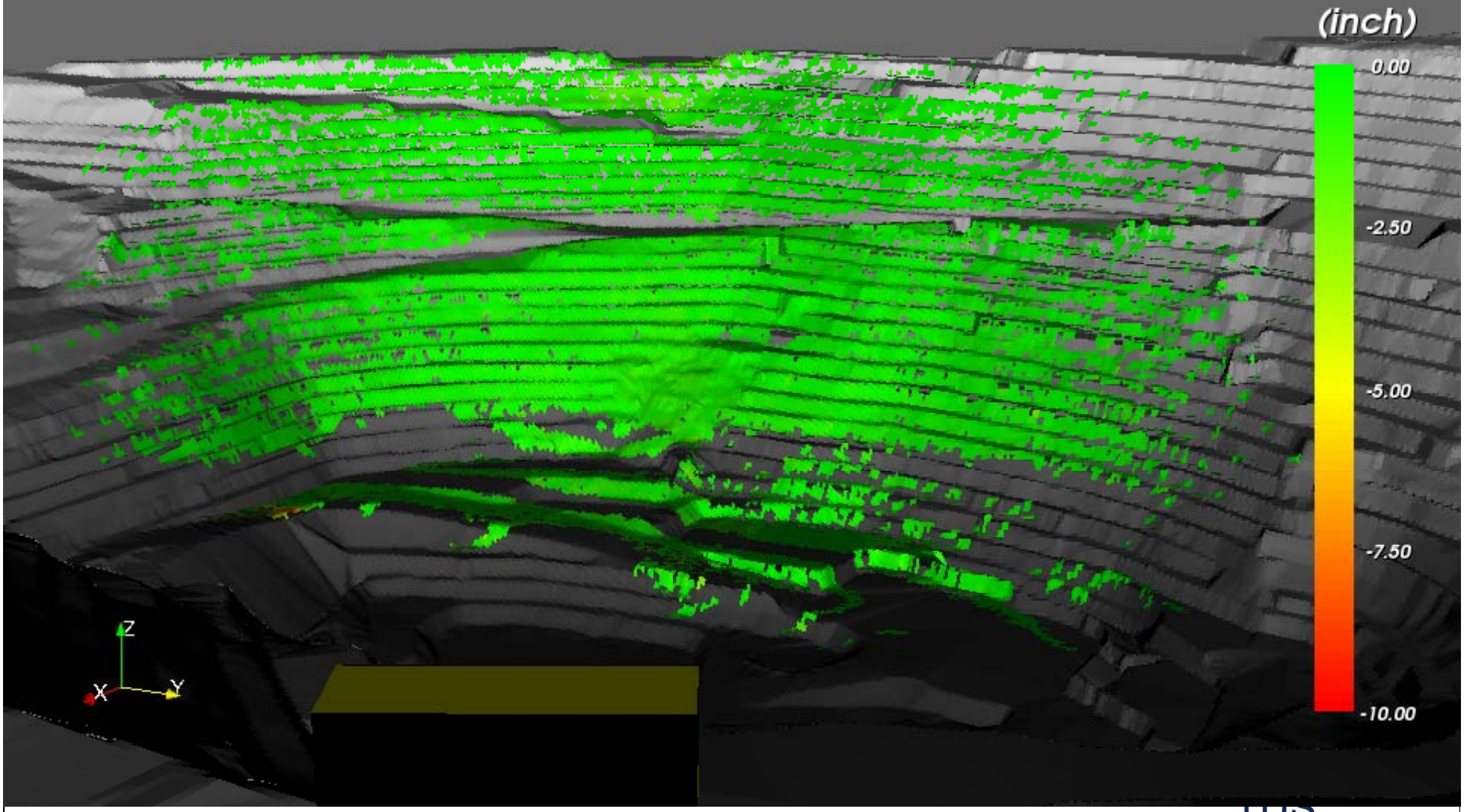
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 18:18 21/03/10

Cumulative displacement from 03/02 to 21/03



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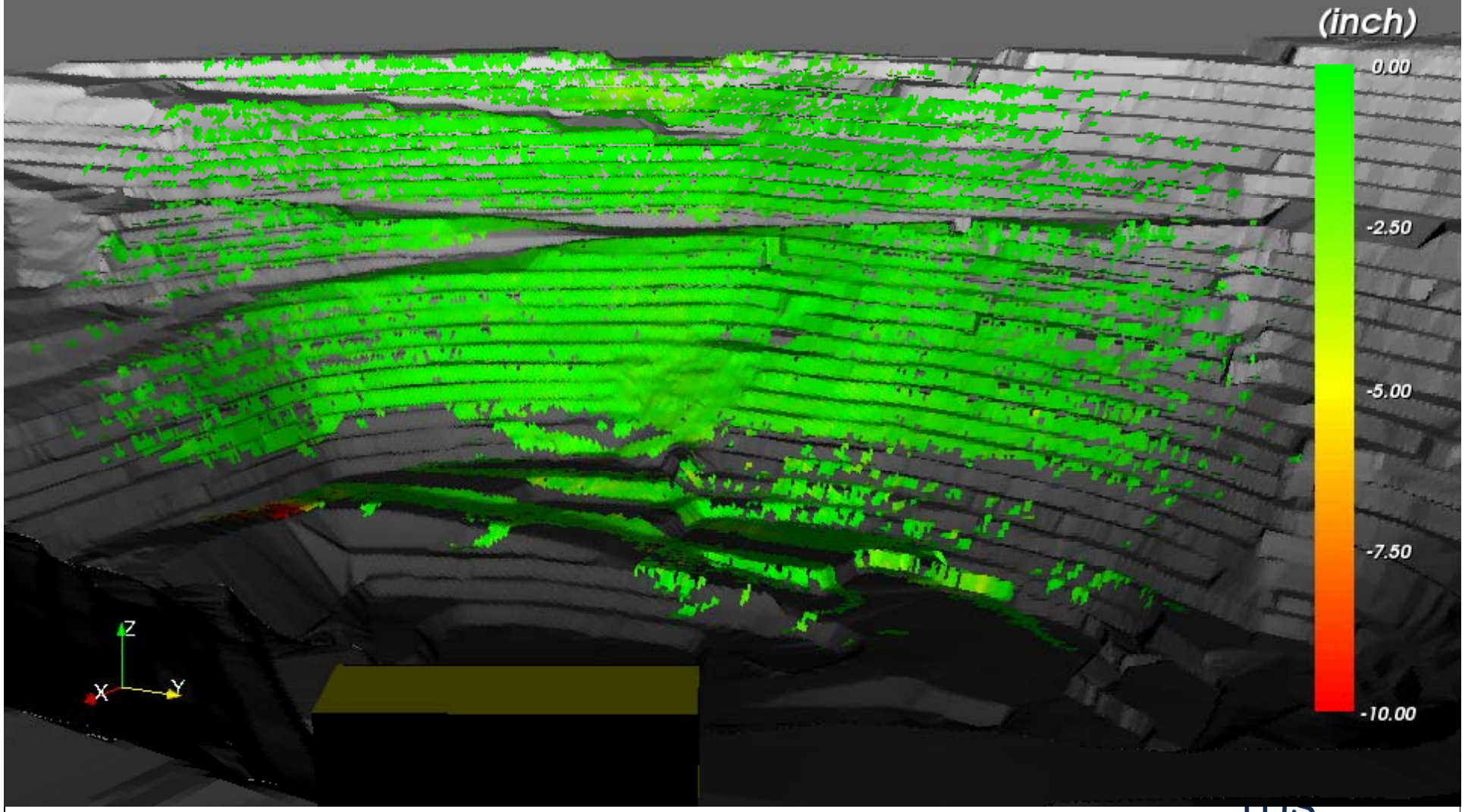
Start Time: 15:33 03/02/10
Stop Time: 16:13 04/04/10

Cumulative displacement from 03/02 to 04/04



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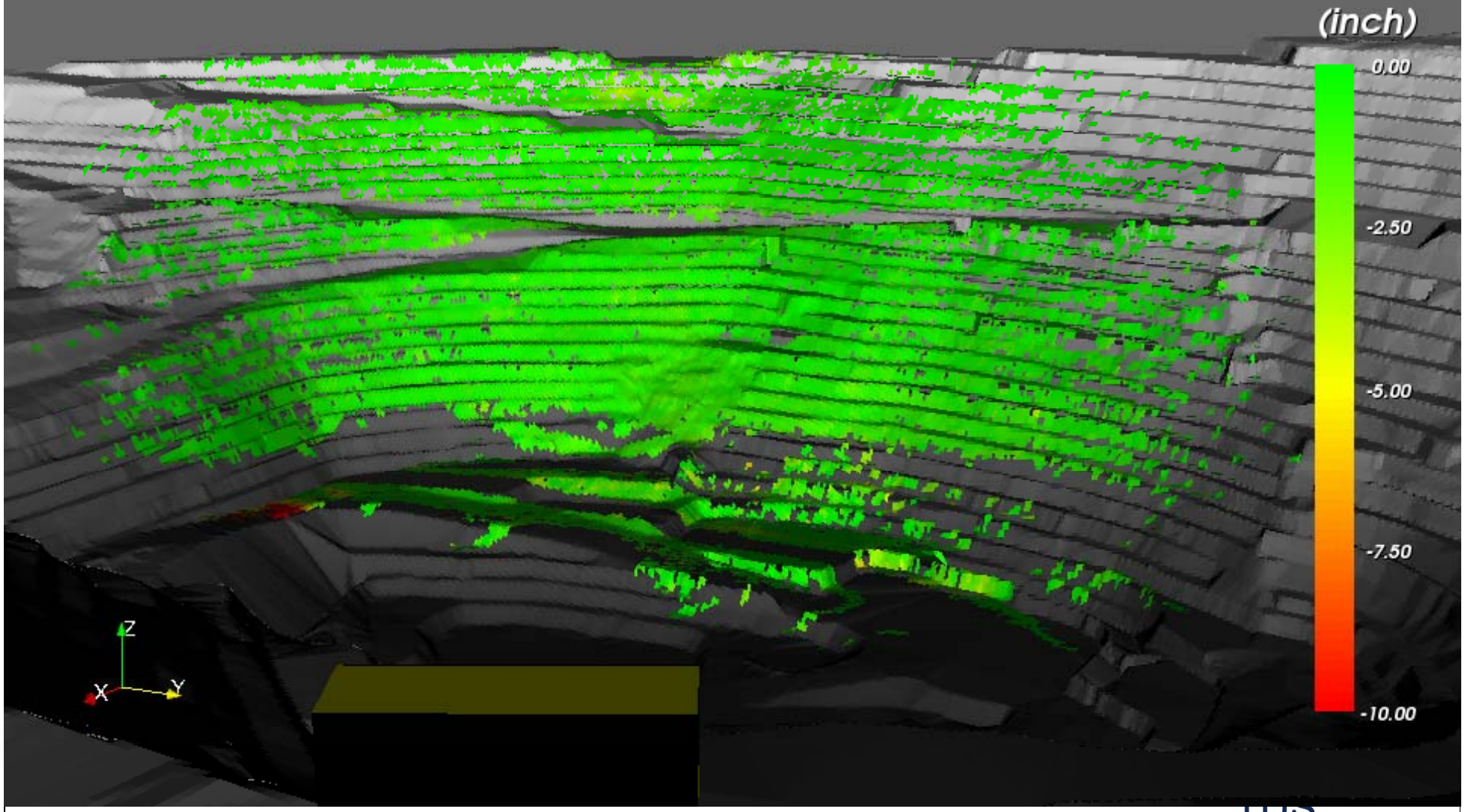
Start Time: 15:33 03/02/10
Stop Time: 12:08 19/04/10

Cumulative displacement from 03/02 to 19/04



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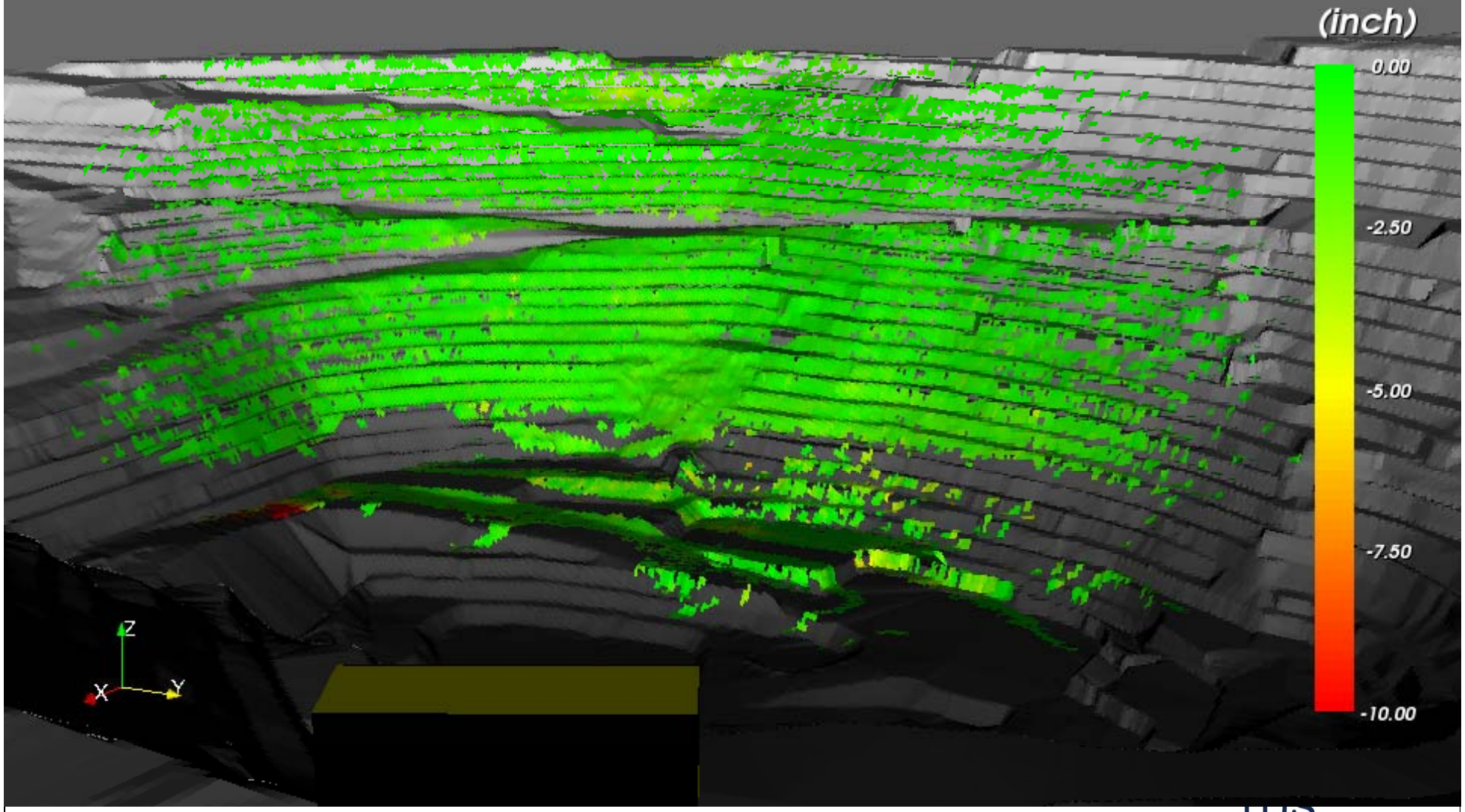
Start Time: 15:33 03/02/10
Stop Time: 16:59 04/05/10

Cumulative displacement from 03/02 to 04/05



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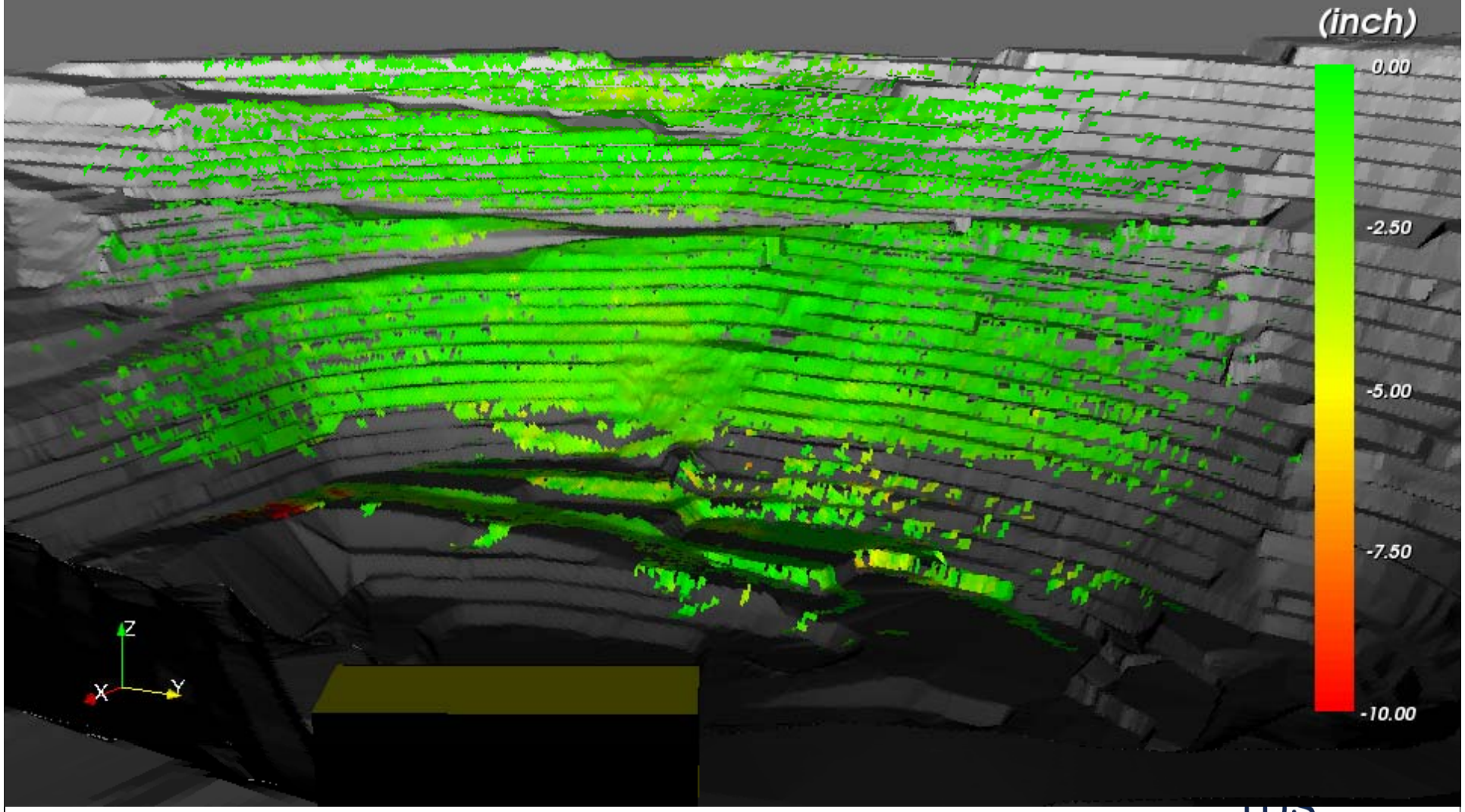
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 18:25 18/05/10

Cumulative displacement from 03/02 to 18/05



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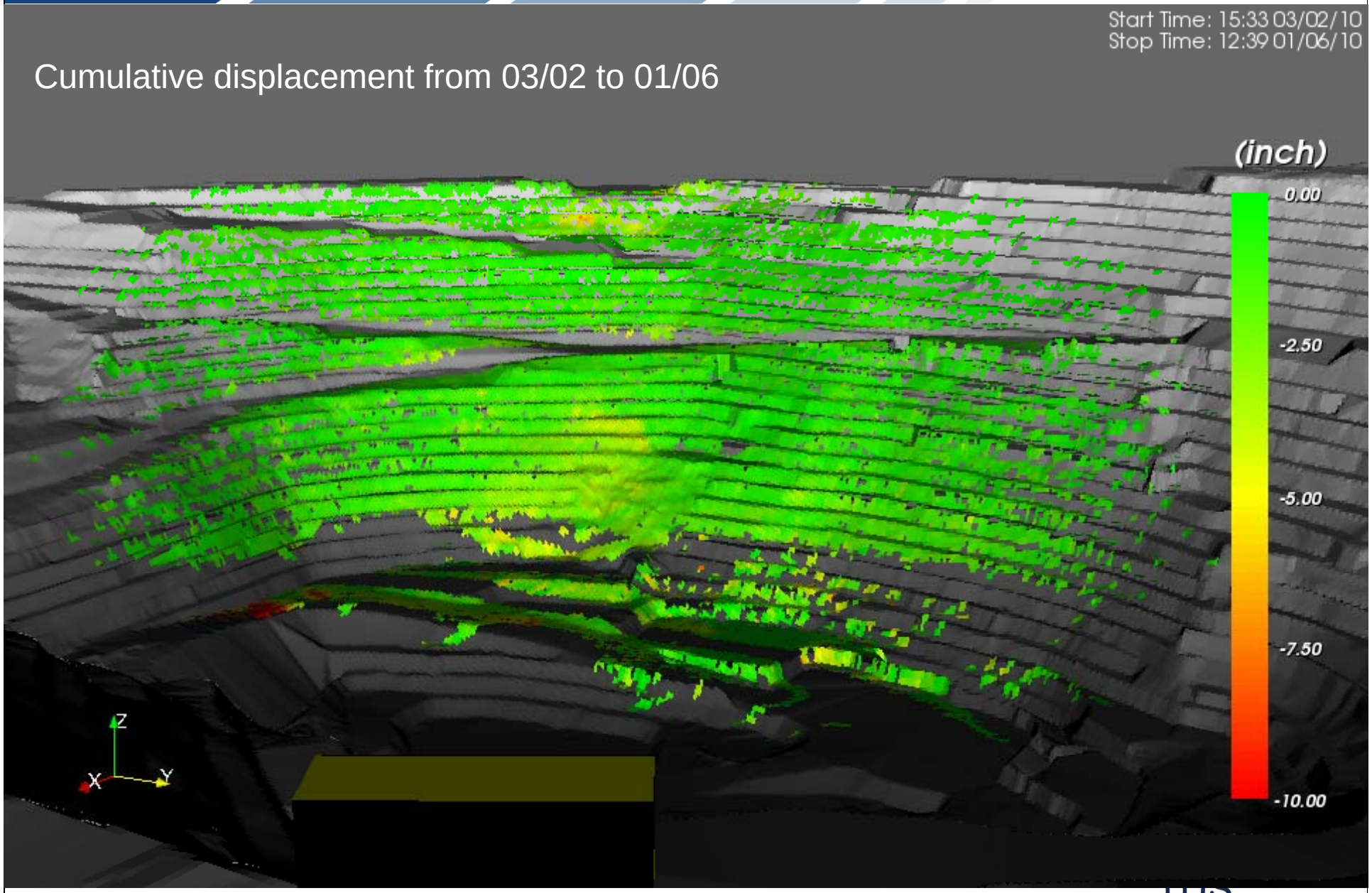
Cumulative displacement from 03/02 to 01/06



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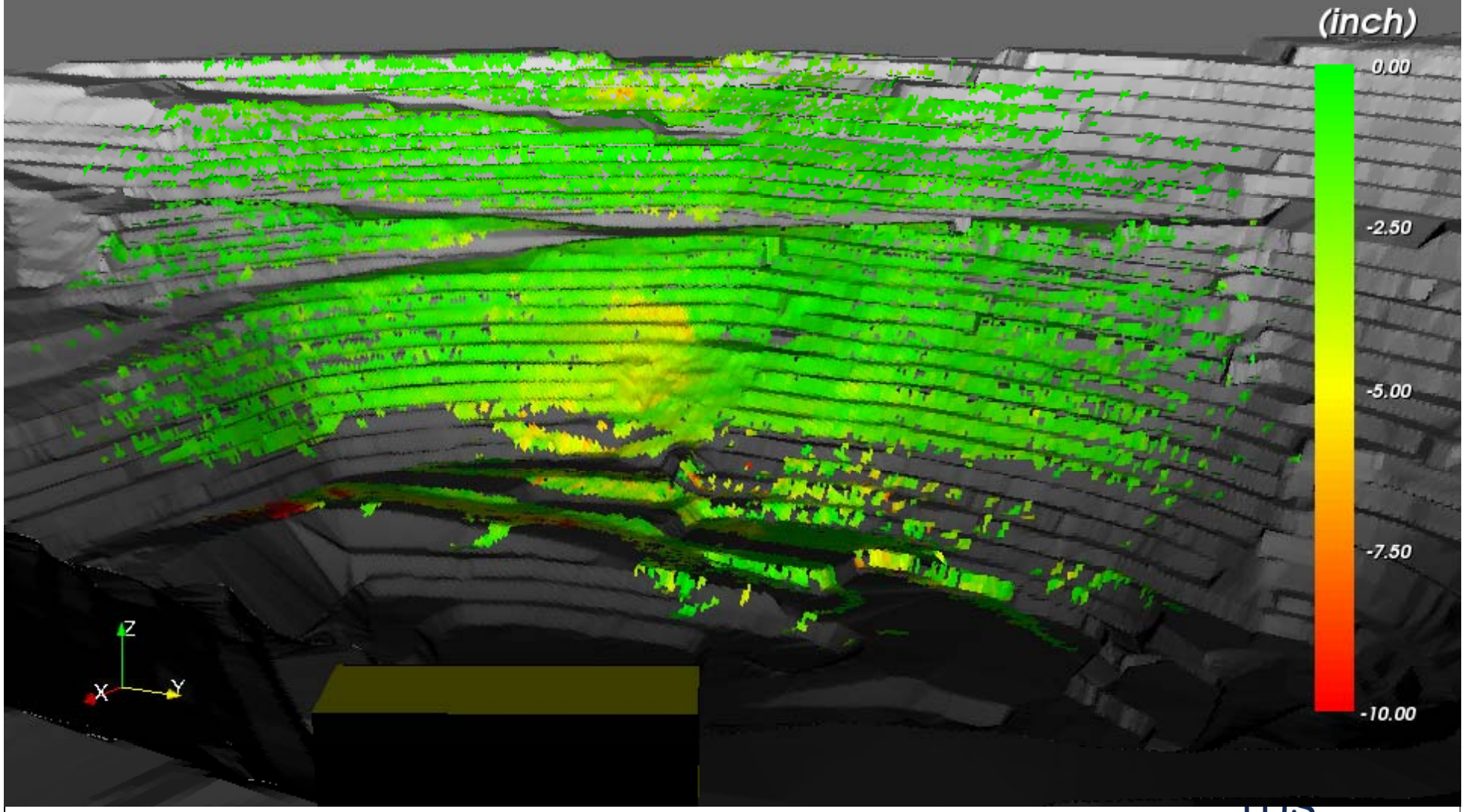
Start Time: 15:33 03/02/10
Stop Time: 16:37 15/06/10

Cumulative displacement from 03/02 to 15/06



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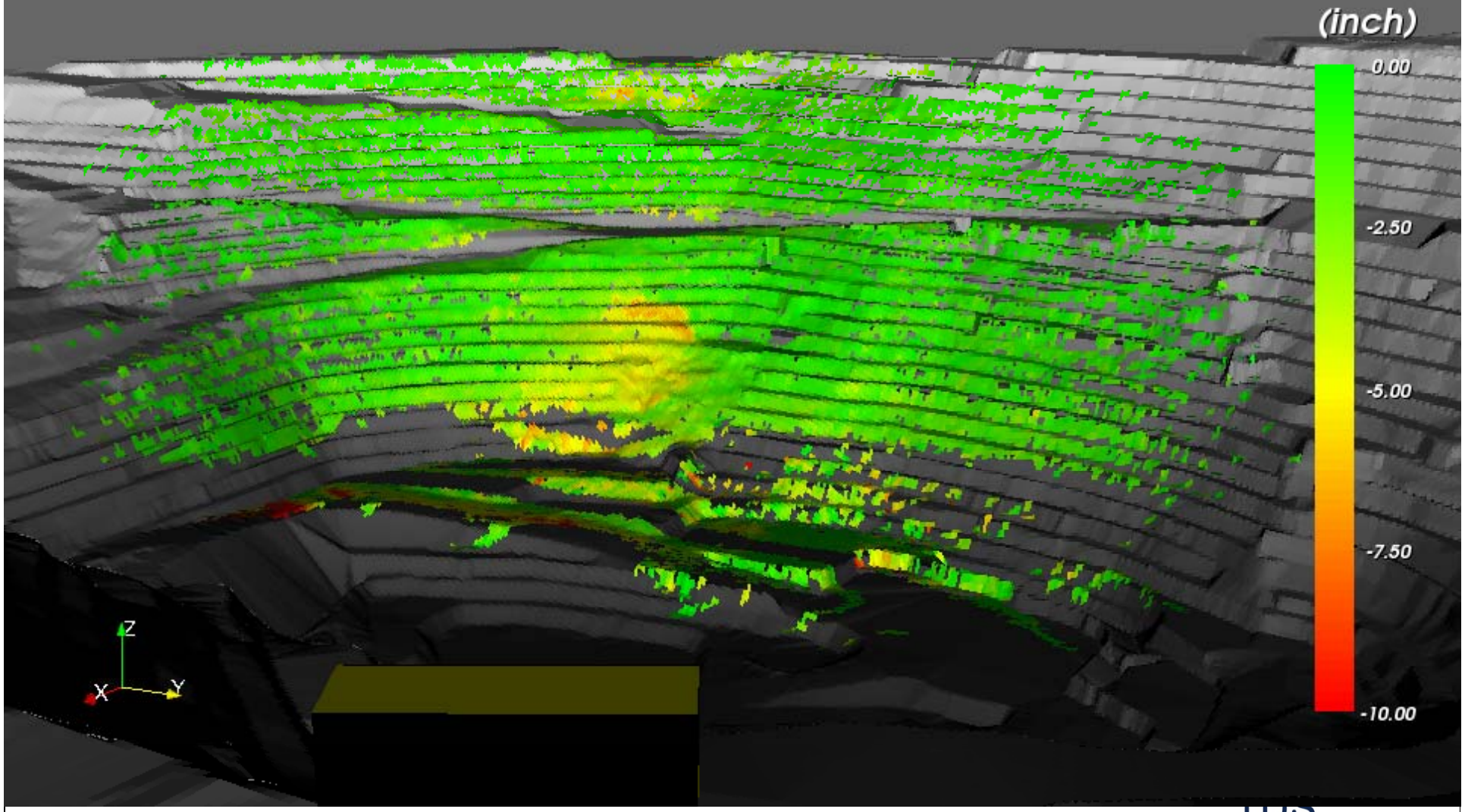
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 13:14 29/06/10

Cumulative displacement from 03/02 to 29/06



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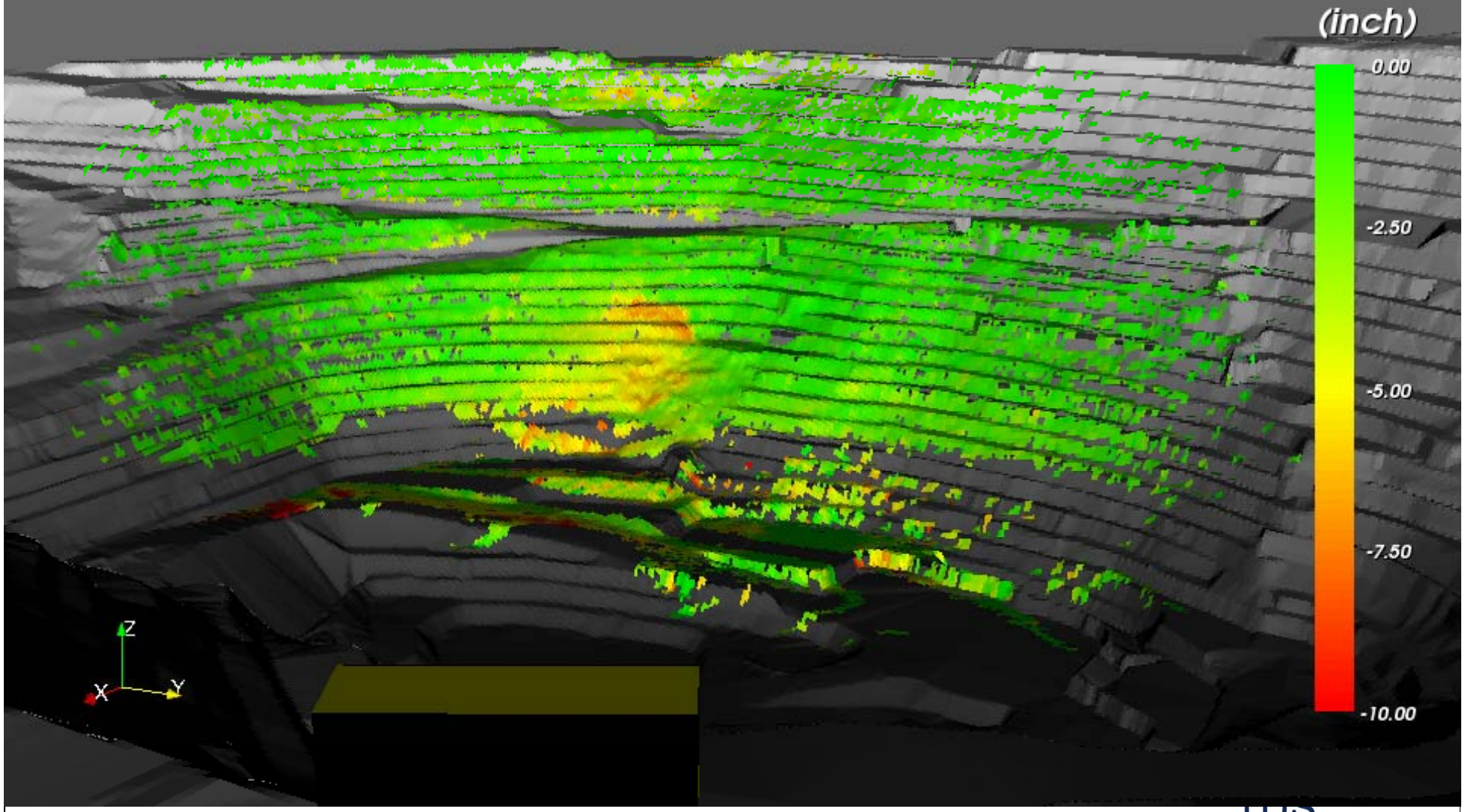
IDS INGEGNERIA DEI SISTEMI

Start Time: 15:33 03/02/10
Stop Time: 13:33 14/07/10

Cumulative displacement from 03/02 to 14/07



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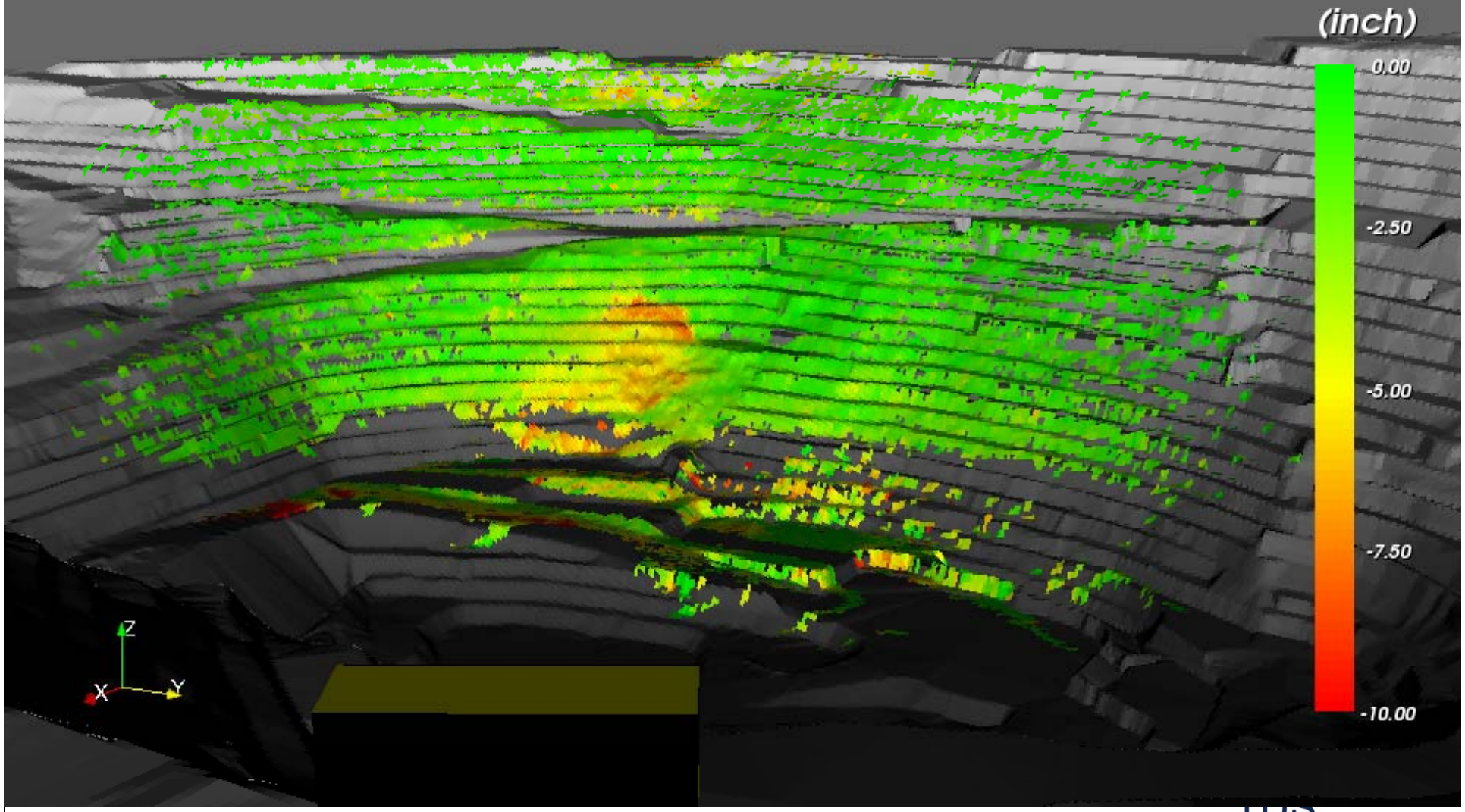
Start Time: 15:33 03/02/10
Stop Time: 13:39 29/07/10

Cumulative displacement from 03/02 to 29/07



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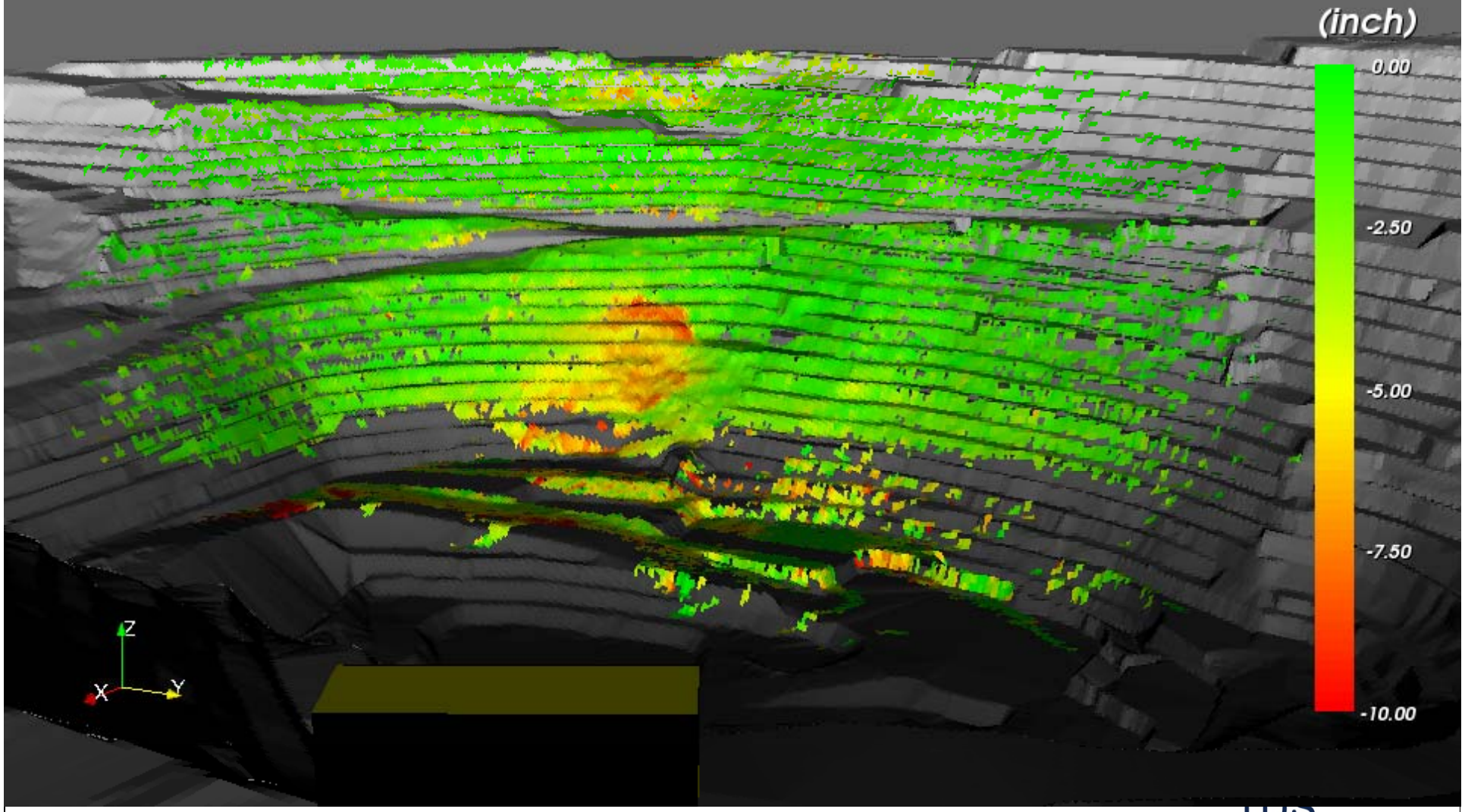
Start Time: 15:33 03/02/10
Stop Time: 13:14 13/08/10

Cumulative displacement from 03/02 to 13/08



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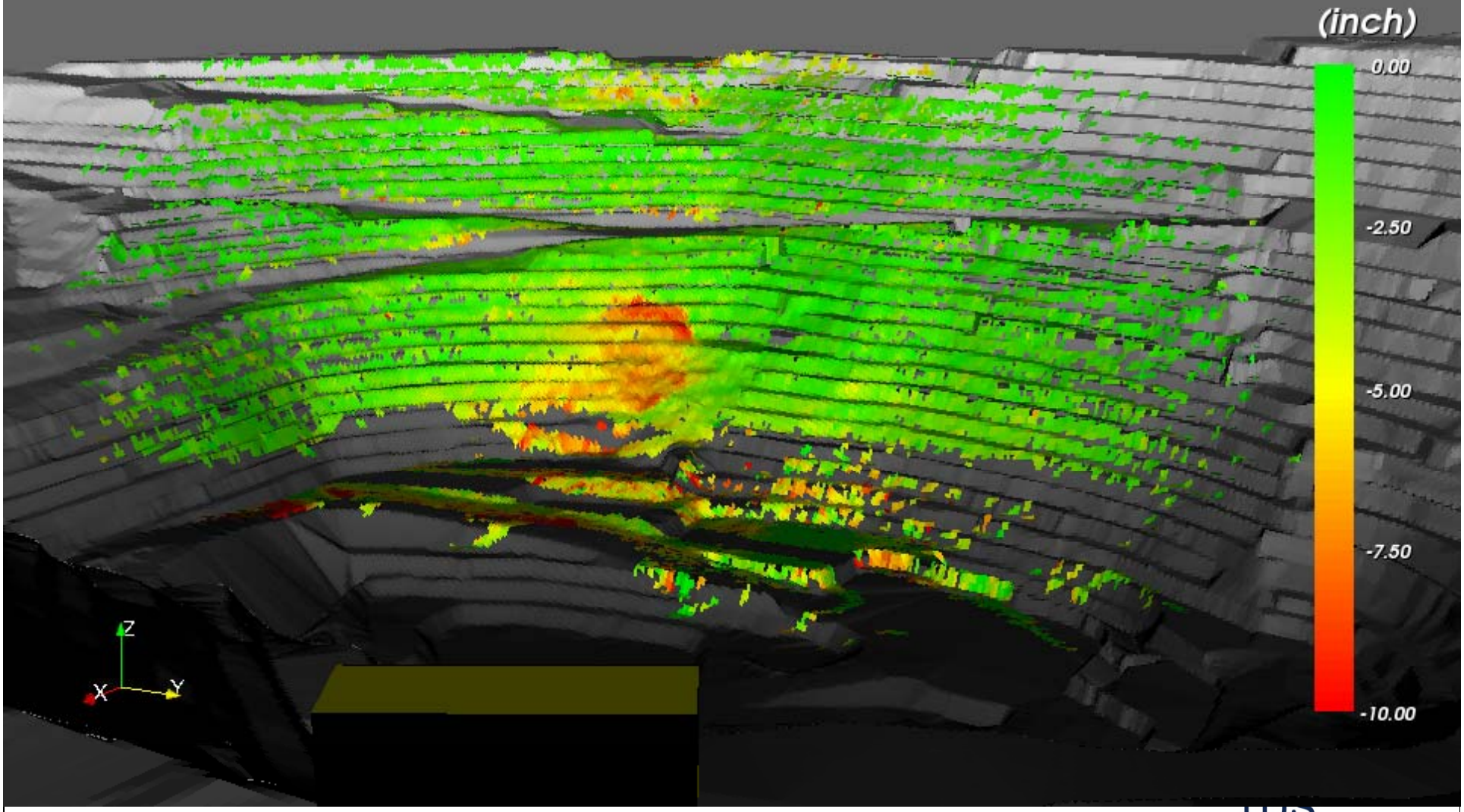
Start Time: 15:33 03/02/10
Stop Time: 15:20 27/08/10

Cumulative displacement from 03/02 to 27/08



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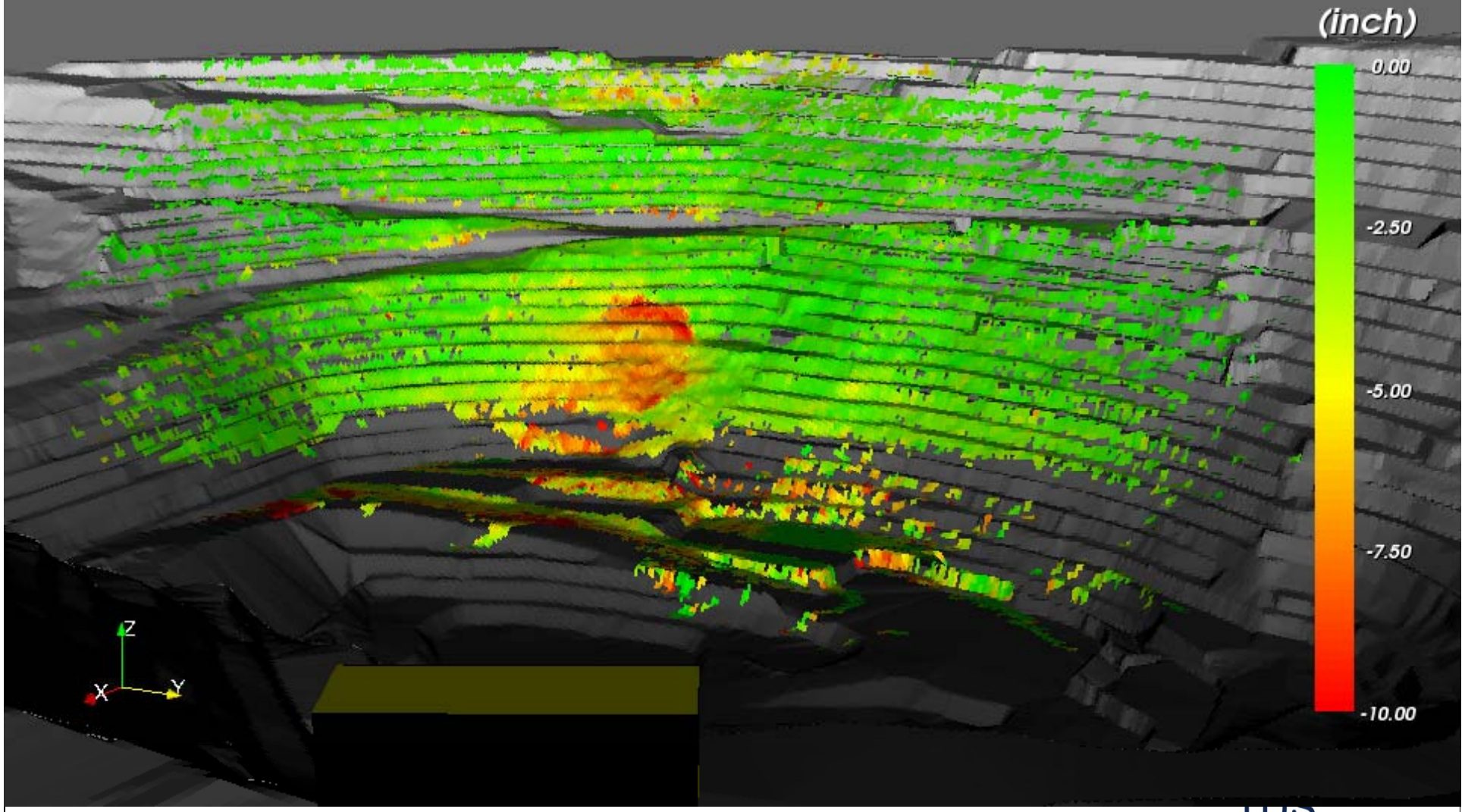
Start Time: 15:33 03/02/10
Stop Time: 10:53 10/09/10

Cumulative displacement from 03/02 to 10/09



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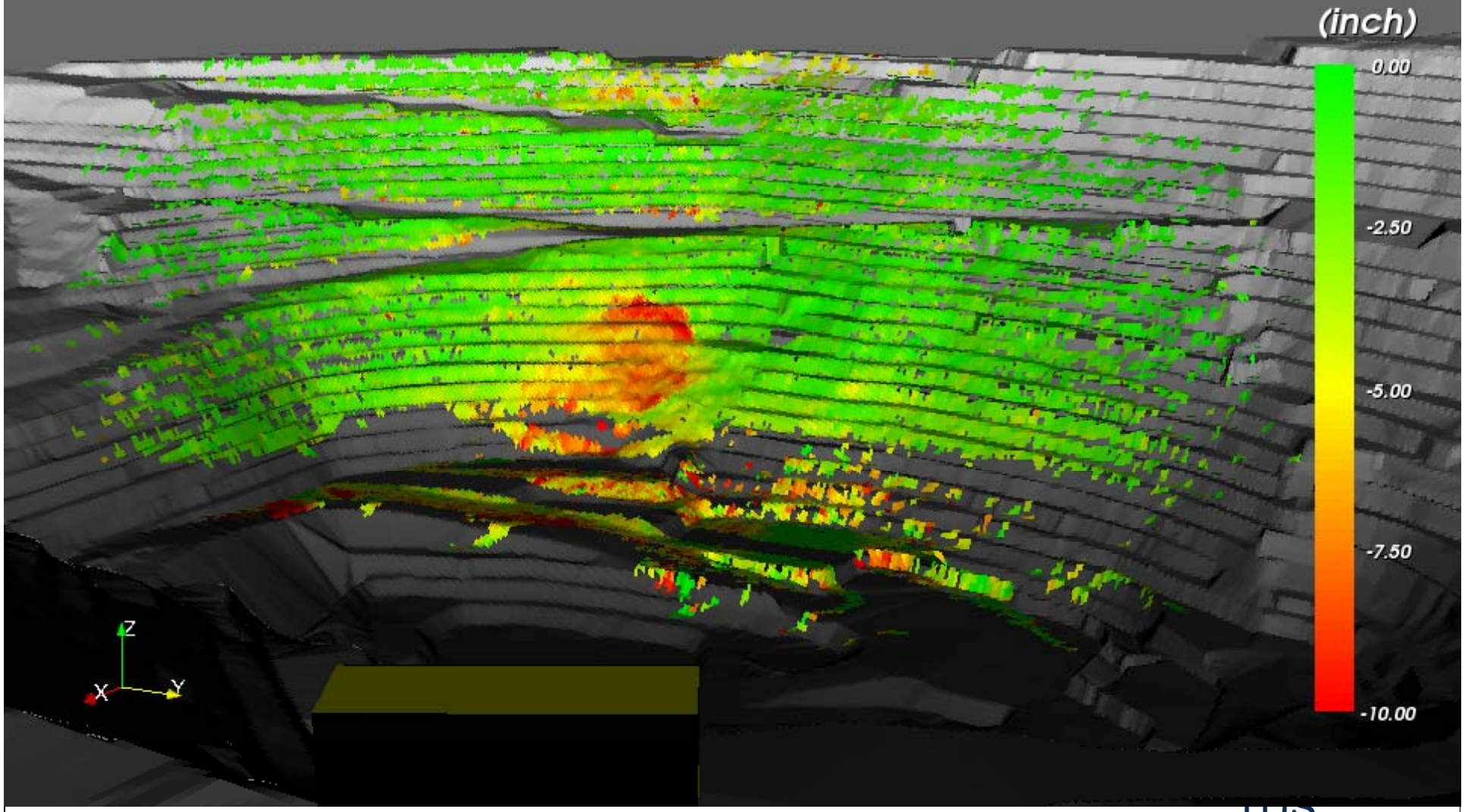
Start Time: 15:33 03/02/10
Stop Time: 08:37 21/09/10

Cumulative displacement from 03/02 to 21/09



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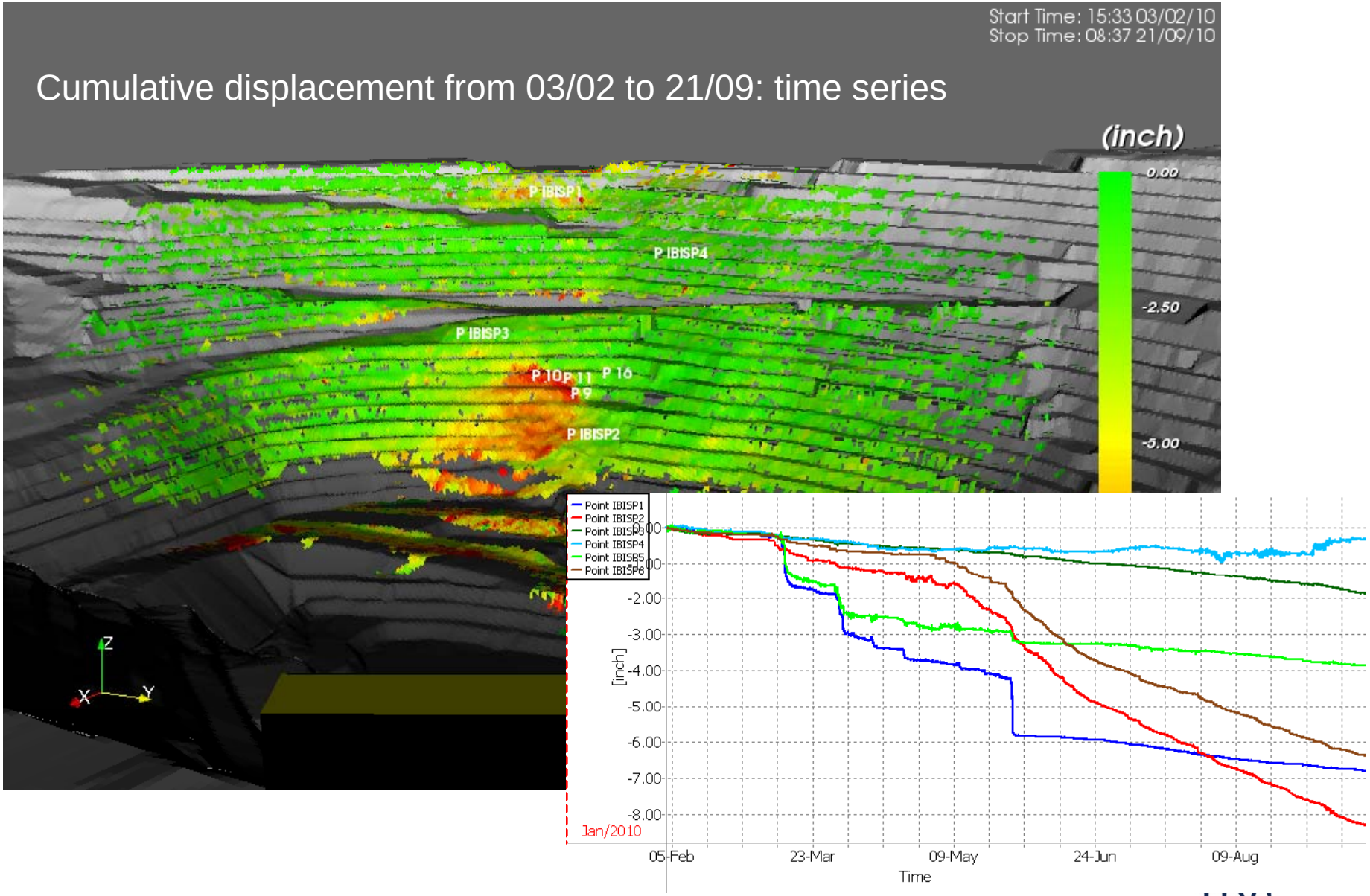

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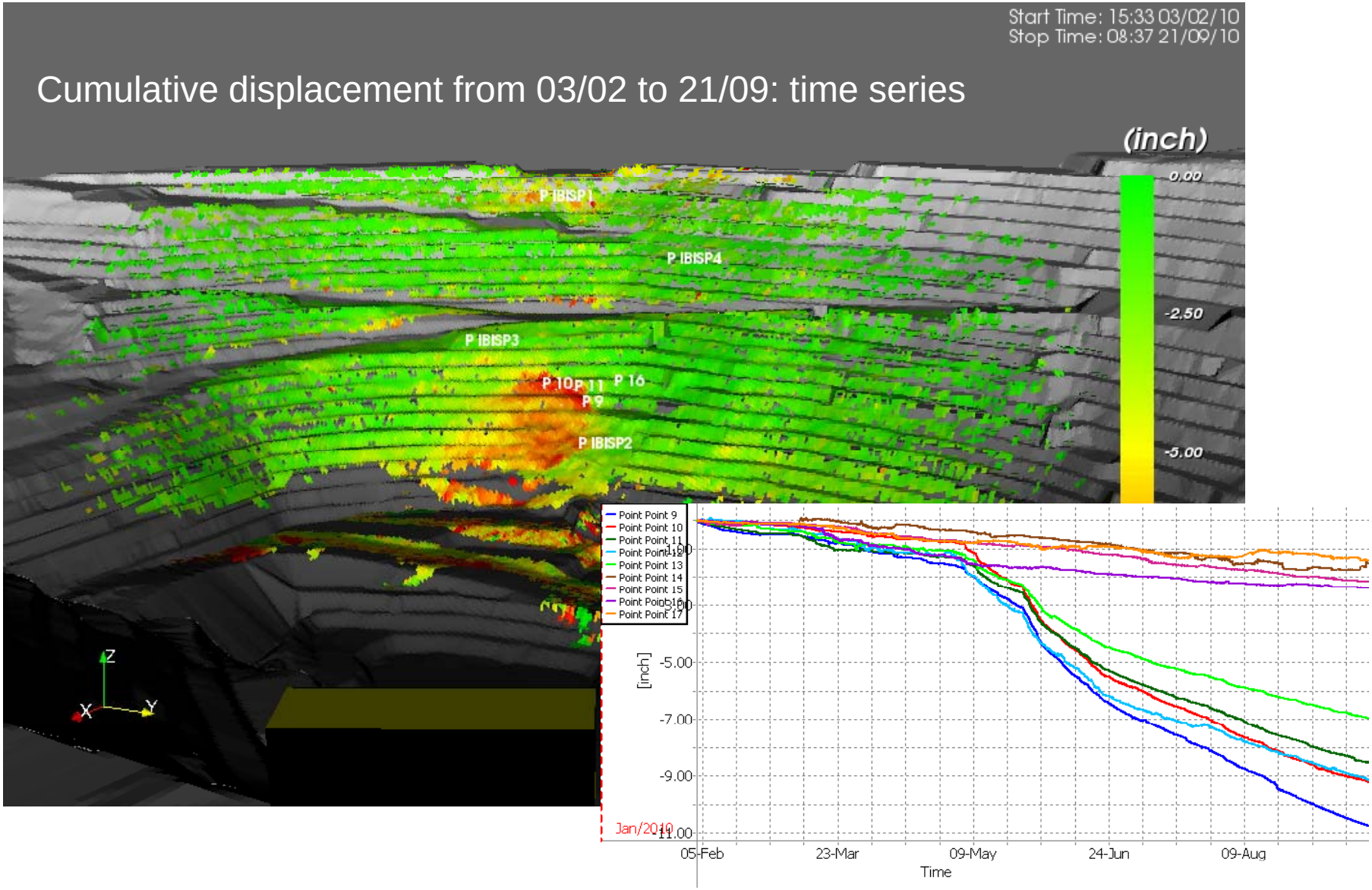
Cumulative displacement from 03/02 to 21/09: time series



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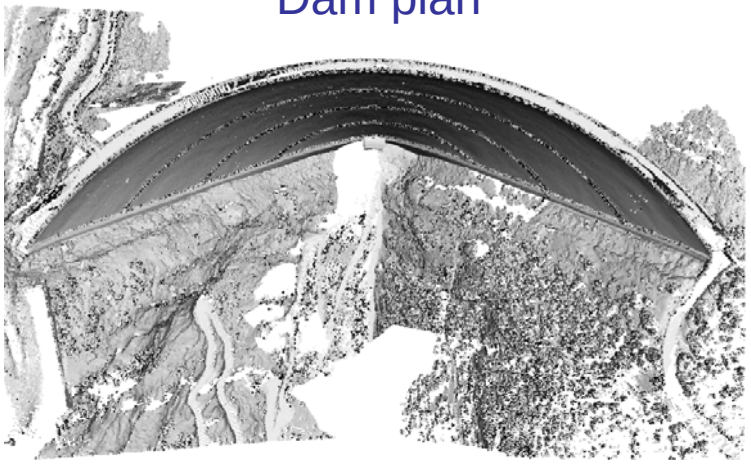
Dam monitoring

Cancano Dam view

Dam plan



Dam characteristics	
Dam Type	Gravity arch
Location	Alpi Retiche - Italy
Dam height (m)	125.5
Crowing length (m)	381

Survey performed with the Surveying Dept. of Milan Polytechnic

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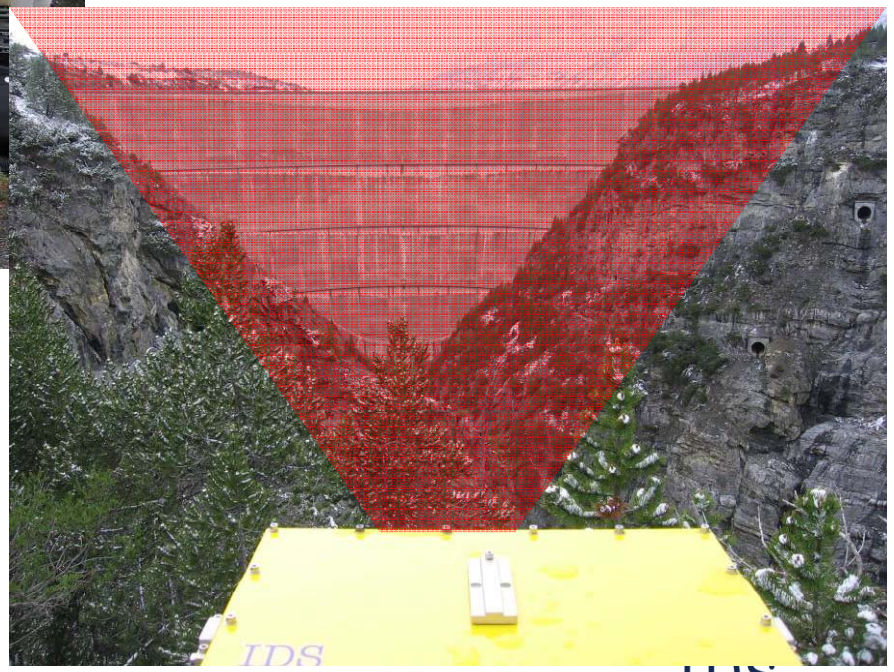
Dam monitoring



IBIS-L configuration

- Dam-sensor distance: 400m
- Range resolution: 0.5m
- Angle resolution: 4.7mrad
- Sampling interval: ca. 9 minutes

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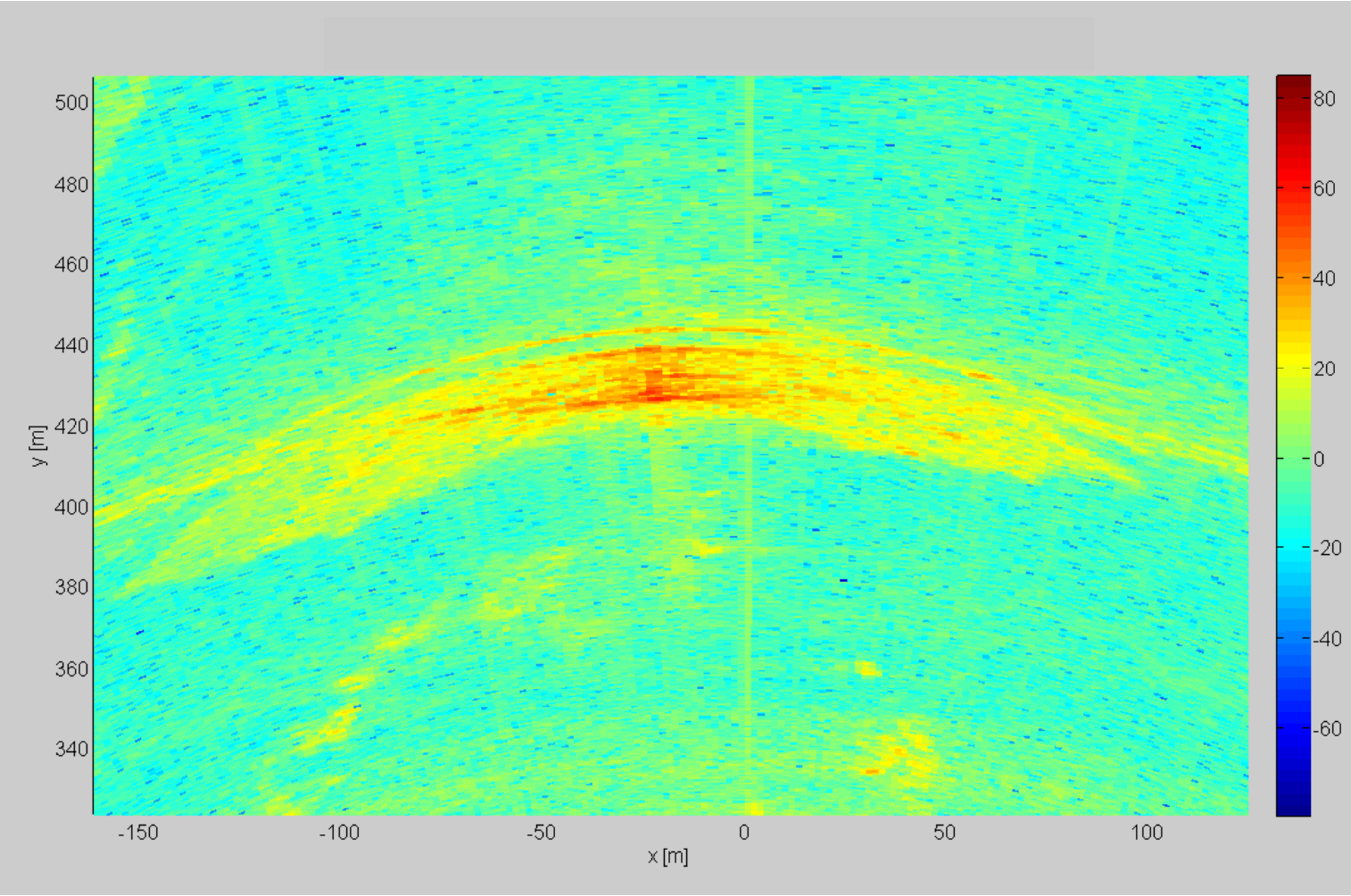
Dam monitoring

Zoom on dam area



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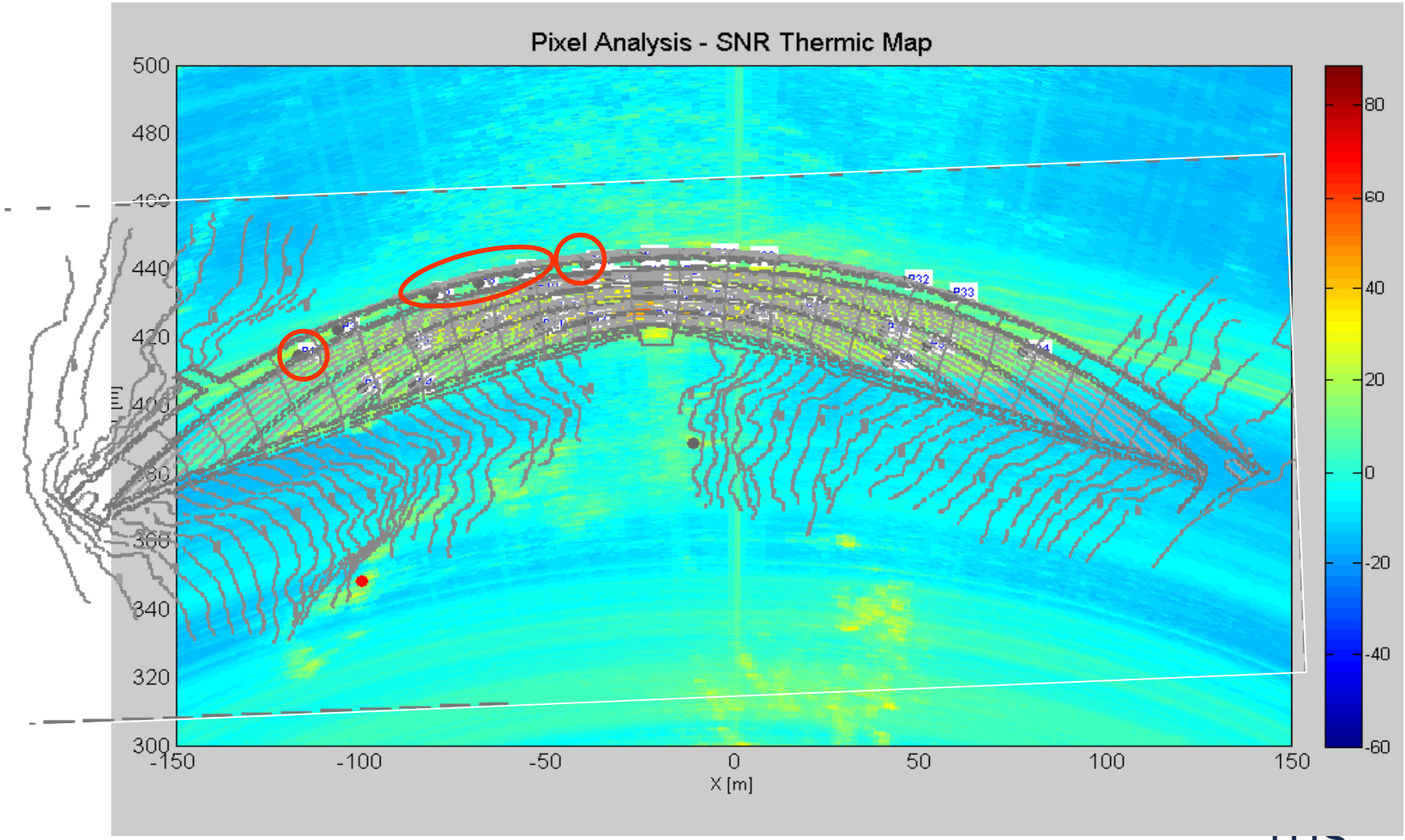
Dam monitoring

Dam Power map projected over plan



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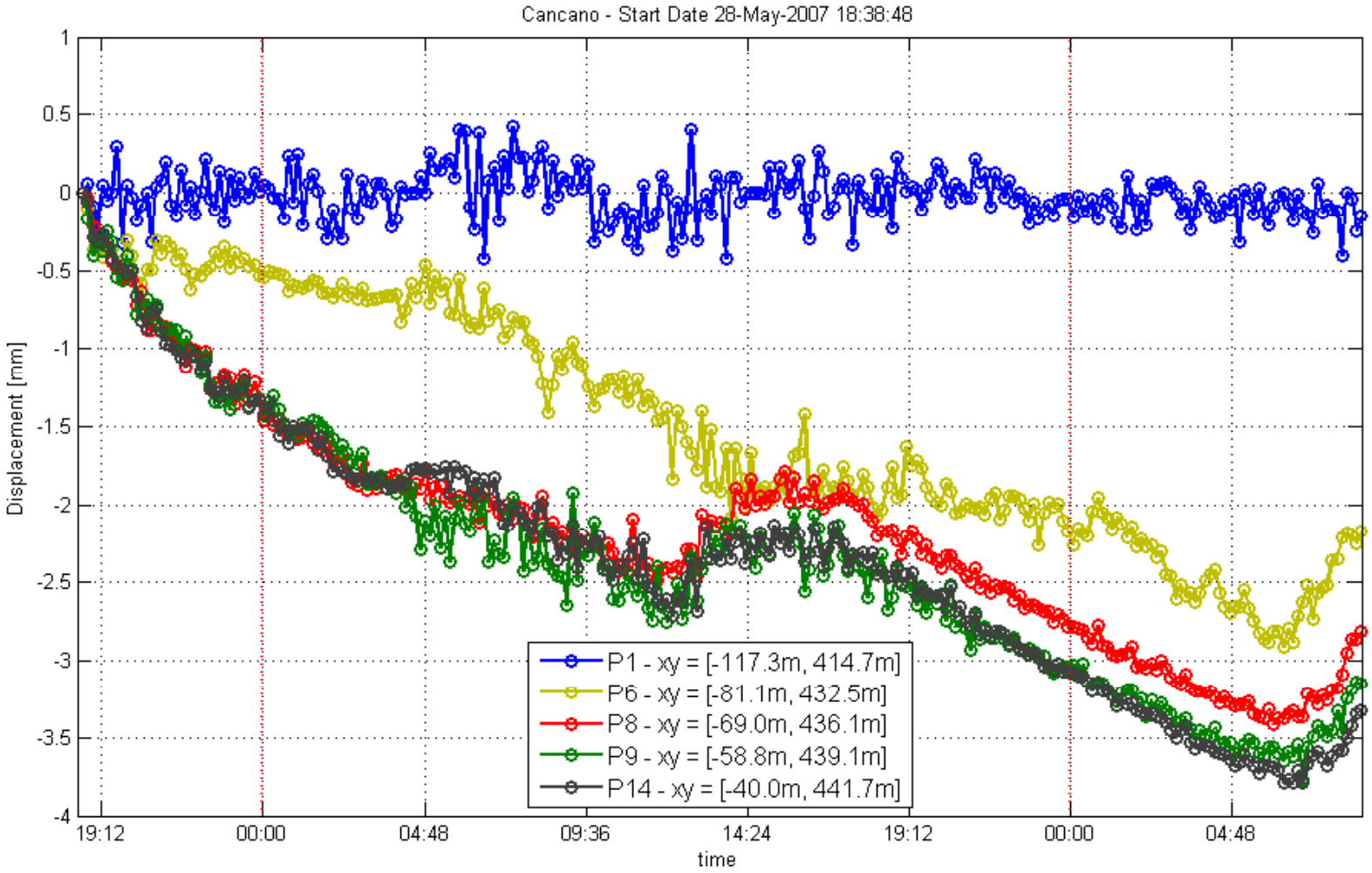
Dam monitoring

Selected pixel L.O.S. displacement – 5 pixel belonging to the dam crown



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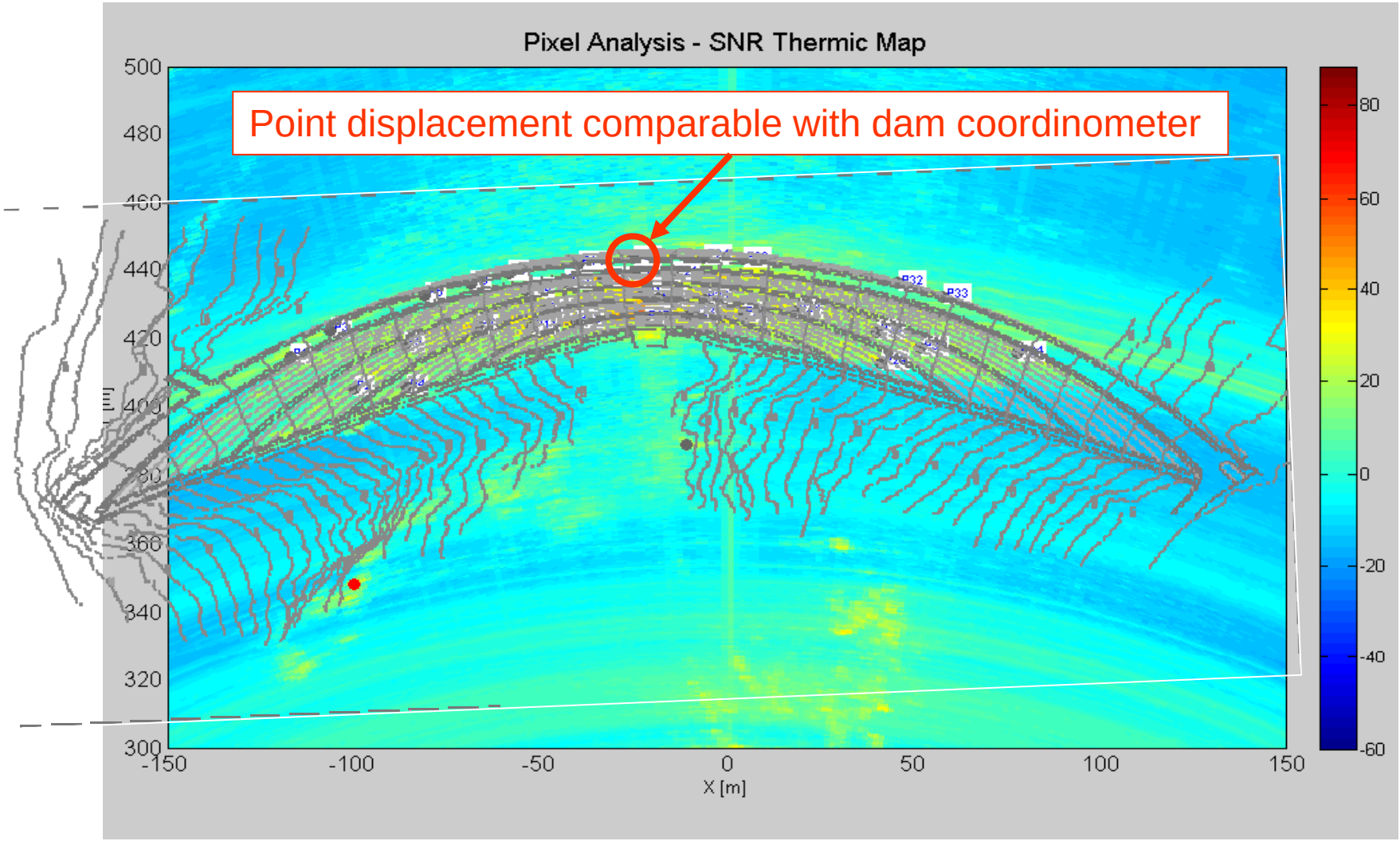
IDS INGEGNERIA DEI SISTEMI

Dam monitoring



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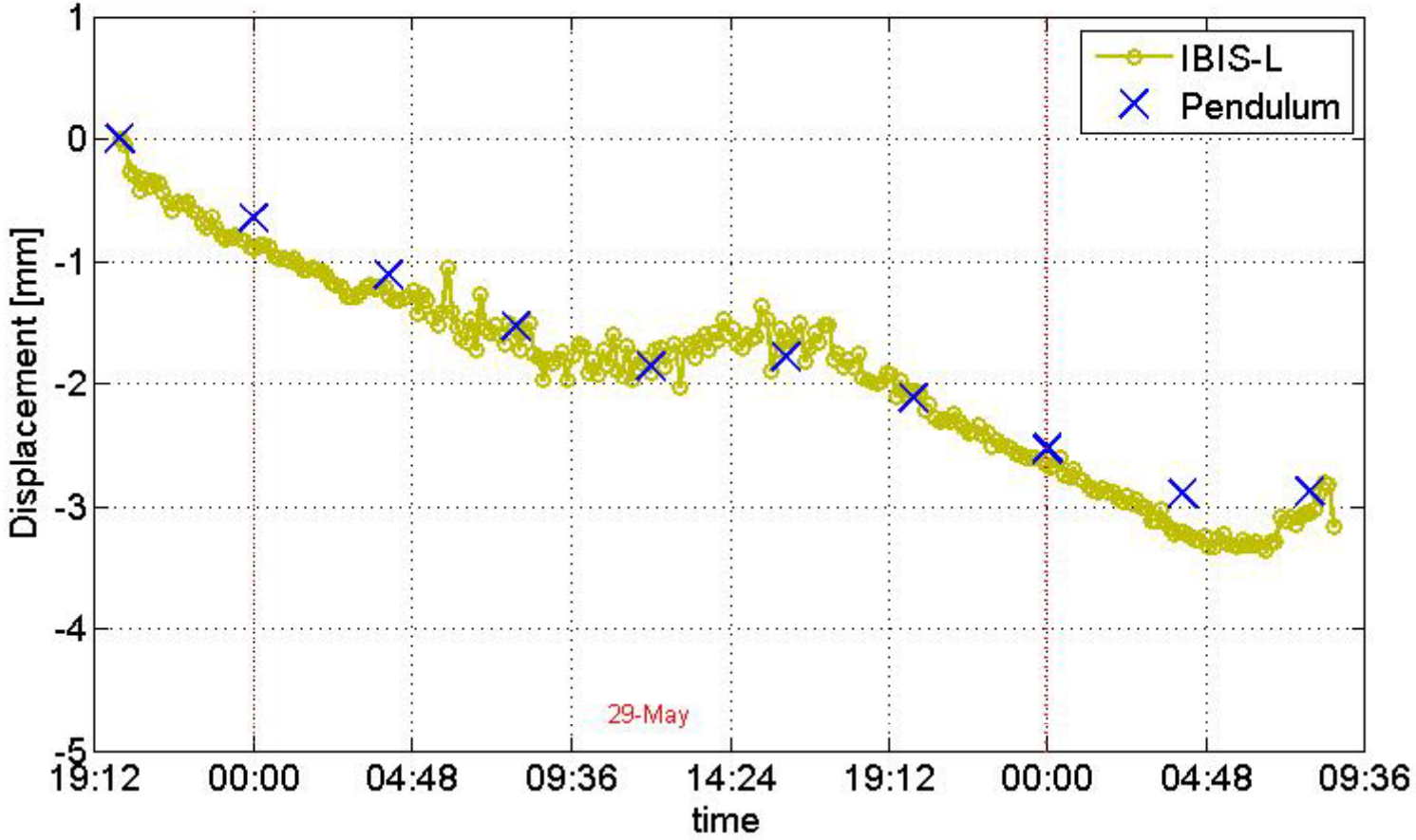
IDS INGEGNERIA DEI SISTEMI

Dam monitoring

Crowining point displacement comparison between IBIS-L and coordinometer measure



IBIS-L sampling interval: 9min
Pendulum sampling interval: 4hours

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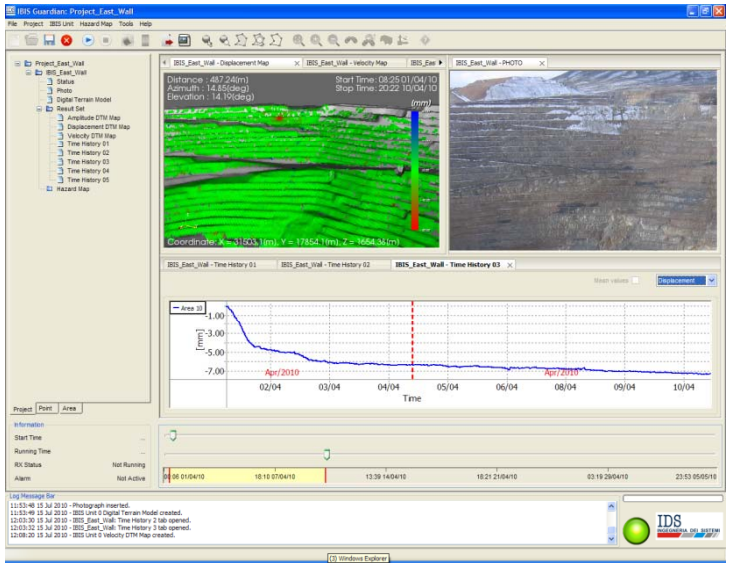
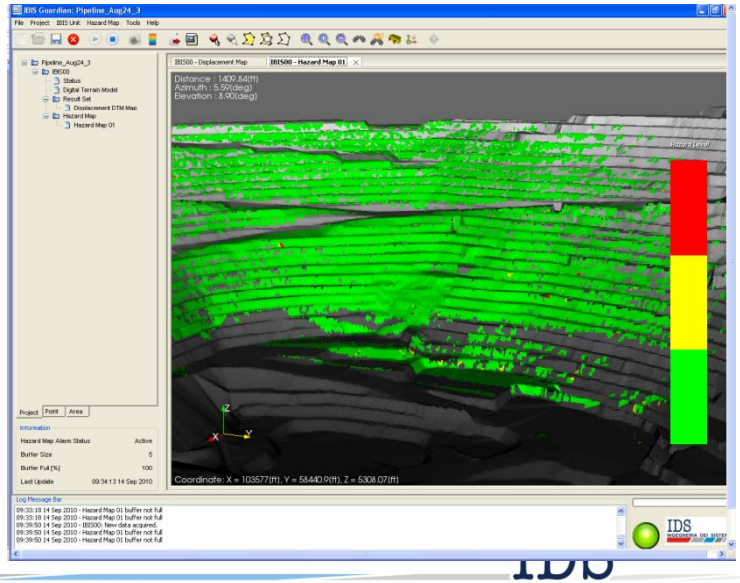
IDS INGEGNERIA DEI SISTEMI

IBIS Guardian

IBIS Guardian

- Real time processing with automatic atmospheric corrections
- Alarm generation with user-defined levels and multiple alarm criteria
- Fully georeferenced outputs
- 3D interactive data handling
- User defined zones for alarm generation
- Exportability of outputs to GIS and mine planning software





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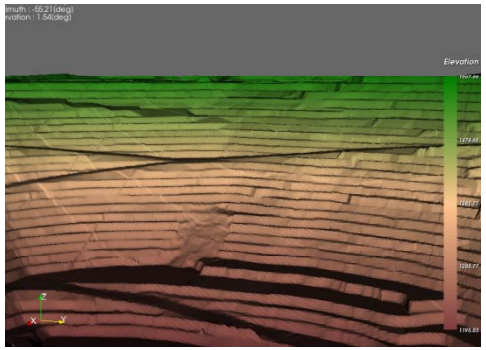
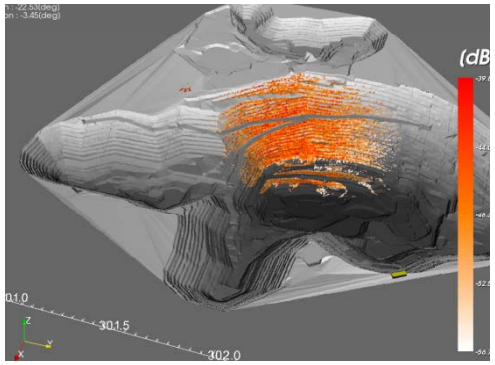
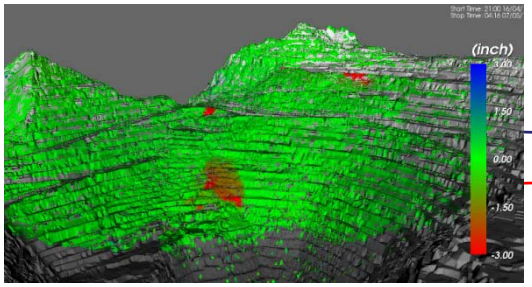
GUARDIAN typical output



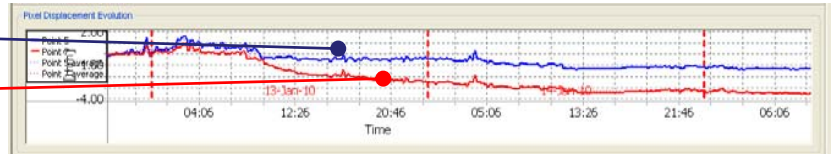
DEM

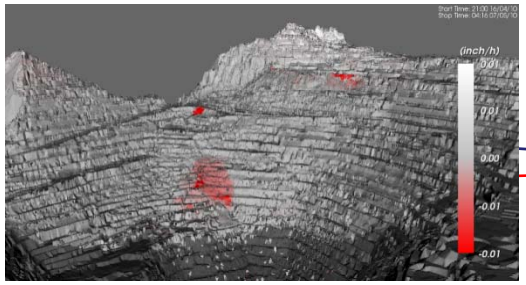


Quality Map
- Values between 0-1
- Reliability of the pixel for distance measurements

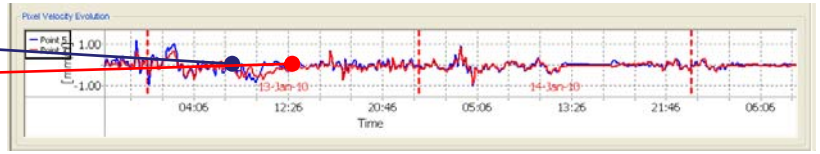


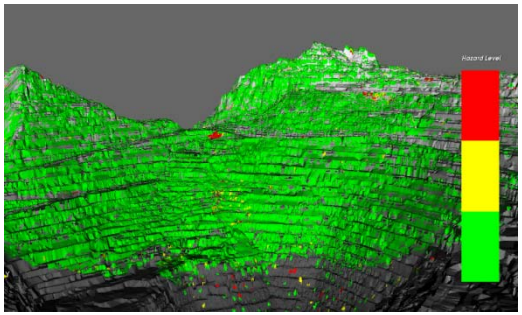
Displacement Map
- in mm for every pixel
- negative displacements are in approach





Velocity Map
- in mm/h for every pixel





Alarm

Moving

Stable

Hazard Map

-Variable number of levels and thresholds
-Automatically updated with the last data
-Exclude / Differentiation of areas
- Trigger the alarms:
  - PC SCREEN
  - SMS
  - EMAIL

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IDS INGEGNERIA DEI SISTEMI

Bridge testing: static live load test

Viaducts crossing Forlanini Avenue (Milan, Italy)

Bridge beams are good reflecting points

Static monitoring of a new bridge:

Determination of displacement of the bridge during a static load test

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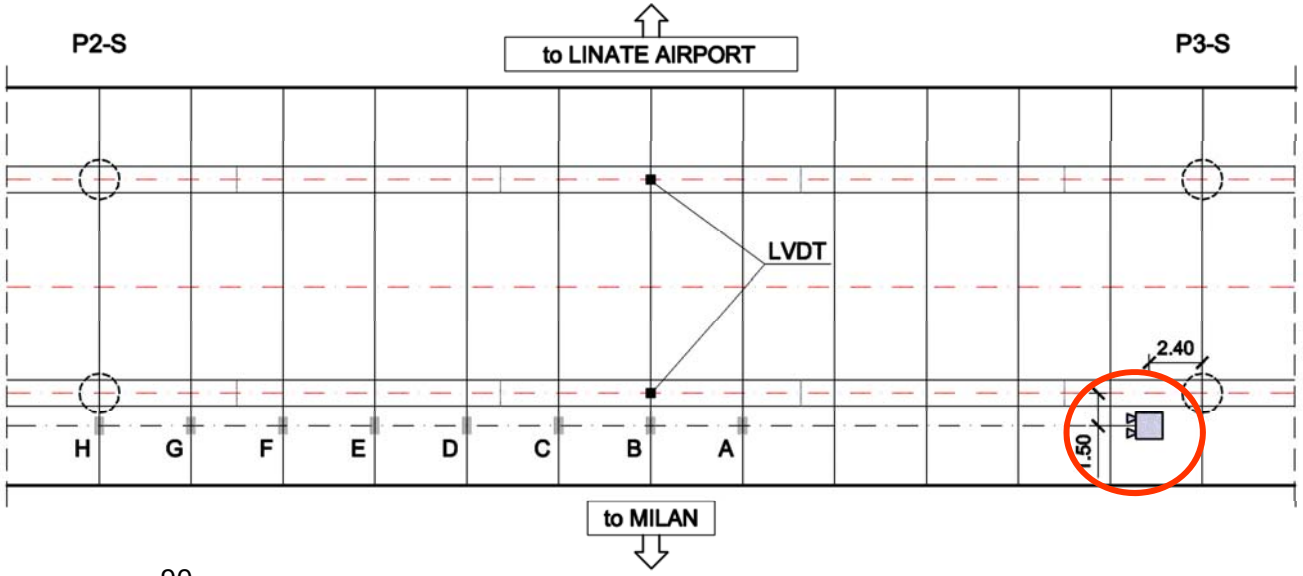
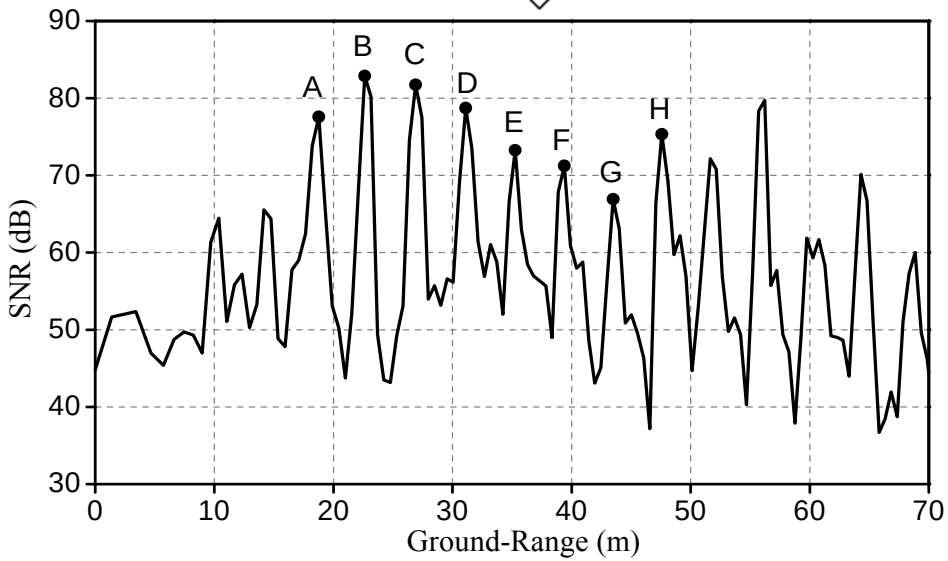
IDS INGEGNERIA DEI SISTEMI

Bridge testing: static live load test





IBIS-S installation

Range profile of P2-S – P3-S span

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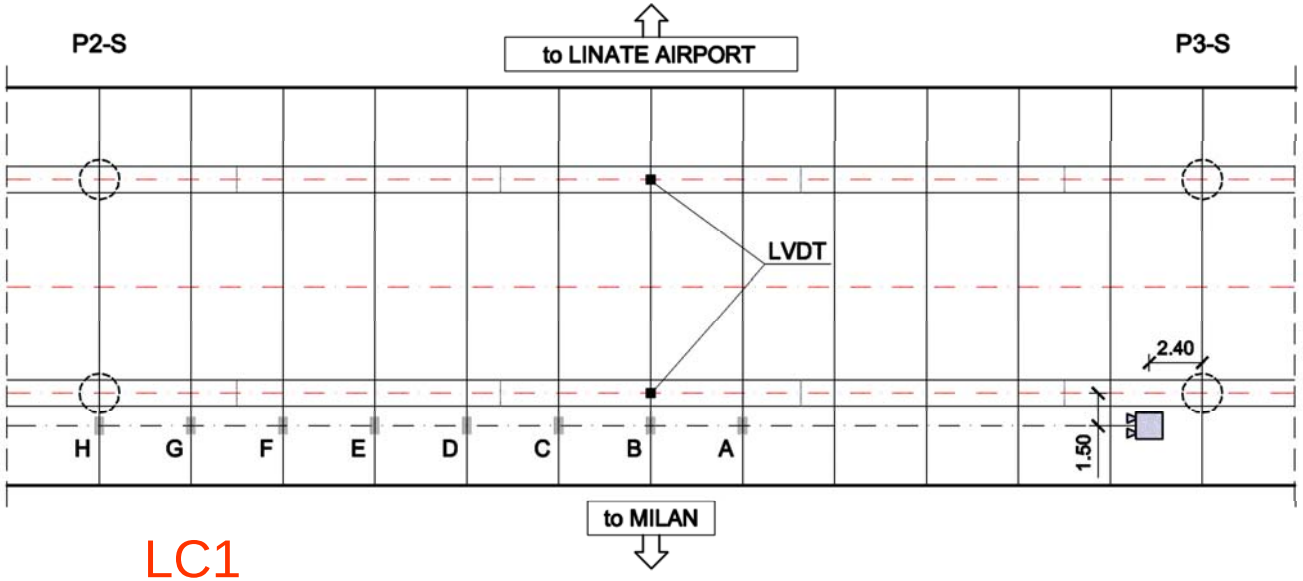
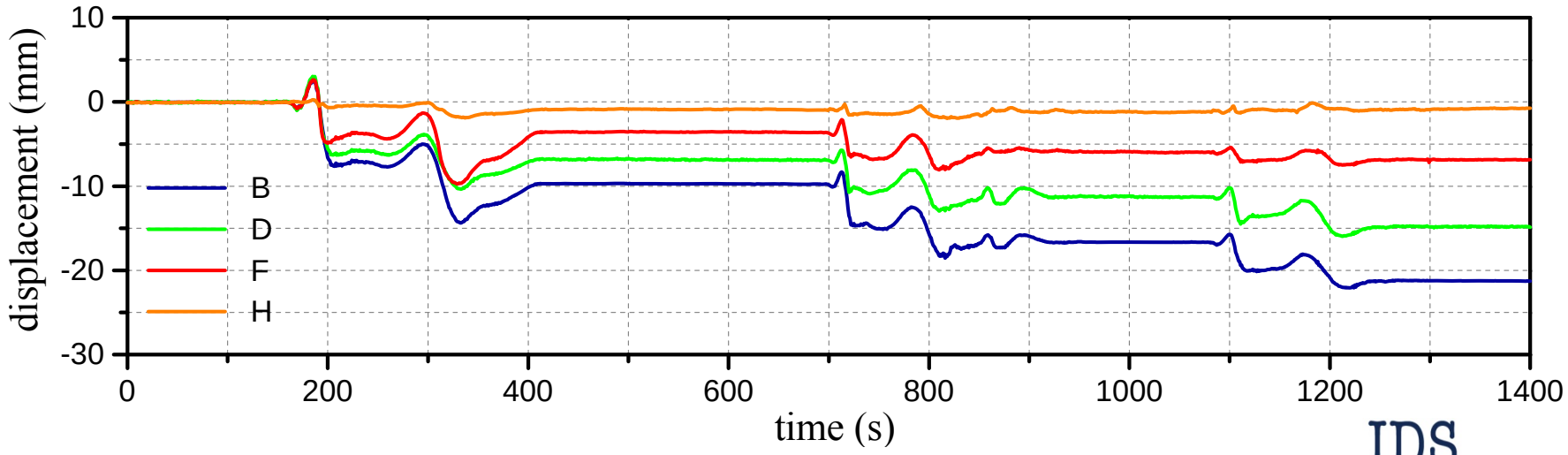
IDS INGEGNERIA DEI SISTEMI

Bridge testing: static live load test



LC1

LVDT



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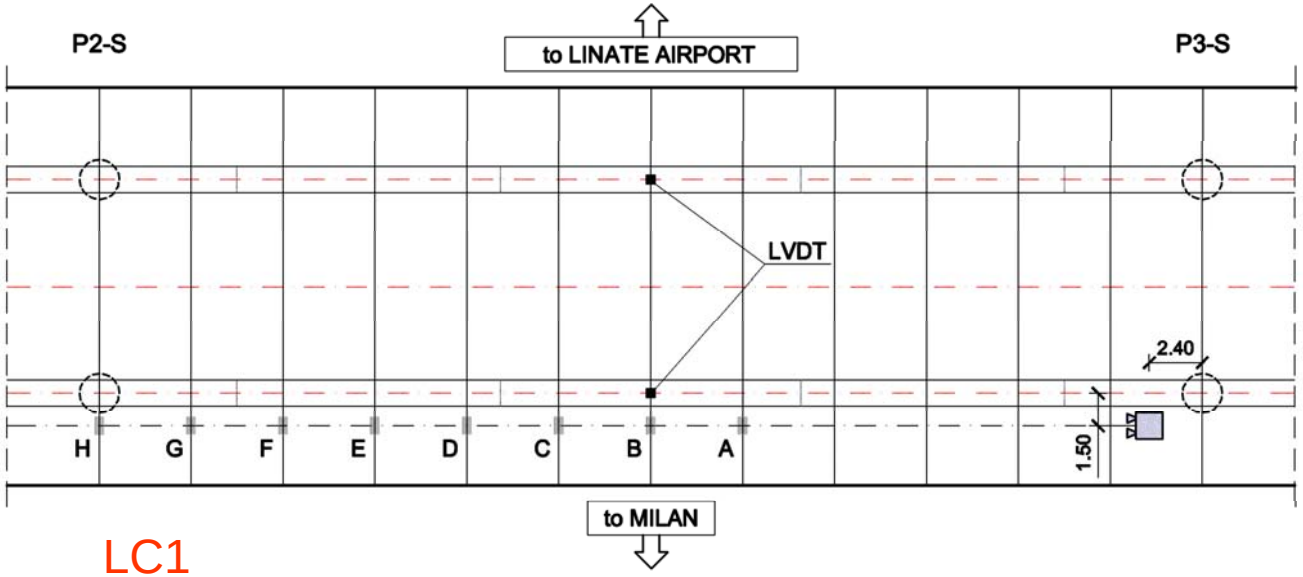
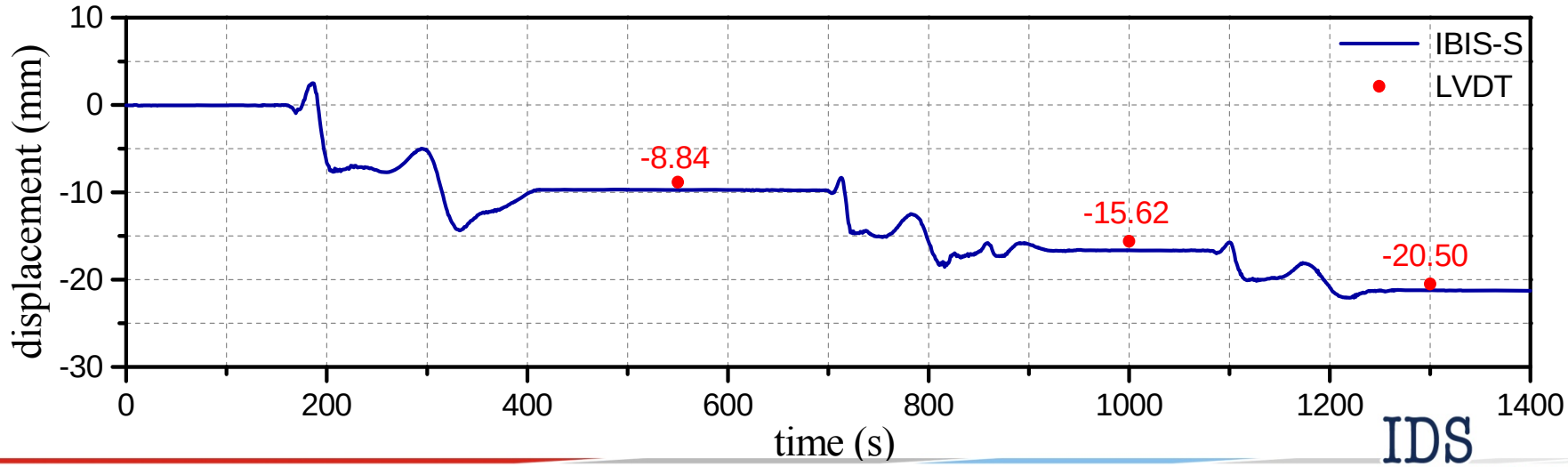
IDS INGEGNERIA DEI SISTEMI

Bridge testing: static live load test



LC1

LVDT



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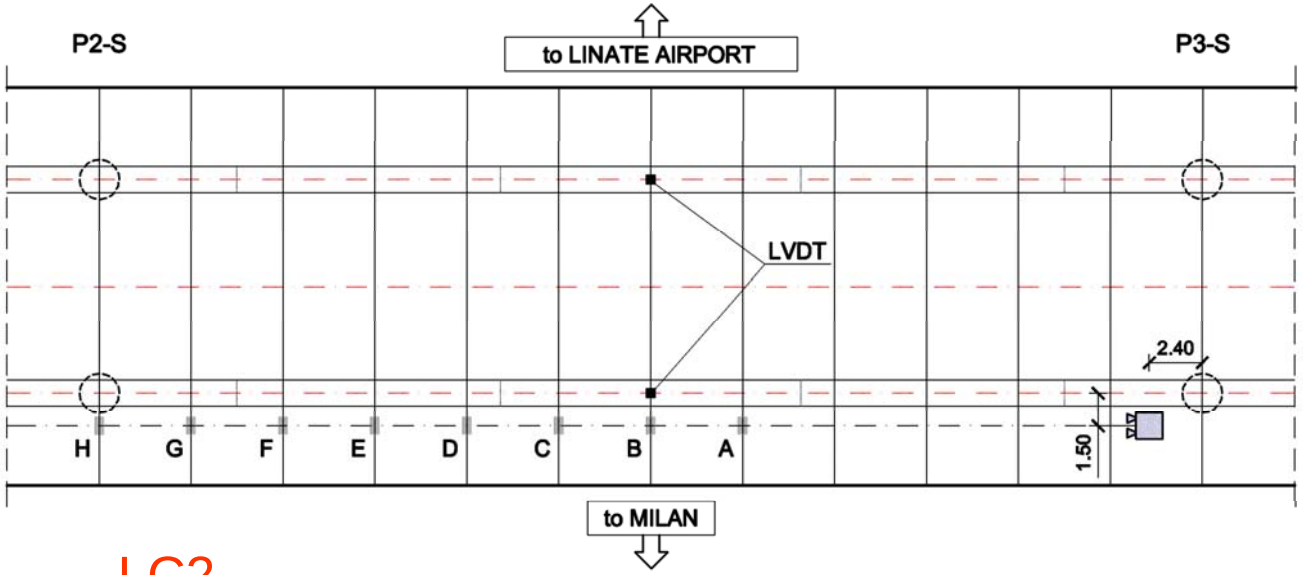
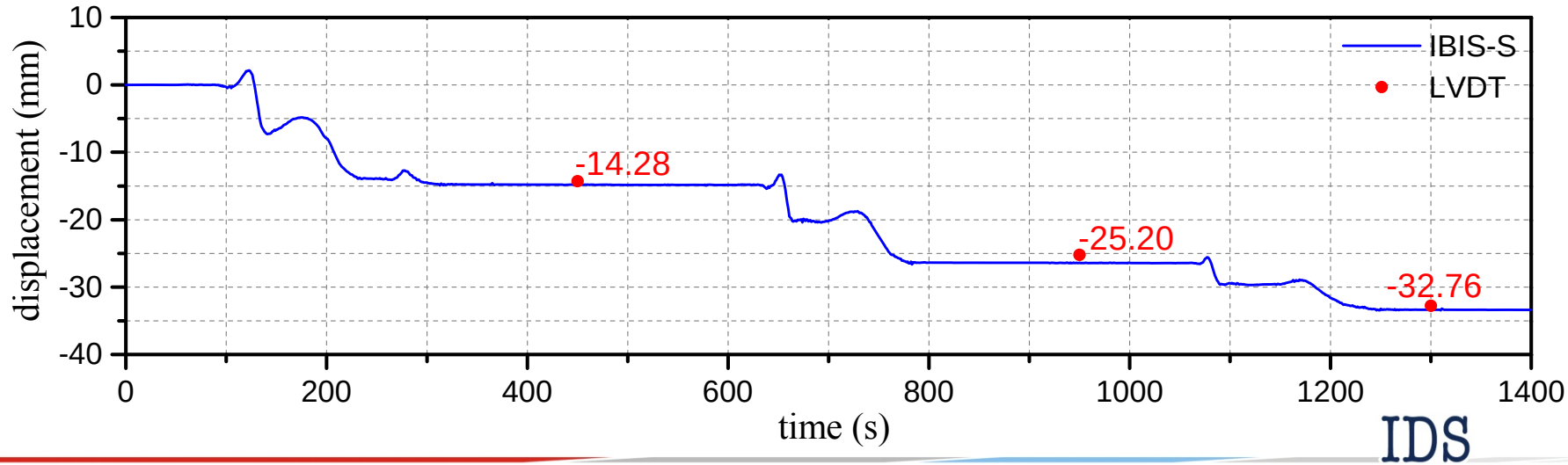
IDS INGEGNERIA DEI SISTEMI

Bridge testing: static live load test



LC2

LVDT



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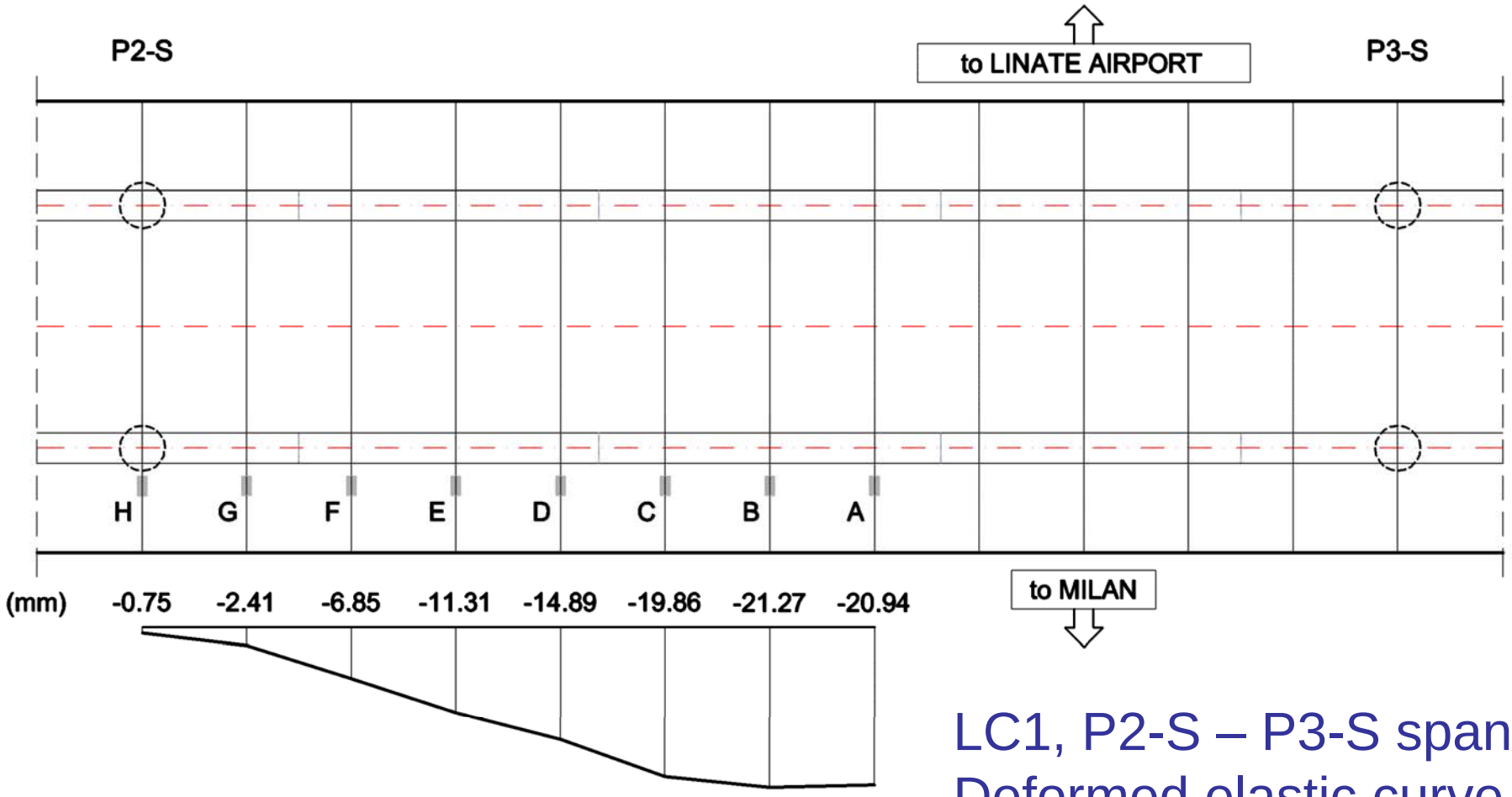
Bridge testing: static live load test



LC1, P2-S – P3-S span: Deformed elastic curve provided by IBIS-S

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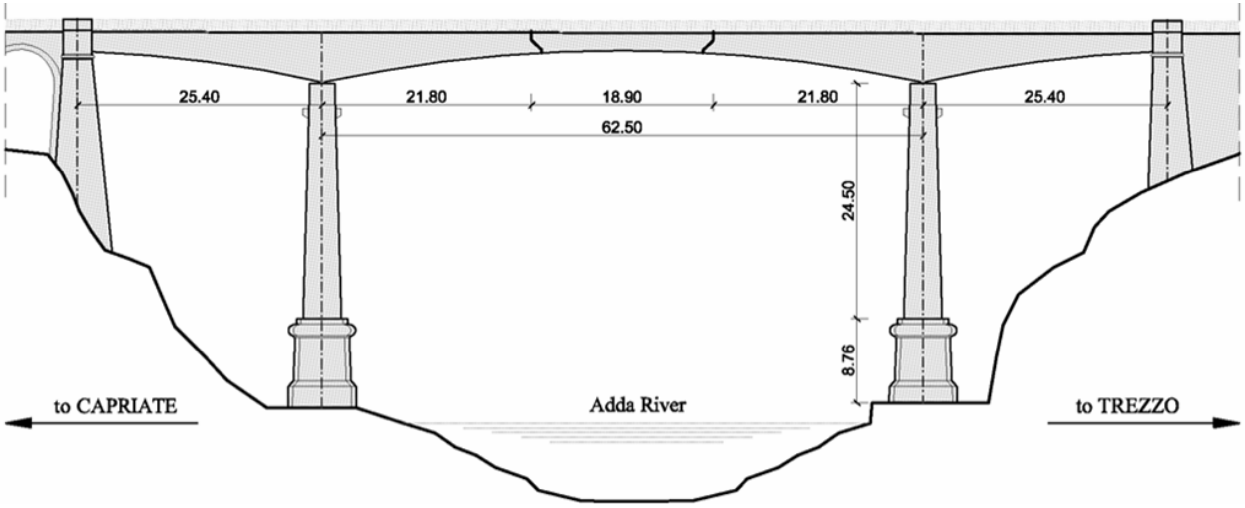
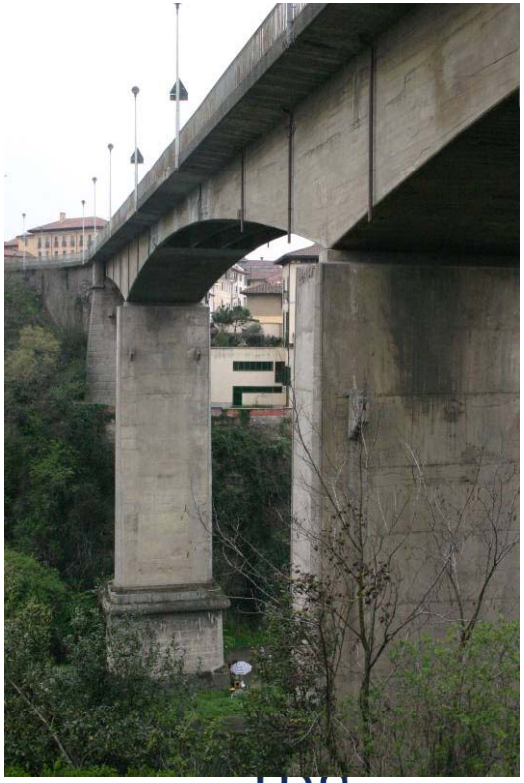
IDS INGEGNERIA DEI SISTEMI

Bridge testing: dynamic test of bridge span

Measurement objective: comparison with accelerometers, resonance frequencies and modal shape retrieval



Central arch length (m): 62.5



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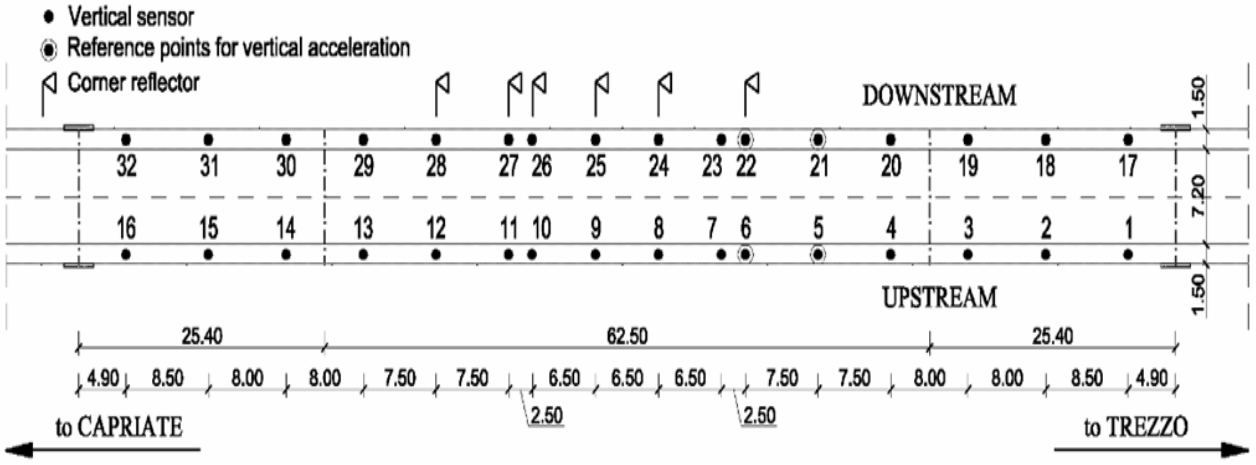
Bridge testing: dynamic test of bridge span

To make a comparison between the results of IBIS-S system and accelerometers system 6 corner reflector were installed at the same position of accelerometers



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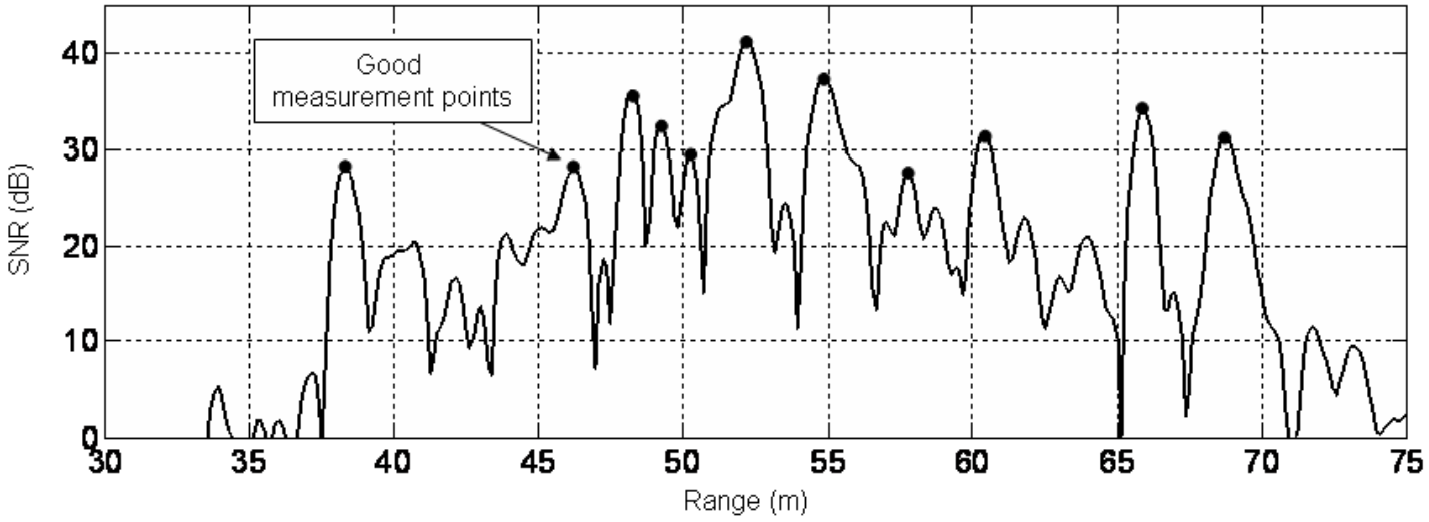
Bridge testing: dynamic test of bridge span

Bridge photograph and range profile



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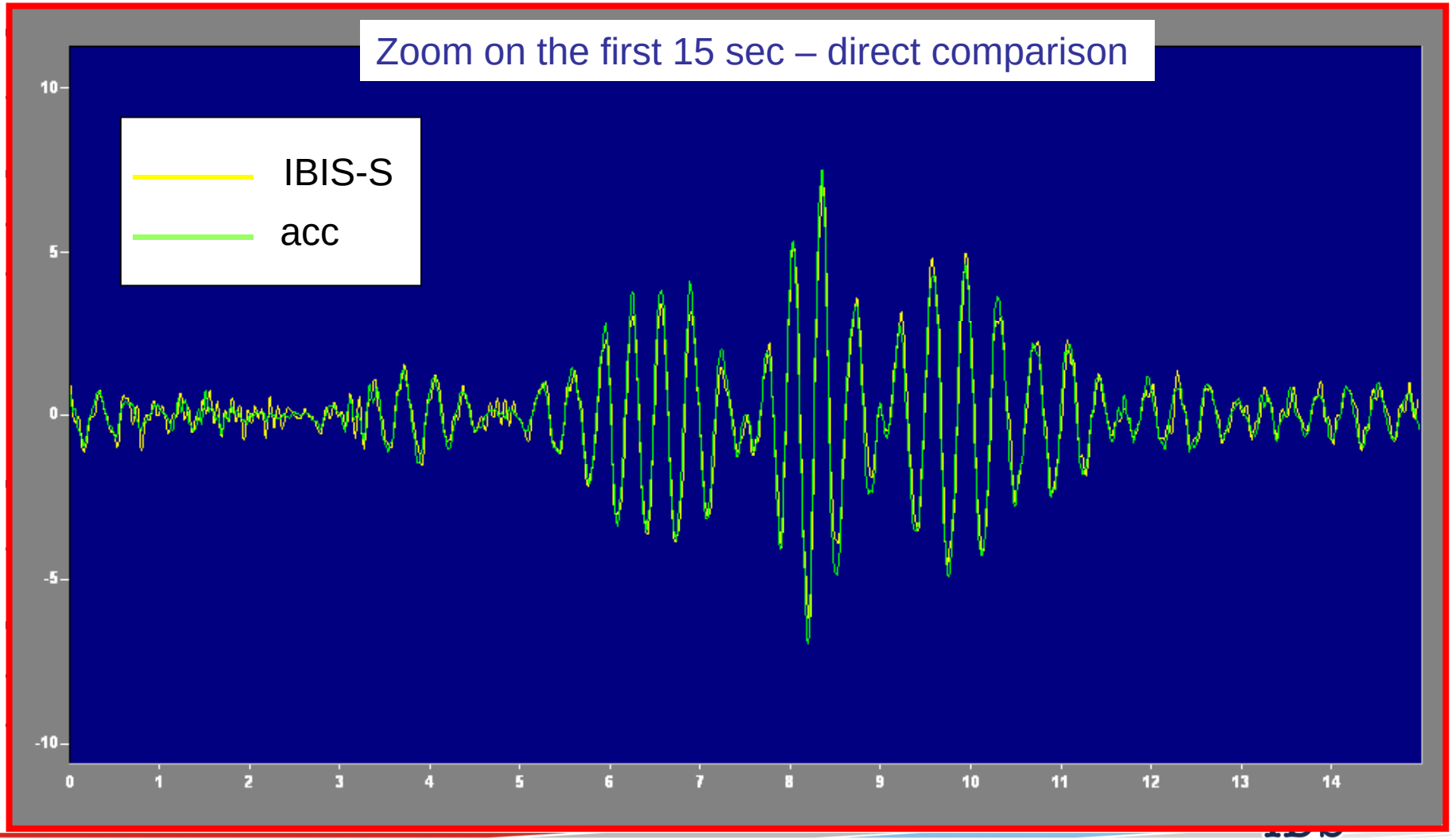
IDS INGEGNERIA DEI SISTEMI

Bridge testing: dynamic test of bridge span

Velocity comparison for Test Point 22



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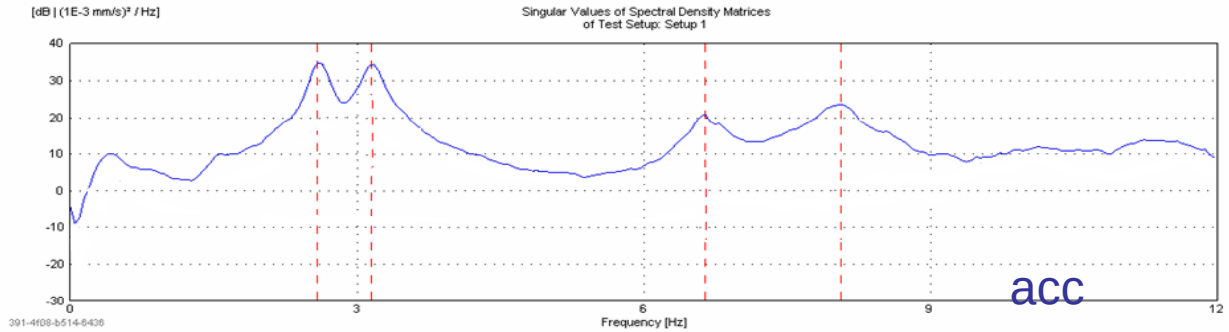
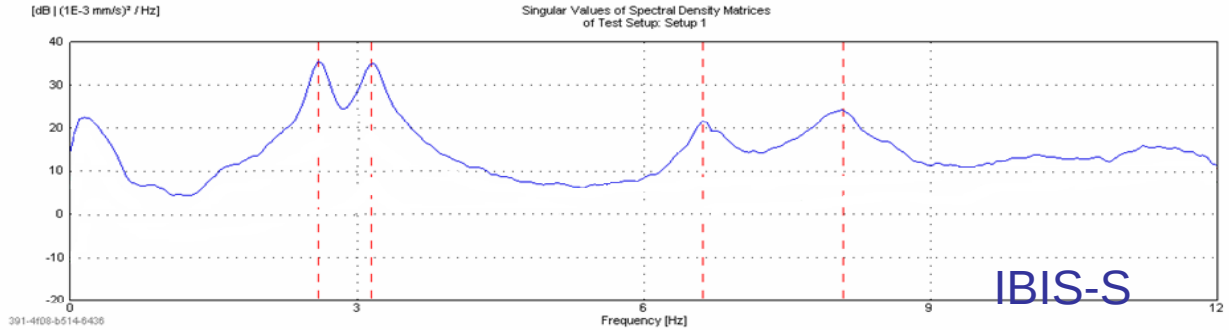
Bridge testing: dynamic test of bridge span





Frequency analysis comparison on 3000sec acquisition duration

Acc detected frequency	IBIS-S detected frequency	Percentage error
Hz	Hz	%
2,617	2,595	0,84
3,164	3,182	-0,57
6,641	6,608	0,50
8,086	8,077	0,11

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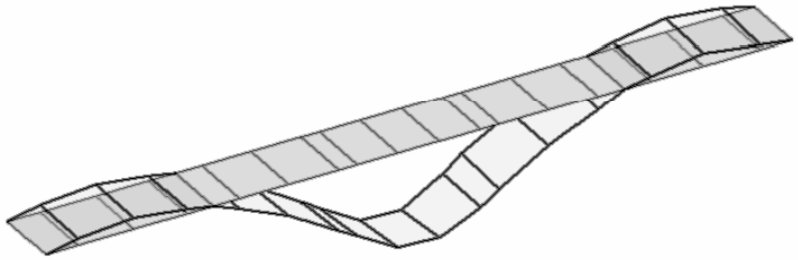
IDS INGEGNERIA DEI SISTEMI

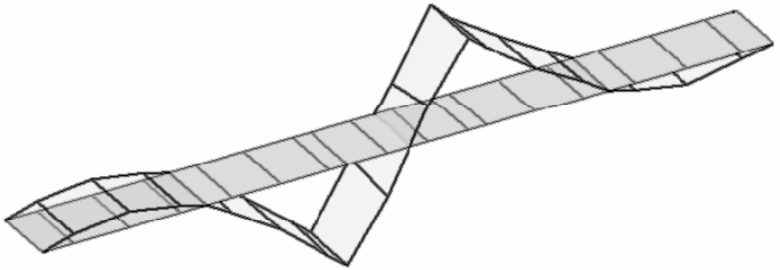
Bridge testing: dynamic test of bridge span

Modal shape obtained by accelerometer data

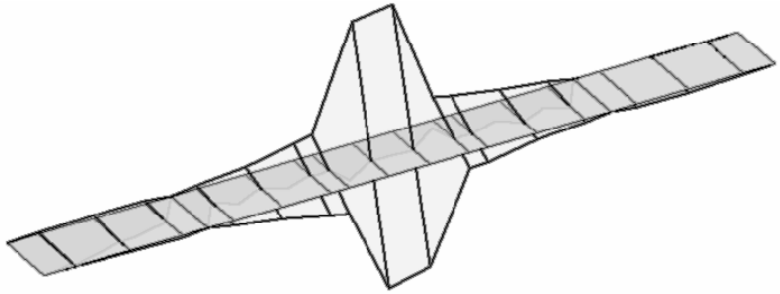
f = 2.617 Hz



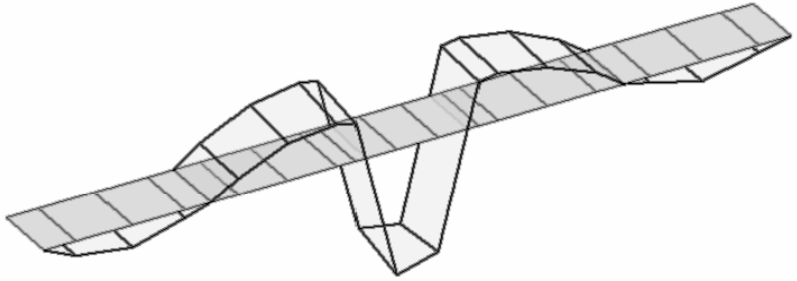
f = 3.164 Hz



f = 6.641 Hz



f = 8.086 Hz



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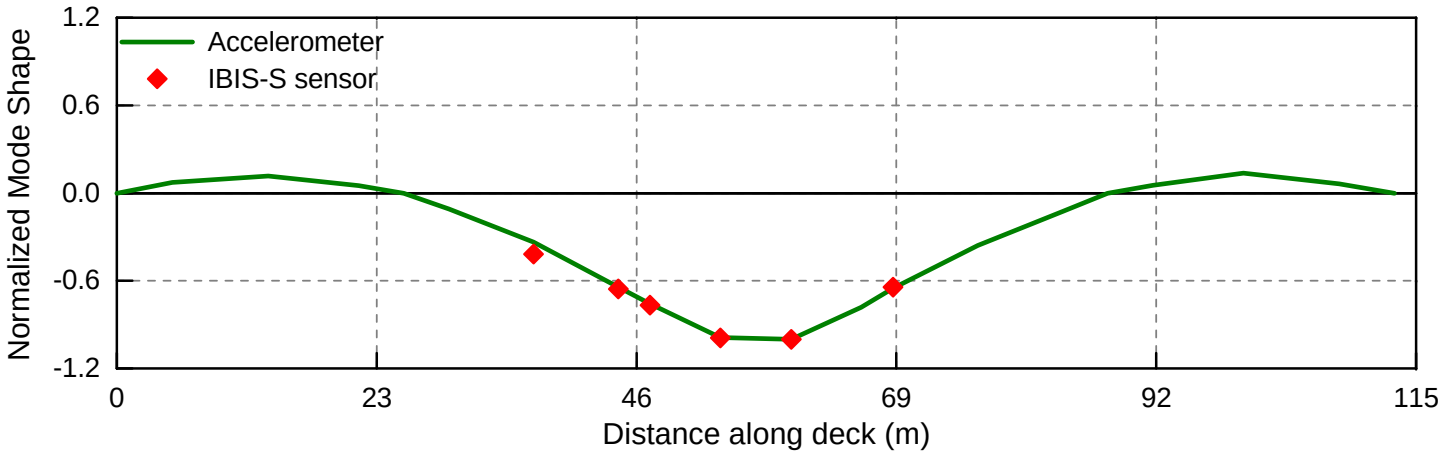
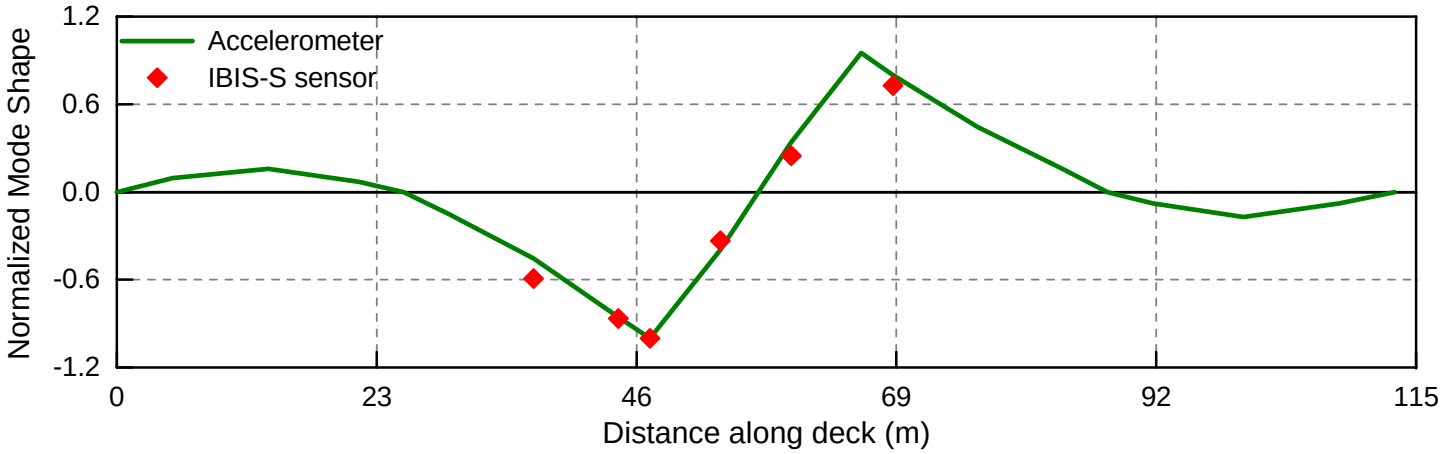
IDS INGEGNERIA DEI SISTEMI

Bridge testing: dynamic test of bridge span

Modal shapes comparison



f=2.617Hz



f=3.164Hz

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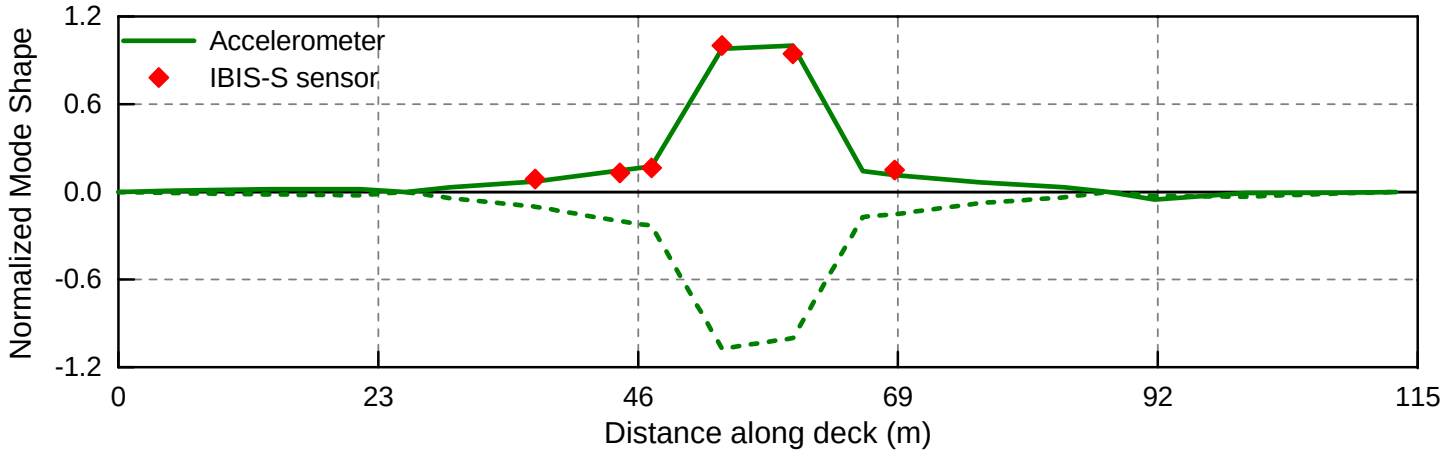
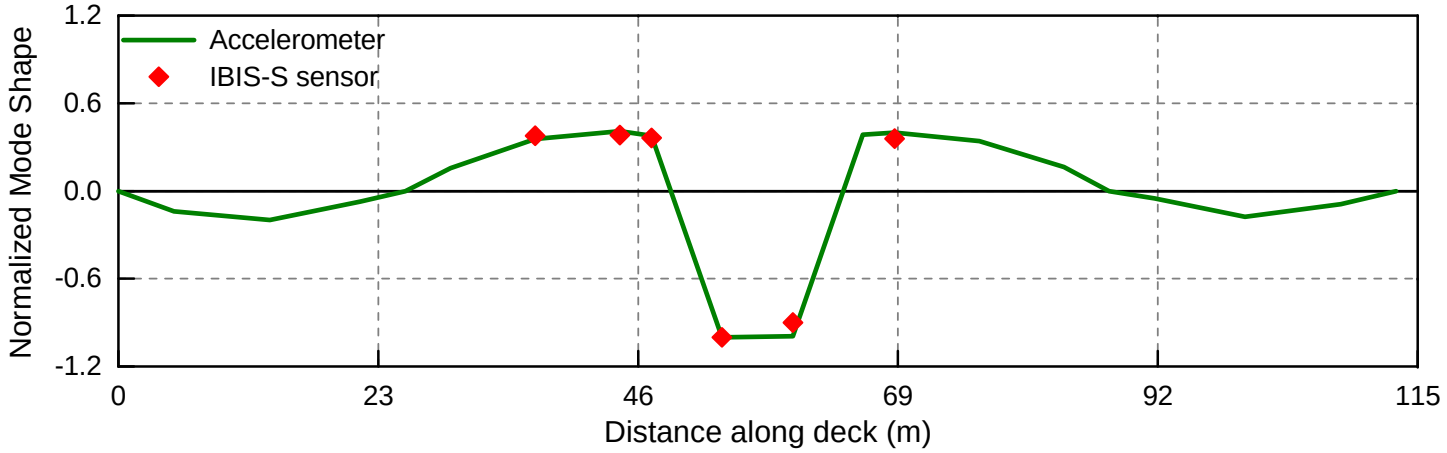
IDS INGEGNERIA DEI SISTEMI

Bridge testing: dynamic test of bridge span

Modal shapes comparison



f=6.641Hz



f=8.086Hz

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IDS INGEGNERIA DEI SISTEMI

Bridge testing: Cable-stayed bridges

Application goal: dynamic analysis done through ambient vibration testing (AVT) aimed at:

- Identify the **amplitude** of the **cable vibrations**;
- Identify the **natural resonant frequencies** and the **cable dumping factors**
- Evaluate the **tension** and the **operating strain** of **cables** to verify the correct distribution of loads and the temporal variation of tensions along the bridge life

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Bridge testing: Cable-stayed bridges

Advantages in the use of IBIS-S:

- Provide **displacement** measurements (useful to evaluate the amplitude of vibrations)
- Very **accurate** measurement: an order of magnitude higher than LDV
- **No traffic shut-done** needed (IBIS can be installed under the bridge or beside the bridge towers)
- **Simultaneuous** measurement on a large number of cables (potentially all cables of each side at once)
- **Rapid** installation and measurement set-up

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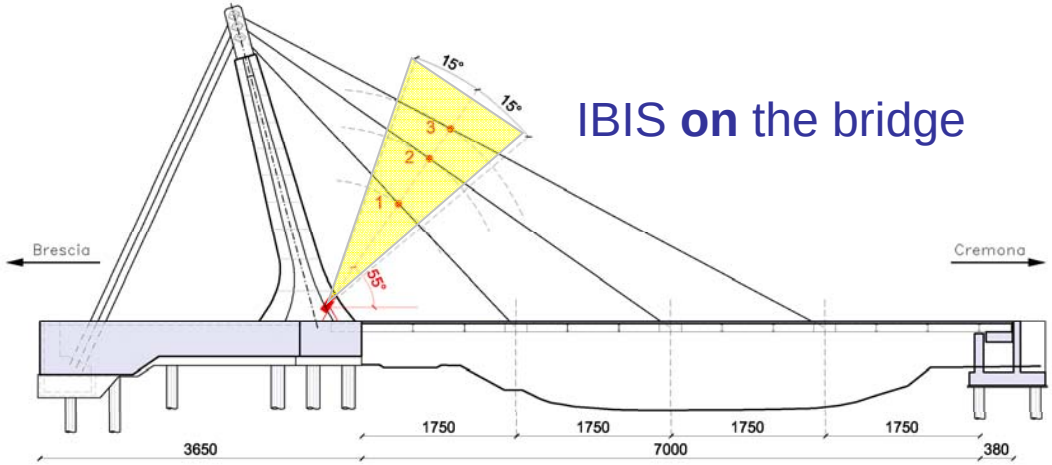
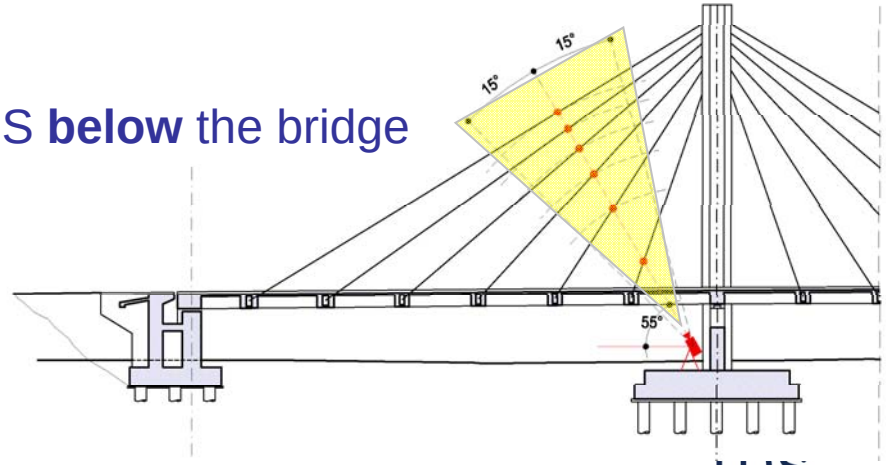
Bridge testing: Cable-stayed bridges

Geometrical sketch of IBIS-S set-up:



IBIS **on** the bridge

IBIS **below** the bridge



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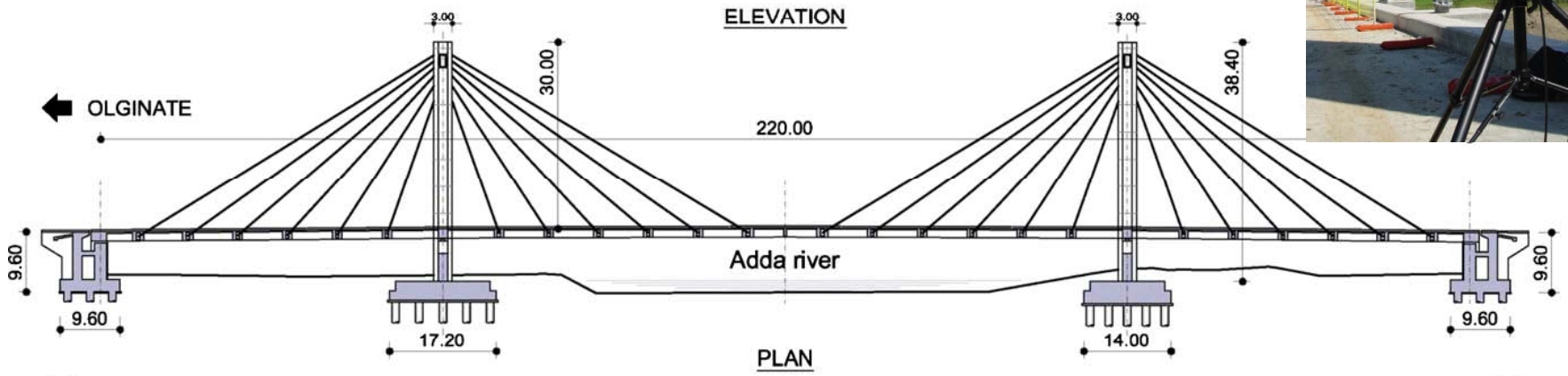
IDS INGEGNERIA DEI SISTEMI

Bridge testing: Cable-stayed bridges



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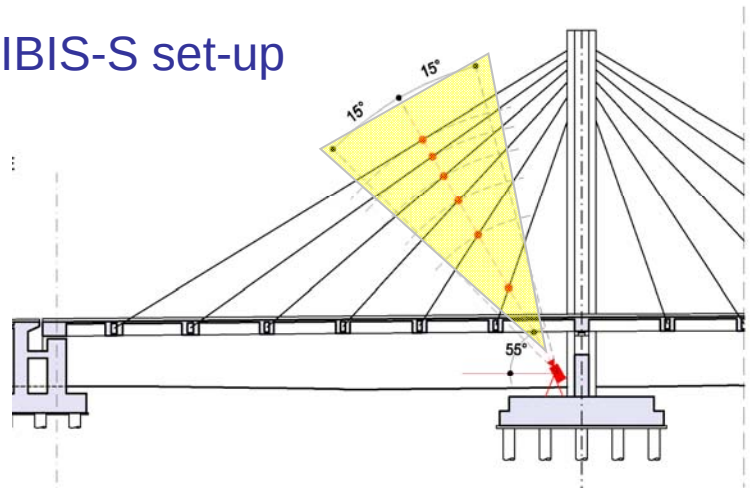
IDS INGEGNERIA DEI SISTEMI

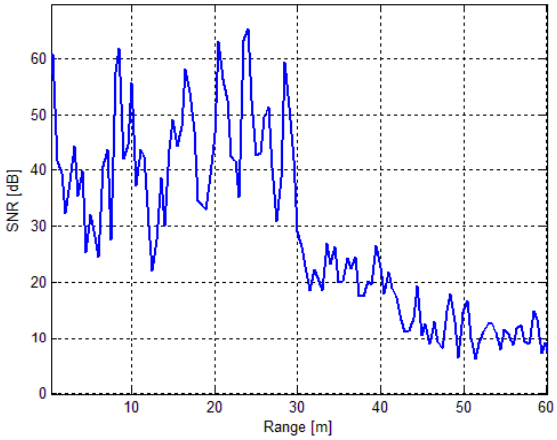
Bridge testing: Cable-stayed bridges

Olginate bridge (Italy)

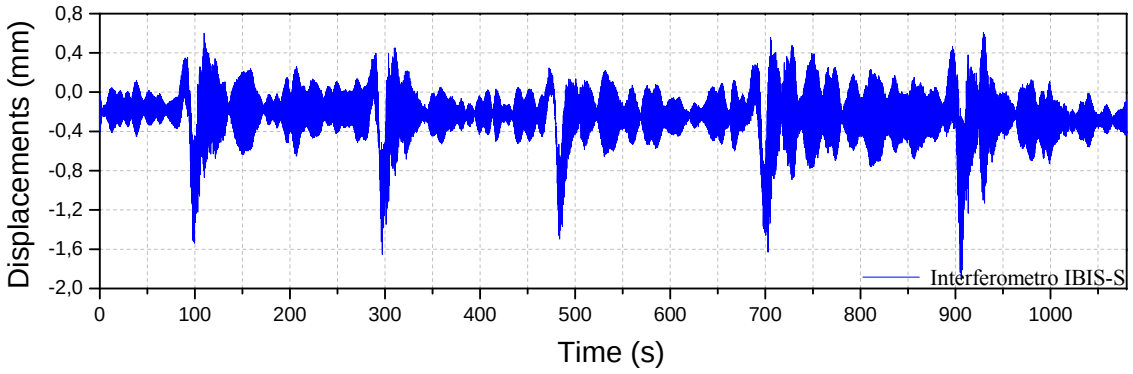
IBIS-S set-up



Range Profile



Displacement graph



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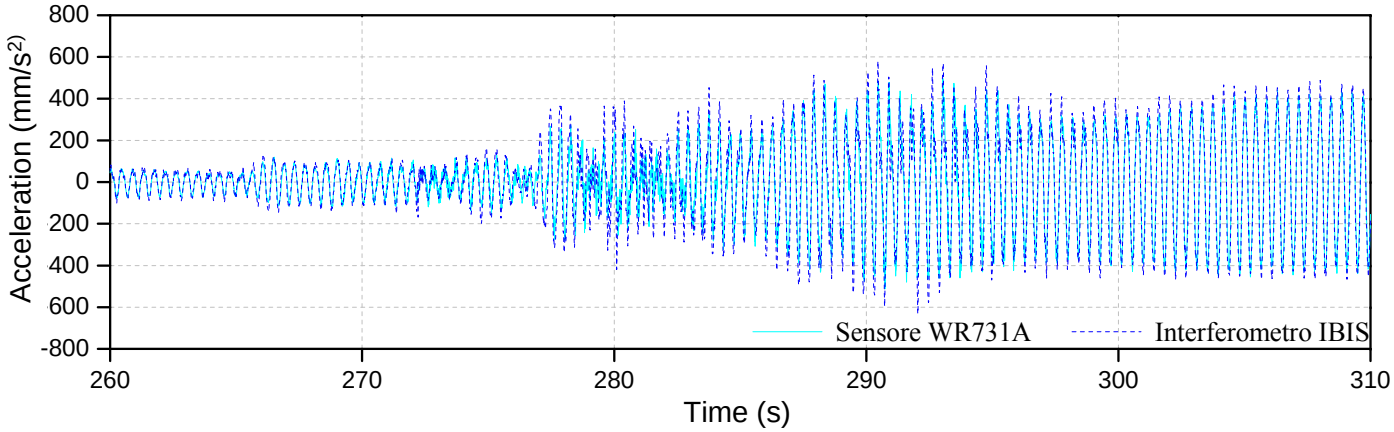
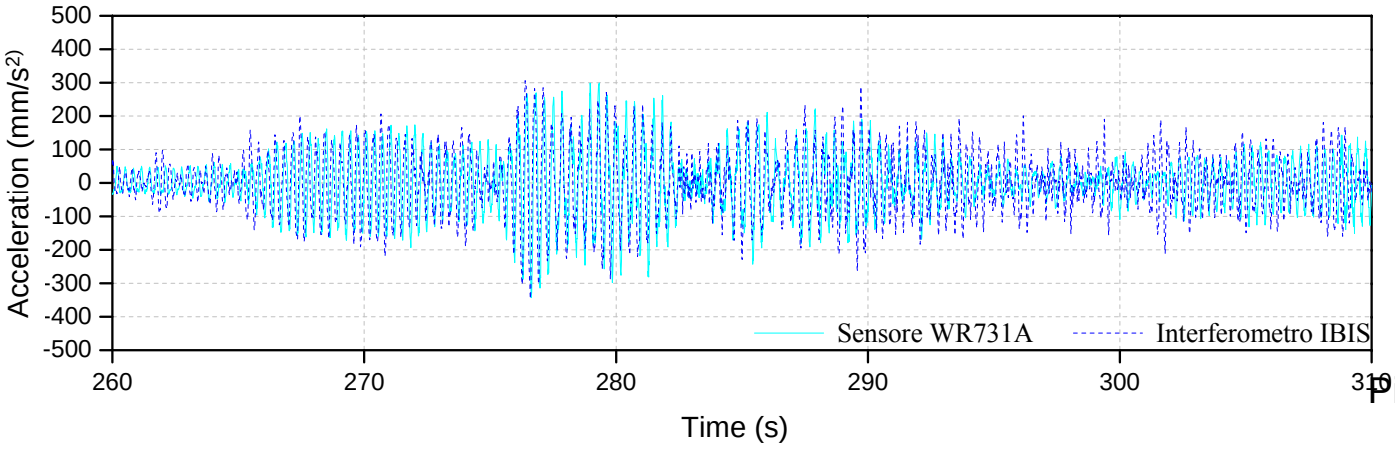
Bridge testing: Cable-stayed bridges

Example: Olginate bridge (Italy)

Comparison with accelerometers





Piezo-electric accel. WR 731A

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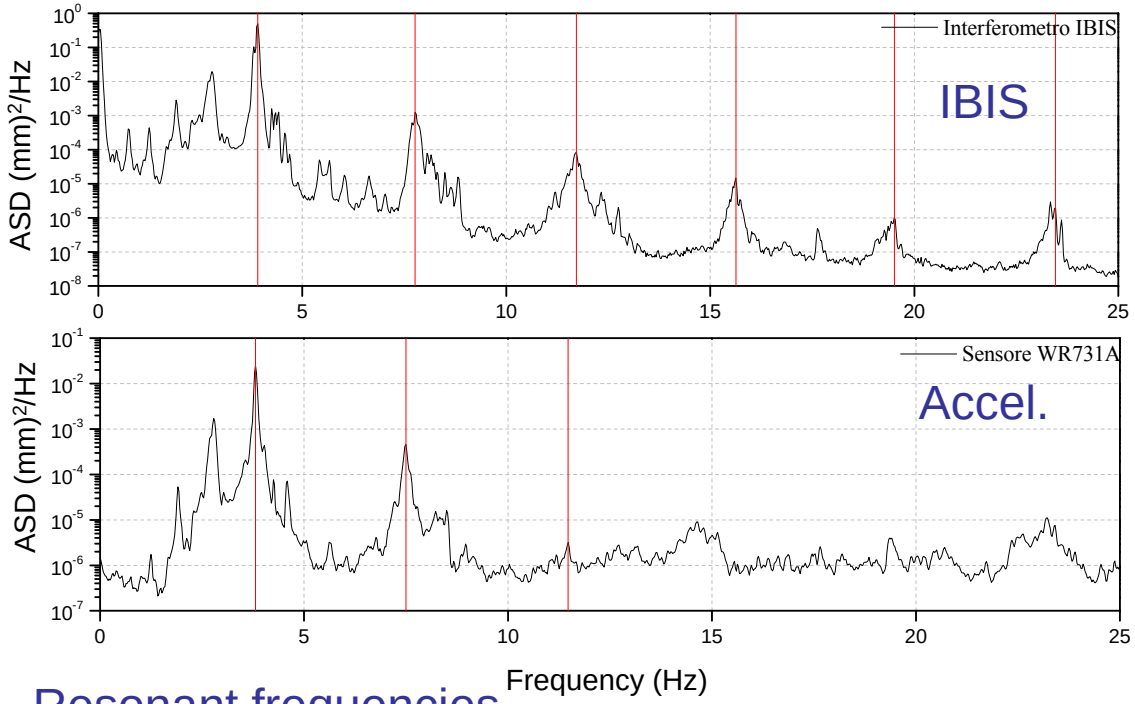
IDS INGEGNERIA DEI SISTEMI

Bridge testing: Cable-stayed bridges

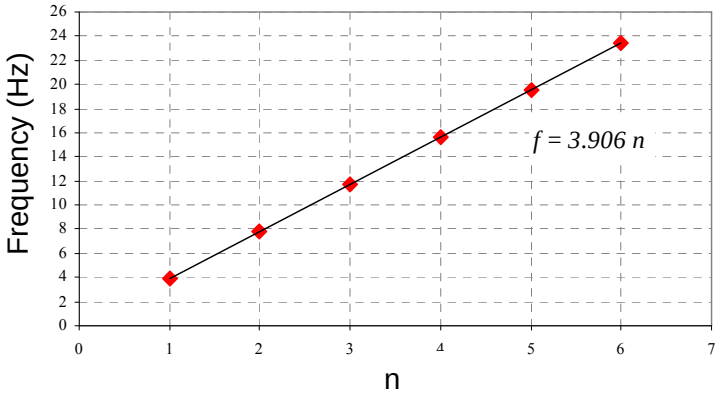
Example: Olginate bridge (Italy)

Frequency Domain Analysis



Resonant frequencies

	f_1 (Hz)	f_2 (Hz)	f_3 (Hz)	f_4 (Hz)	f_5 (Hz)	f_6 (Hz)
IBIS-S	3.906	7.764	11.720	15.630	19.510	23.460
Accel.	3.809	7.495	11.470			



Tension

Cable S09'			
IBIS-S		**Accelerometer**	
f_{exp} (Hz)	**Tension (kN)**	f_{exp} (Hz)	**Tension (kN)**
3.906	1883.1	3.809	1790.7
7.764	1860.0	7.495	1733.3
11.720	1883.7	11.470	1804.2
15.630	1884.5		
19.510	1879.2		
23.460	1886.9		
	1880		**1776**

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IDS INGEGNERIA DEI SISTEMI

High-rise structures: chimney testing

Measurement objective: measurement of the displacements of the old and new chimney and identification of their resonance frequencies

Old chimney

Chimney high: 183m

Measurement parameters:

maximum range: 300 m
sampling frequency: 50 Hz
range resolution: 0.5 m
distance from the target: ~ 50 m

New chimney

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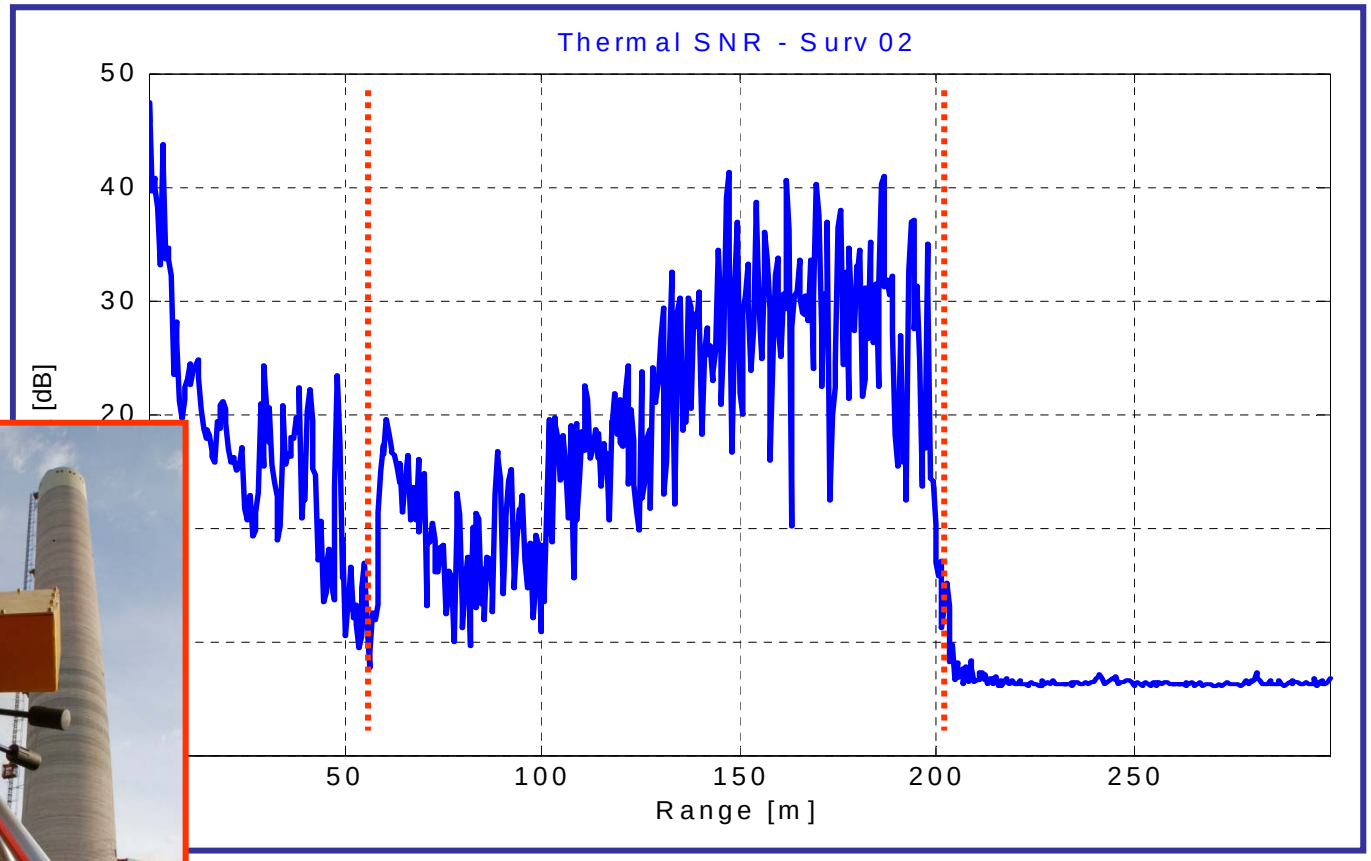
IDS INGEGNERIA DEI SISTEMI

High-rise structures: chimney testing

Range profile of the new chimney



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IDS INGEGNERIA DEI SISTEMI

High-rise structures: chimney testing

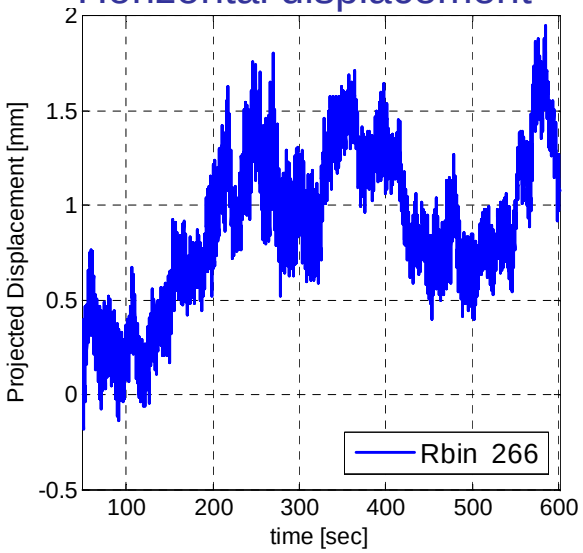
New chimney

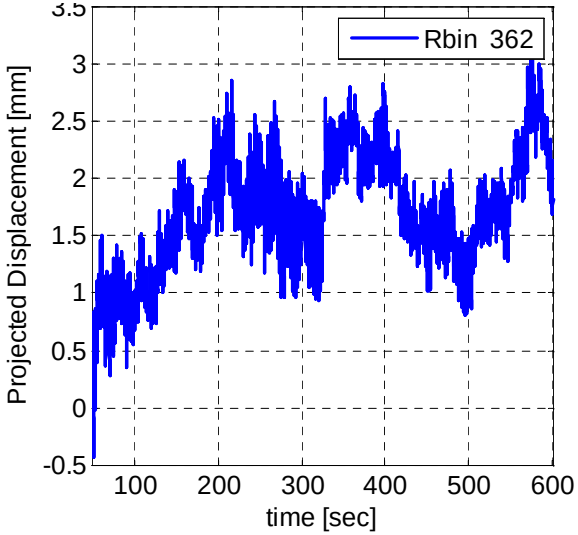
Point located at the middle of the chimney, at a height of 121 m

Point located at the top of the chimney, at a height of 172 m

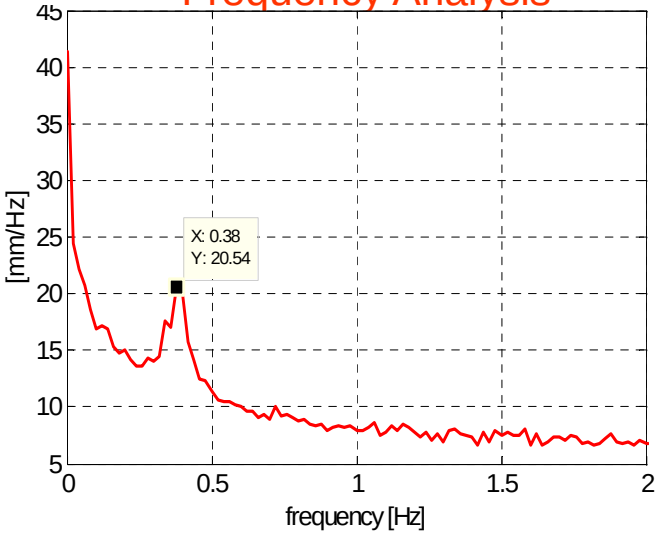
Identified frequency: 0.38 Hz

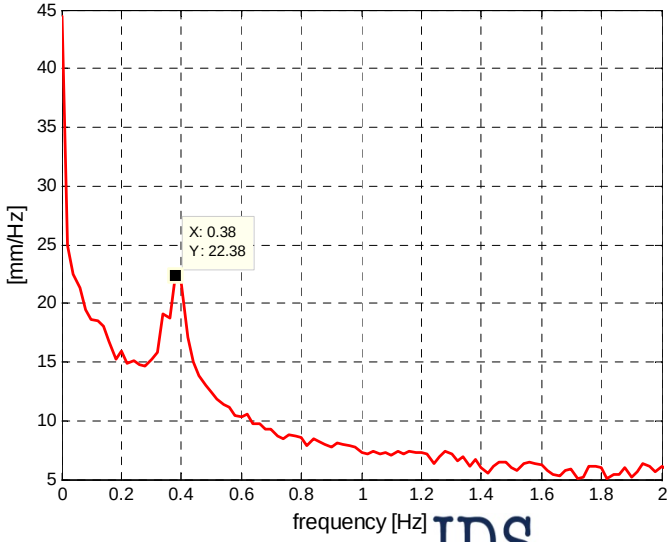
Horizontal displacement





Frequency Analysis





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IDS INGEGNERIA DEI SISTEMI

Convegno ALIG:

La tecnologia georadar per la diagnostica non distruttiva dei manufatti

PISA 13 Maggio 2011

Paolo Papeschi

Guido Manacorda

Alessandro Simi

con il patrocinio :

ORDINE GEOLOGI REGIONE TOSCANA

con la collaborazione :

IDS Ingegneria dei Sistemi SpA

POLITECNICO DI MILANO

BOVIAR srl

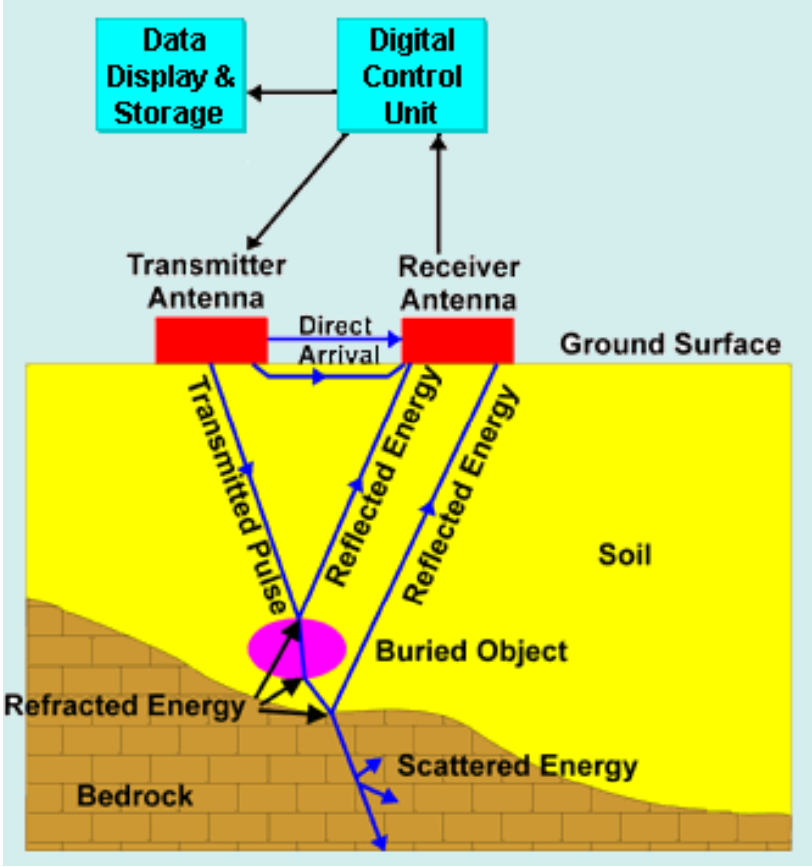
www.boviar.com

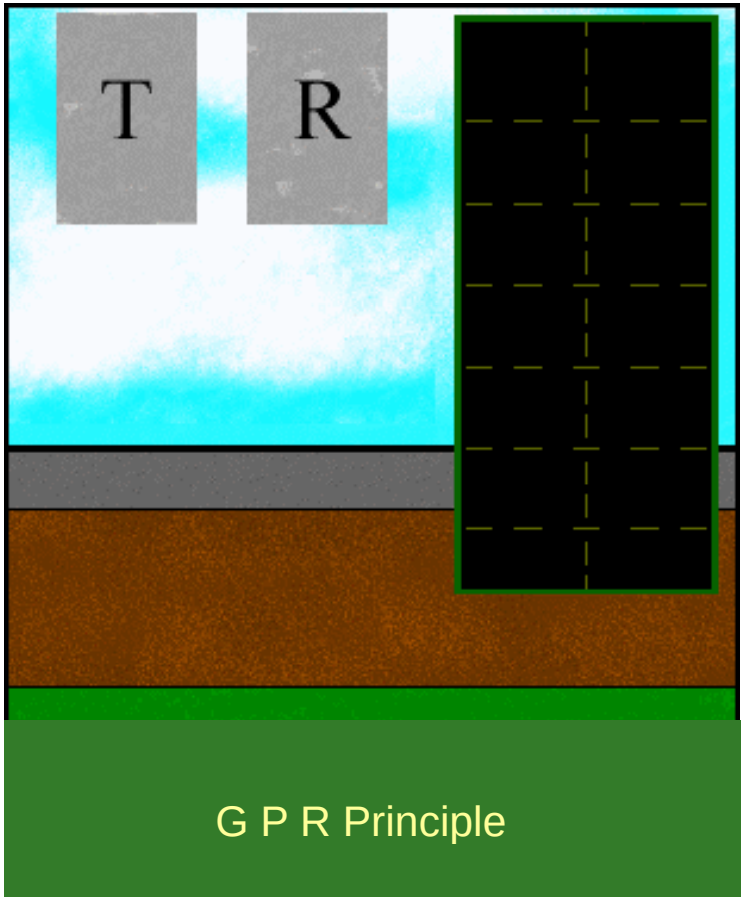
Introduzione

- IL G.P.R. (Ground Penetrating Radar) impiega l'energia elettromagnetica a radiofrequenza per l'indagine della struttura del sottosuolo o di costruzioni antropiche, senza alterarne la loro struttura fisica.
- Questo rende la prospezione molto più veloce ed economica rispetto alle tradizionali indagini invasive.
- Perciò il G.P.R. si presta ad una varietà di applicazioni tipo:
  - Ricerca di sottoservizi (tubature, cavi).
  - Individuazione di siti archeologici.
  - Valutazione dell'integrità di strutture (mura, tunnel, pavimenti).
  - Applicazioni geologiche (ricerca di cavità e fratture).
  - Verifica di fondazioni ed altro ancora.

GROUND PENETRATING RADAR (GPR)

GPR è una tecnologia che è stata sviluppata per indagini superficiali ad alta risoluzione e per indigini nel sottosuolo. GPR utilizza onde eem ad alta frequenza impulsate tipicamente comprese tra 25 MHz e 2000 MHz.





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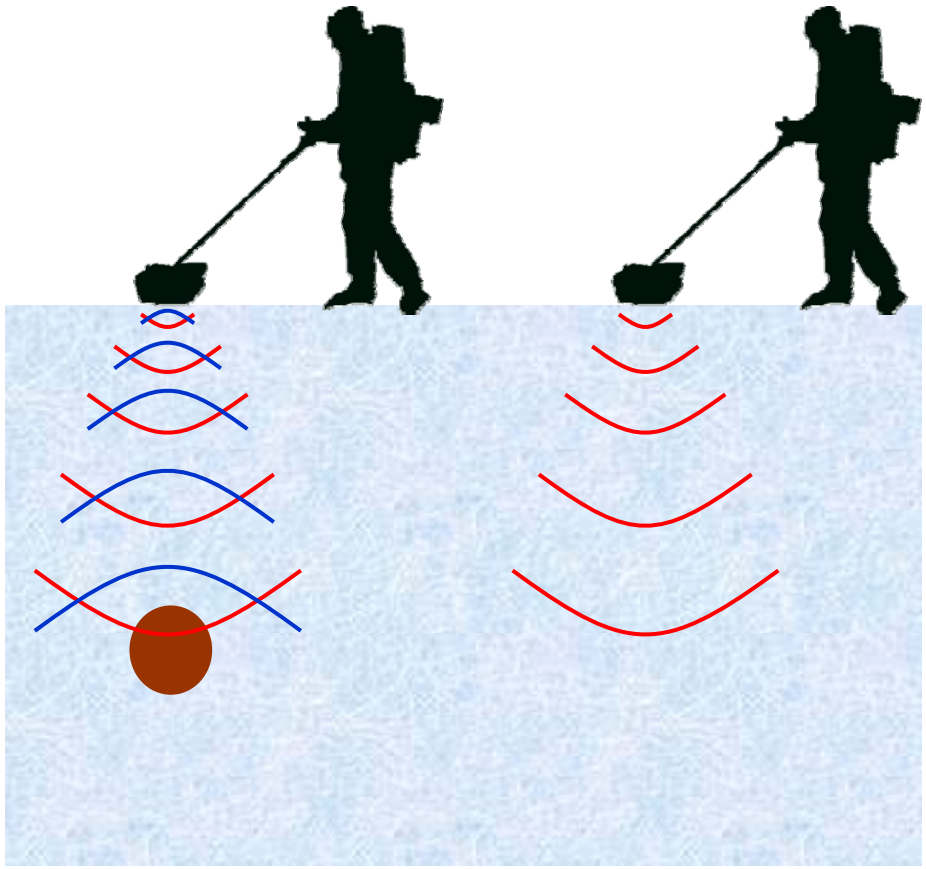
Principio di funzionamento

- ✓ Il Georadar trasmette un impulso molto breve (1-2 ns) di energia nel materiale mediante una antenna
- ✓ L'Energia riflessa dalle interfacce e dalle discontinuità viene registrata da un'antenna
- ✓ Profondità e risoluzione sono correlate alle frequenze trasmesse, all'energia trasmessa, alle proprietà elettromagnetiche dei materiali e dalle caratteristiche dei bersagli



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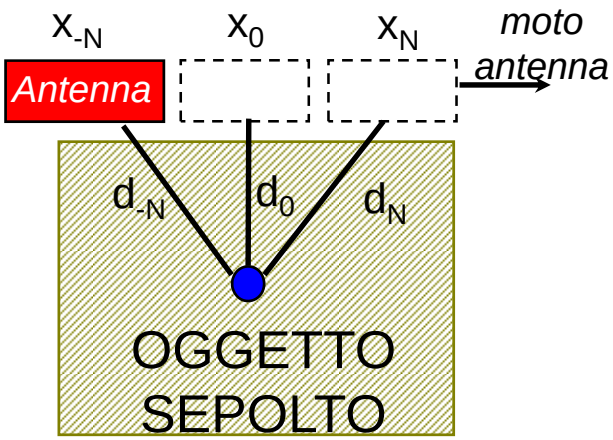
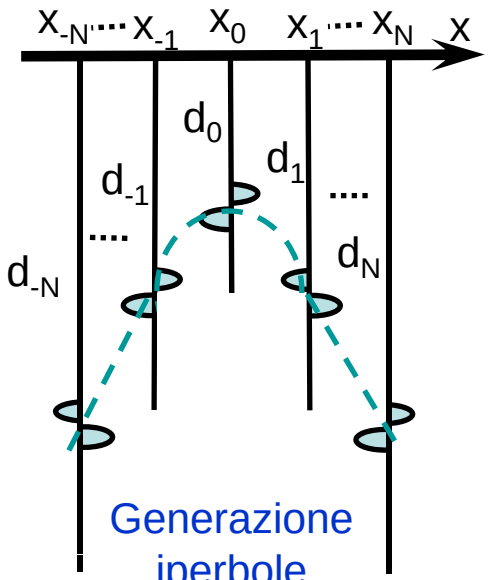
Generazione della mappa

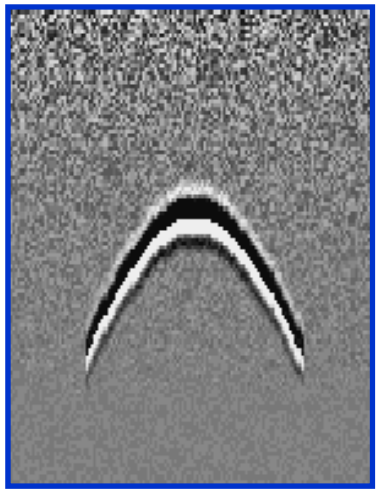
L'oggetto sepolto viene 'visto' dal georadar in modo deformato



Acquisizione



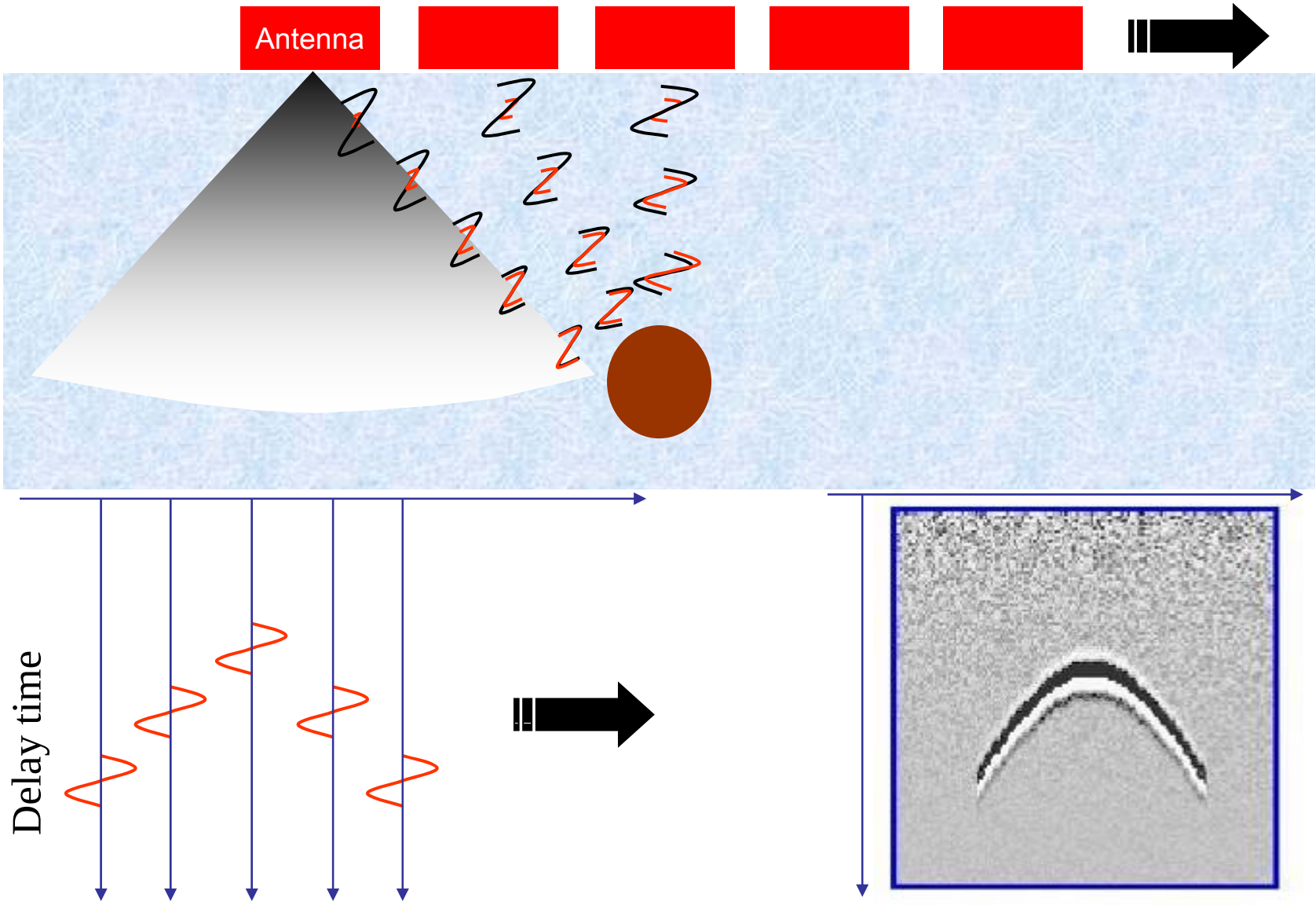
Generazione iperbole



Mappa radar

Il RADAR "vede" il bersaglio in un intorno della posizione di minima distanza

L'oggetto sepolto risulta visibile se:
- si trova nel fascio irradiazione antenna
- rapporto segnale /clutter > minimo valore sufficiente alla rivelazione



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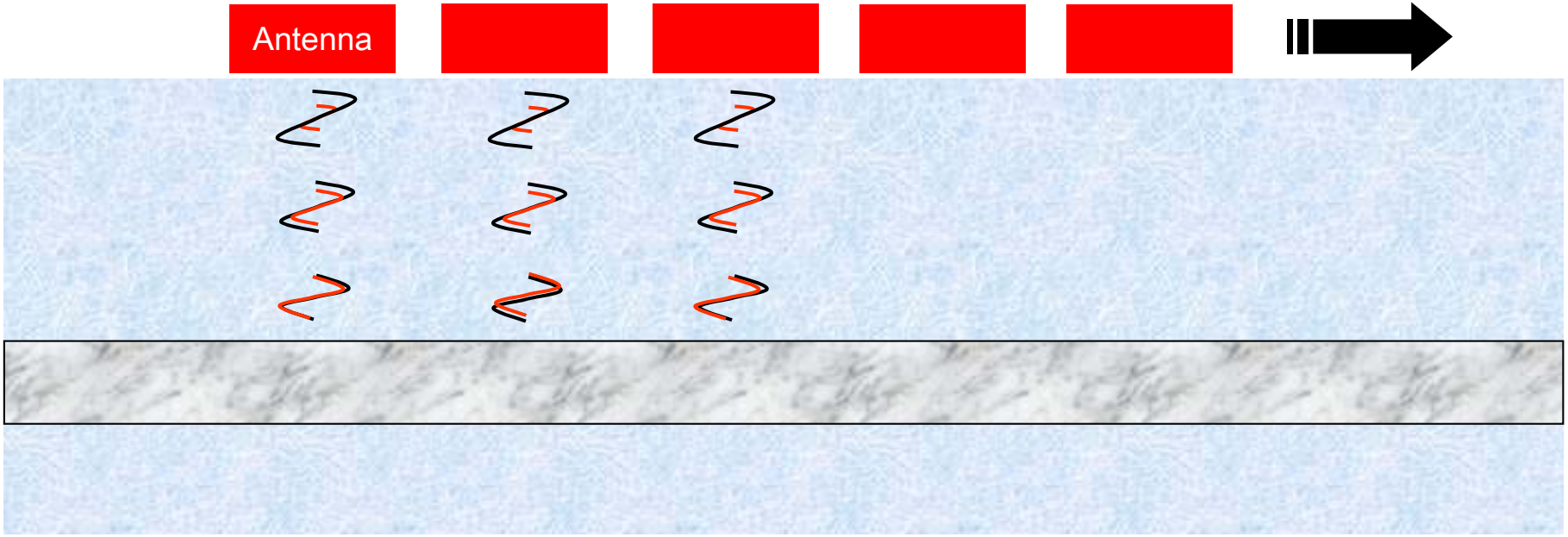

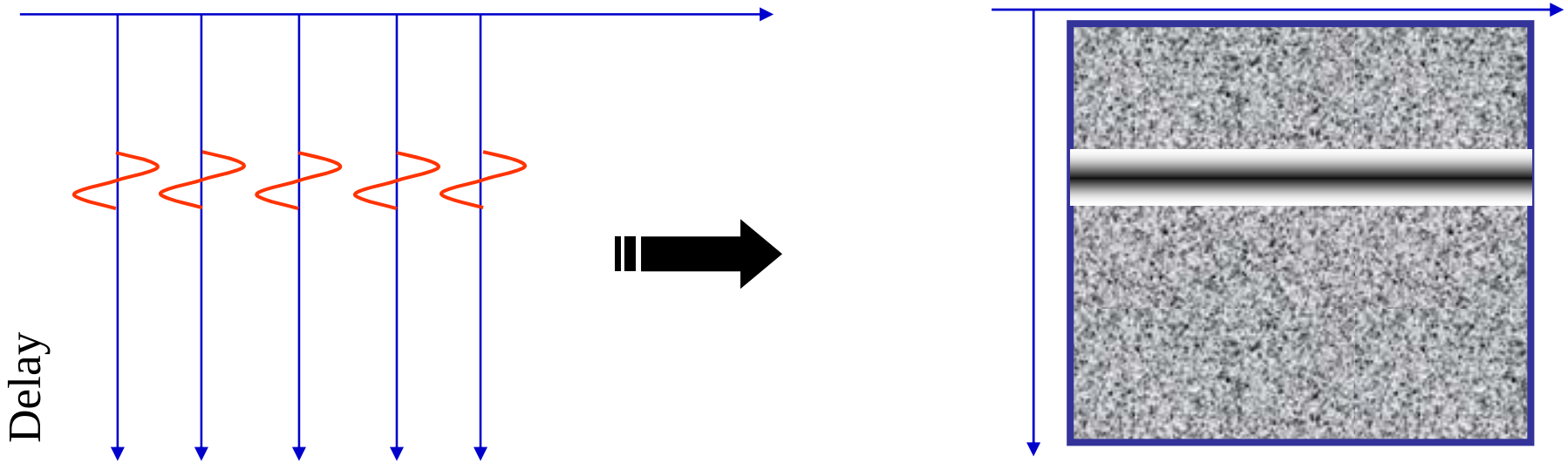

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Diverse antenne a diversa frequenze…

Le applicazioni

Utilities

Transportations

Civil and Structures

Geology and Environment

Archaeology and Cultural Heritage

Forensic and Security

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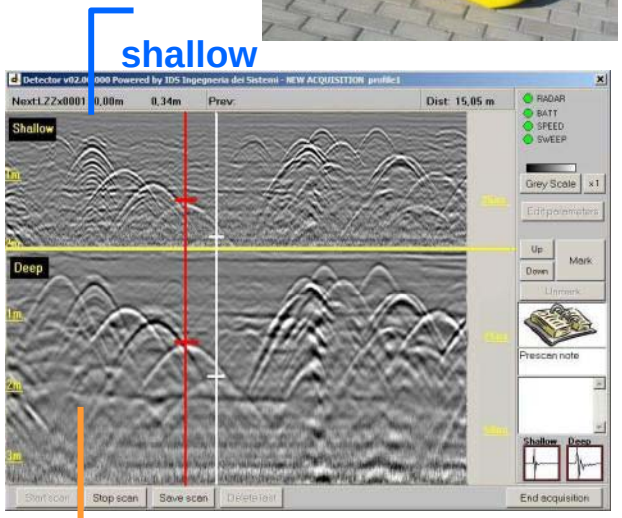
Utilities Detection and Mapping

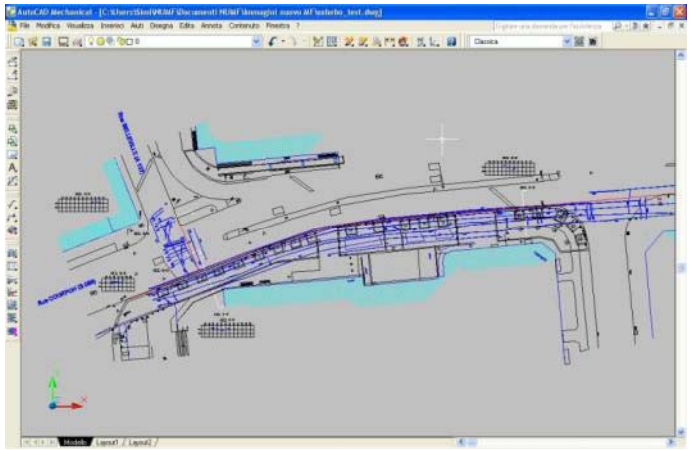
Detector Duo:

real-time detection of pipes

RIS MF Hi-Mod:

Utilities mapping on all zones





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Utilities Detection and Mapping

Stream: massive arrays for the fast mapping of utilities

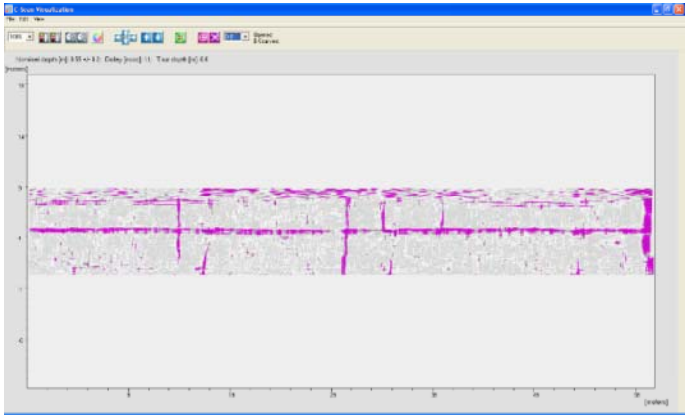
Stream EM:

Vehicle towed array for extensive road utility mapping

Stream MT:

Fast utility mapping for Mini-Trenching applications

Underground road mapping obtained by simple vehicle passages, up to 15 km/h



Mapping by single, longitudinal passage along the trench line

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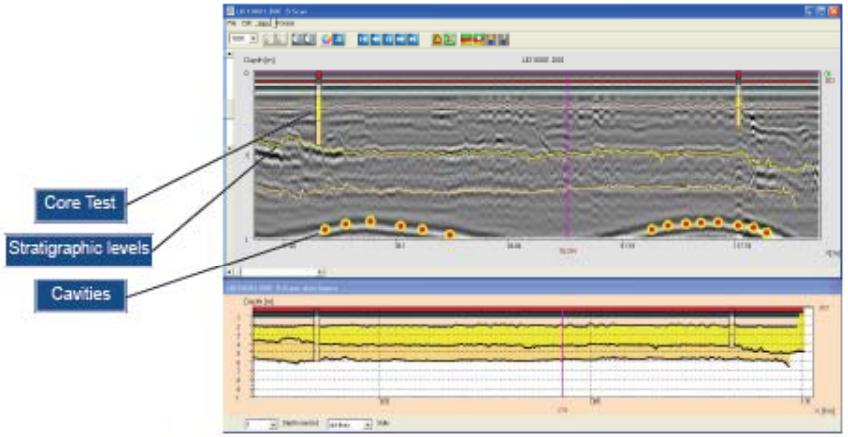
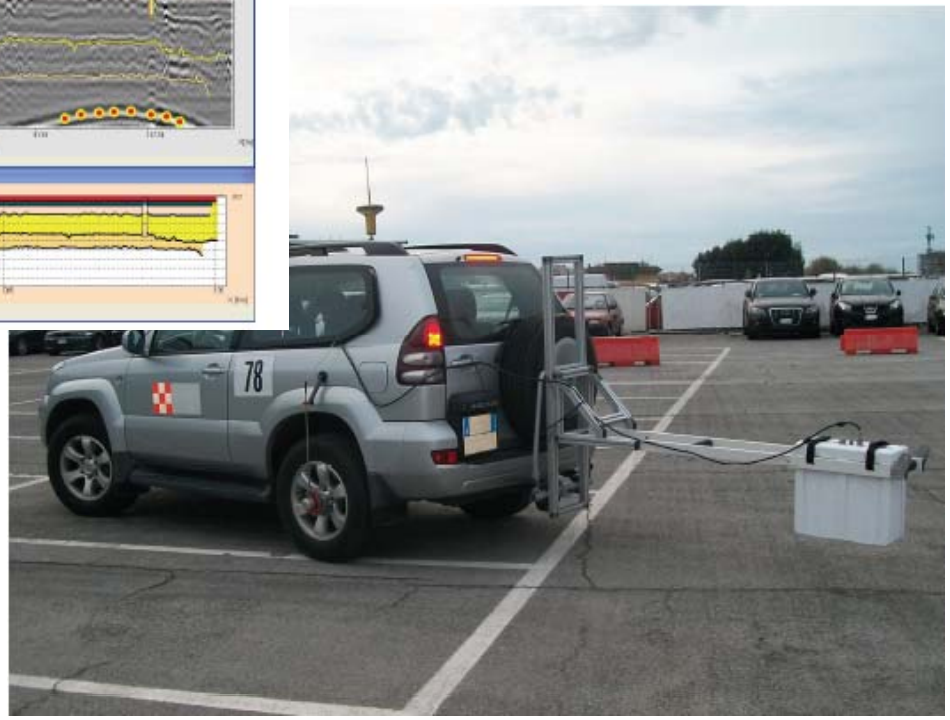
Road Engineering



Imaging of the different levels of the road, with cores and cavities



RIS Hi-Pave:

The fastest and most flexible solution for road assessment surveys

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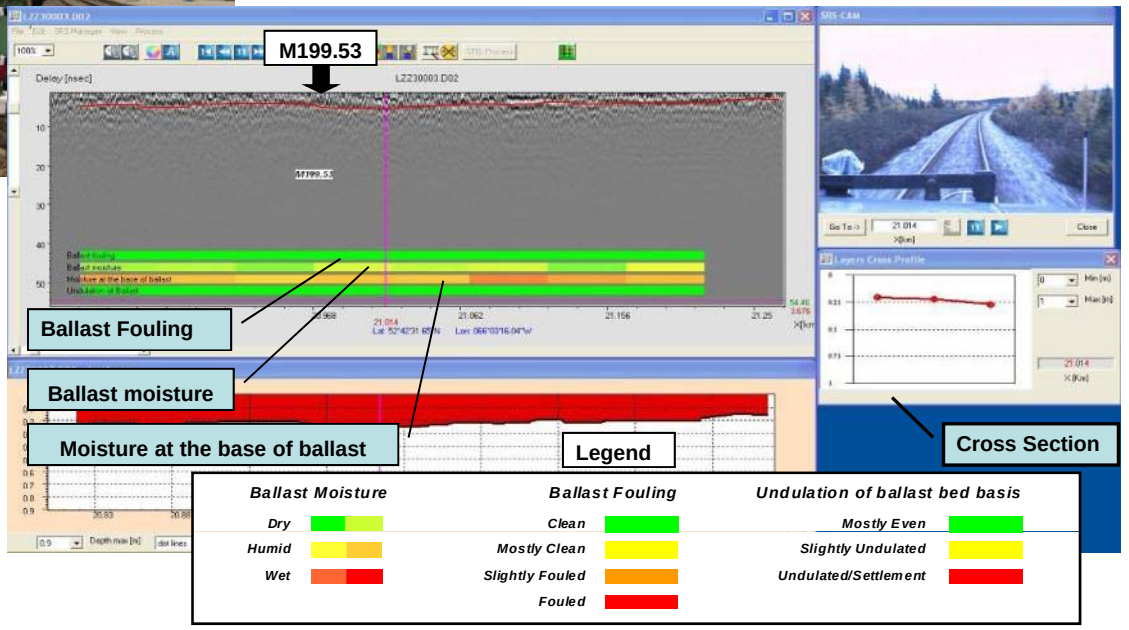
Railway Engineering

SafeRailSystem (SRS):

Continuous mapping of railway ballast status



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Civil and Structure Engineering

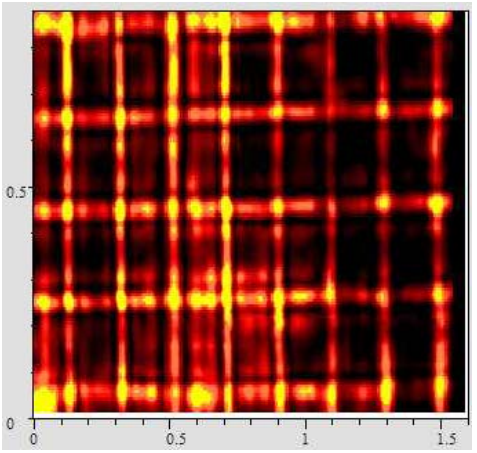
RIS Aladdin:

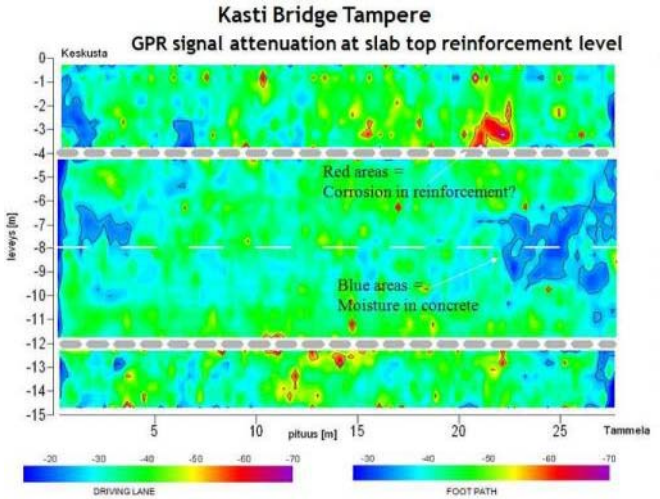
Analysis of the internal status of structures

RIS Hi-BrigHT:

Array for bridge deck survey

Imaging of concrete rebar and internal structures





Bridge deck maps for the evaluation of layer thicknesses, moisture and corrosion damages

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Civil and Structure Engineering:

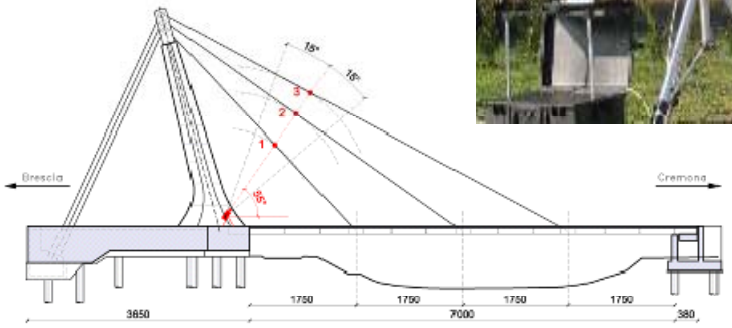
Interferometric Radar: IDS is currently the only one world manufacturer of radar technology for structural displacement applications

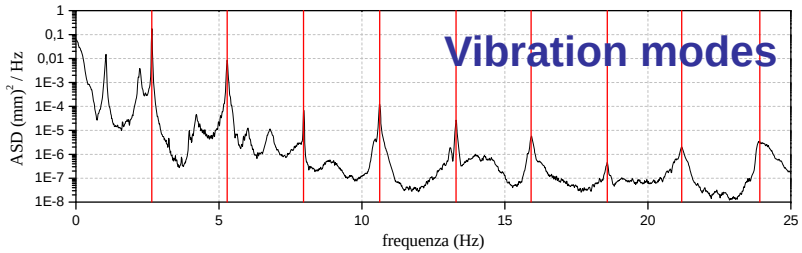
IBIS-S:

Dynamic and static monitoring of bridges and linear structures

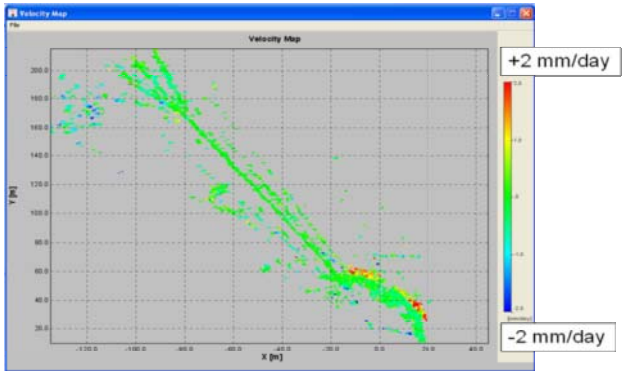
IBIS-L:

Static monitoring of large structures





Vibration modes



Dam displacements

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Geology and Environment

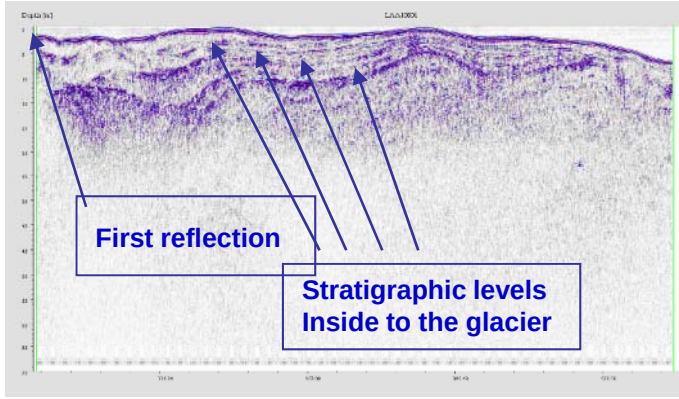
Stream-X:

Fast environment survey and clearance of large areas

RIS ONE-PLUS:

Flexible and complete solutions for geology

Tomographic maps showing archeological structures in large areas



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Geology and Environment

IBIS-M, a dedicated configuration to enter into the Mining Market

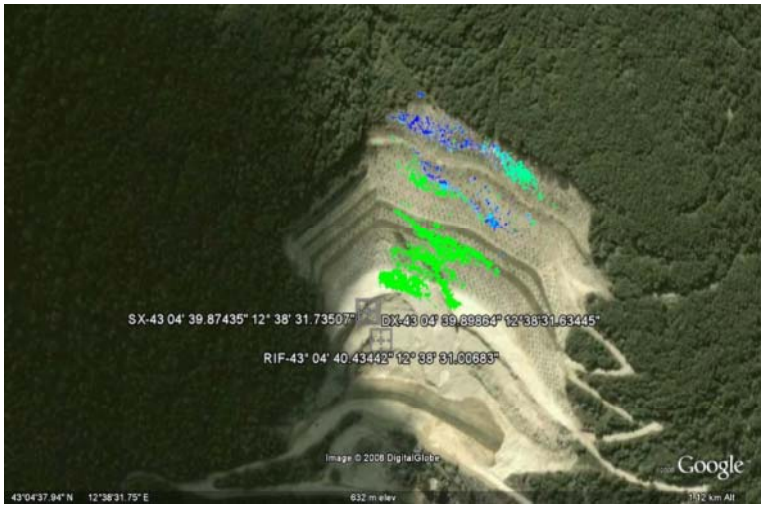
IBIS-L:

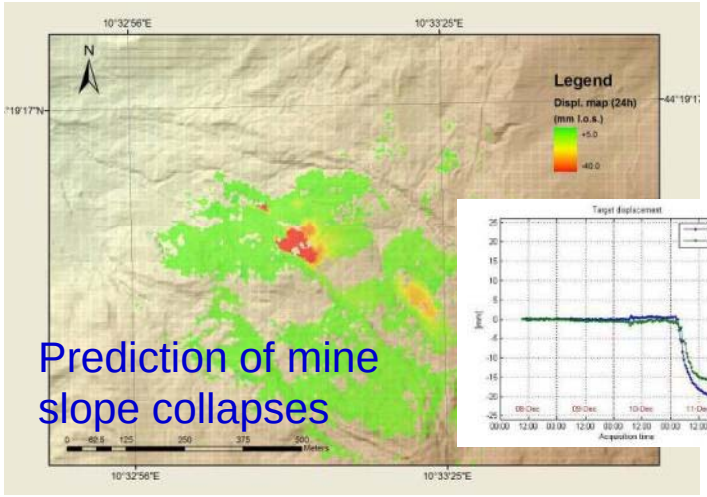
Monitoring of landslides

IBIS-M:

Early Warning for mine slope instabilities

Slope displacement map overimposed on a Google picture





Prediction of mine slope collapses

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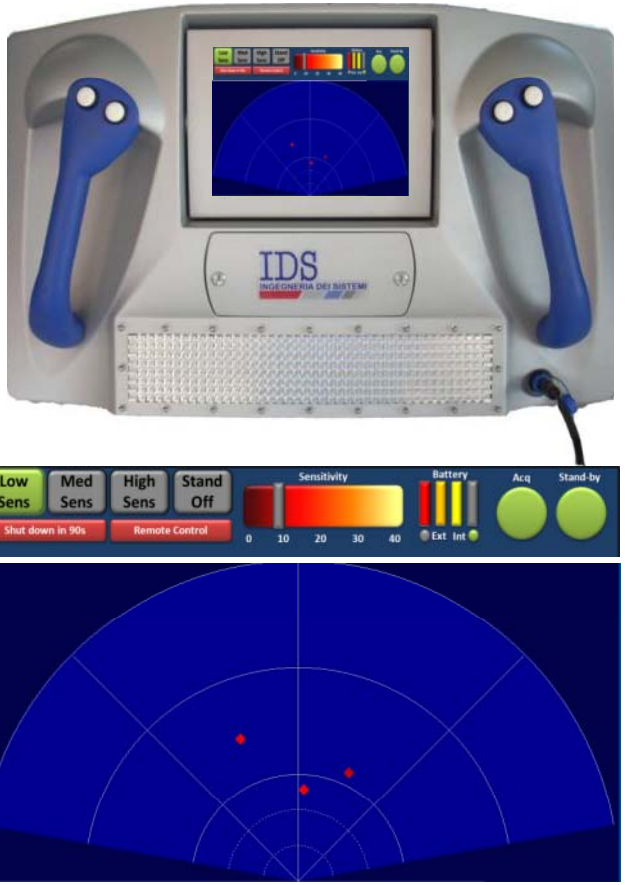
Forensic and Public Security

Sila system:

Location of cavities, tunnels, buried bodies



TWR

(Through Wall Radar);

(*under development*)

Location of people behind walls

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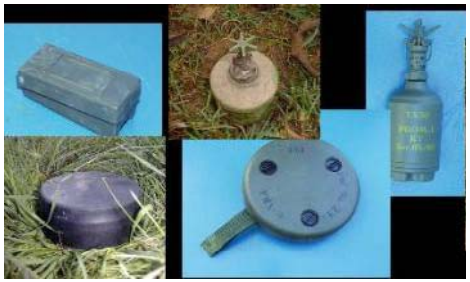
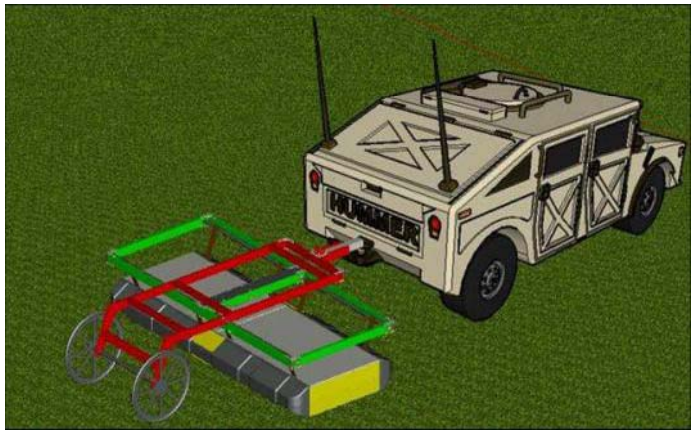
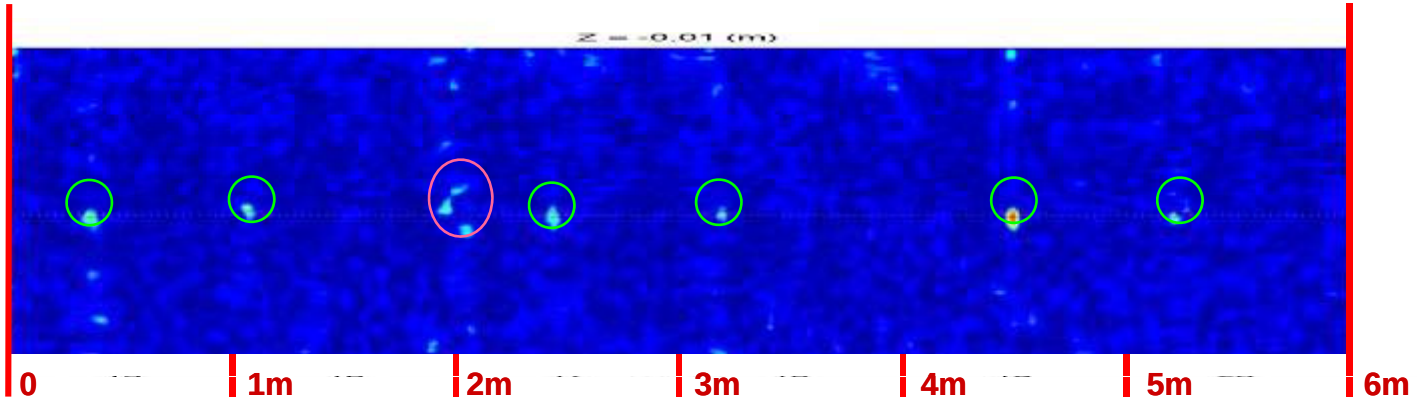


IED/UXO/mine detection



Configuration proposed for IED (Improvised Explosive Device), UXO (Unexploded Ordnance) and mine detection (under development)



Focalised GPR data at shallow depth

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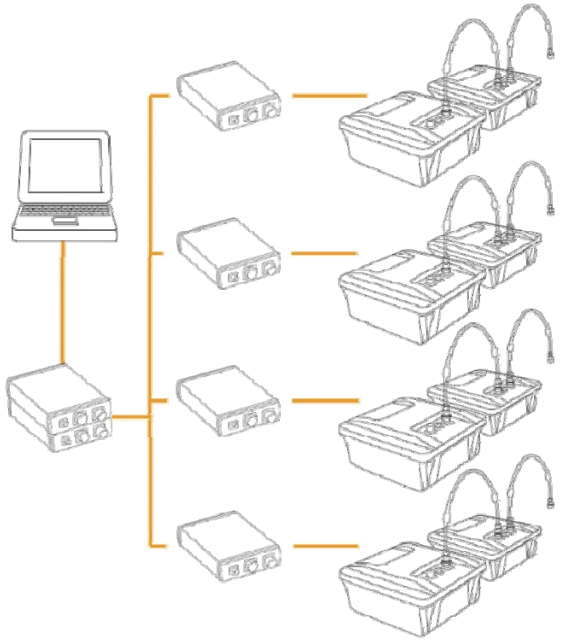
IDS Radar Control Unit

FAST WAVE

New DAD FastWave unique features:

- 6 times faster than the previous DAD K2
- The fastest control unit on the market:
  - 4760 scan/sec @128 samples
  - 2 channels acquired simultaneously
- Chain connection:
  - Antenna elements connected in “cascade”
- Multiple DAD can be synchronized in a “network of DAD’s”



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FOCUS

- Ponti
- Strade
- Strutture

DETECTING BRIDGE DECK DEFECTS WITH HIGH RESOLUTION GROUND PENETRATING RADAR

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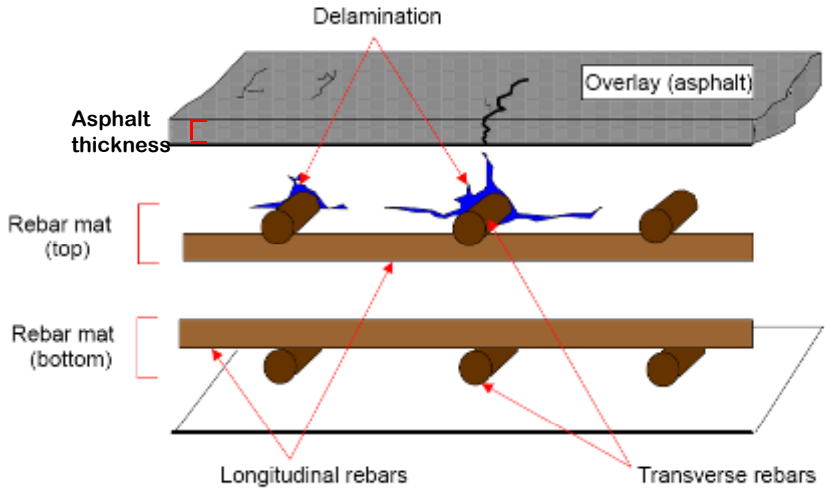
Bridges background

- **Factors causing damage to concrete bridge decks**
  - Traffic loading
  - Corrosion of reinforcement
  - Climate effects → Freeze thaw cycles
  - Initial damage resulting from poor design or construction
  - Inadequate maintenance practices

- **Difficulties to assess bridge deck deterioration**
  - Asphalt overlay
  - Deterioration occur below the surface
  - NDT methods required



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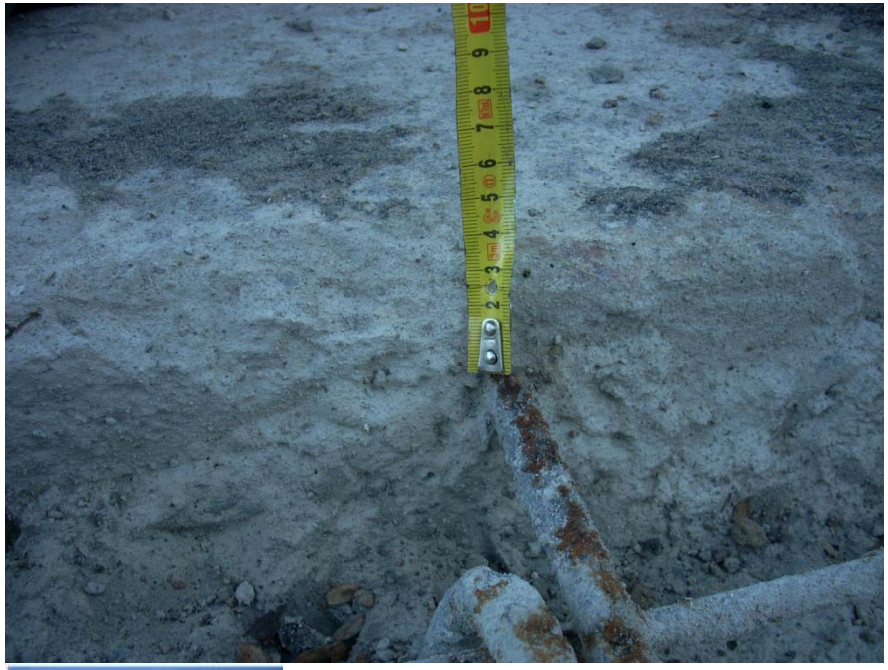
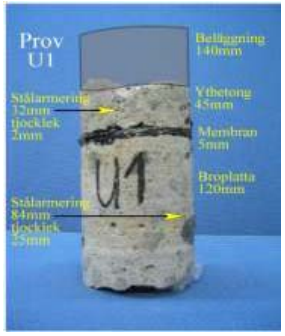
Traditional methods for bridge deck survey





Visual Inspection:
- prone to errors
- comes too late for preventing damages
- subjective

Core samples:
- discontinuous
- destructive
- expensive

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GPR Survey For Bridge Deck Assessment

GPR methods have many advantages in preventive maintenance:

- continuous mapping of bridge conditions
- non-destructive
- permits to detect hidden defects in their early stage
- permits to localize maintenance interventions
- The higher costs of GPR survey w.r.t. visual inspection are greatly compensated by savings in maintenance and repair

but…

Available GPR instruments are:

- too slow in the collection phase
- not specialized; not easy to use and difficult in data interpretation

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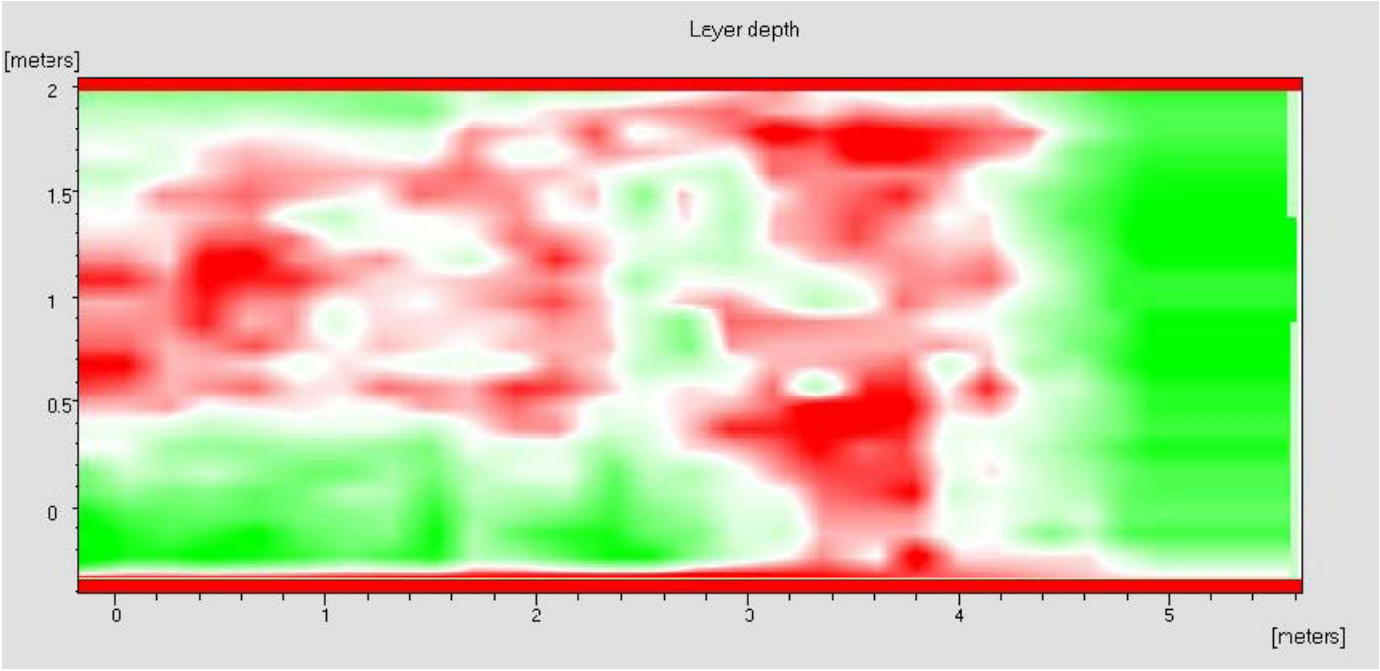
Bridge Deck survey: expected output

- Asphalt and concrete slab thickness measure
- Drainage and other buried pipes mapping
- Rebars depth measure
- Areas with defects (moisture and delamination)



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RIS HiBrighT system requirements

- Very dense data collection
- Double polarization
- High resolution of defects
- Quick data acquisition
- Lightweight and compact design
- High maneuverability and easiness to use

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System main features

- High frequency antenna: 2 GHz
- Large number of channels: 16 channels array
- Dense channels spacing: 10 cm
- Double polarization
- High acquisition speed: > 6km/h
- Light and compact trolley

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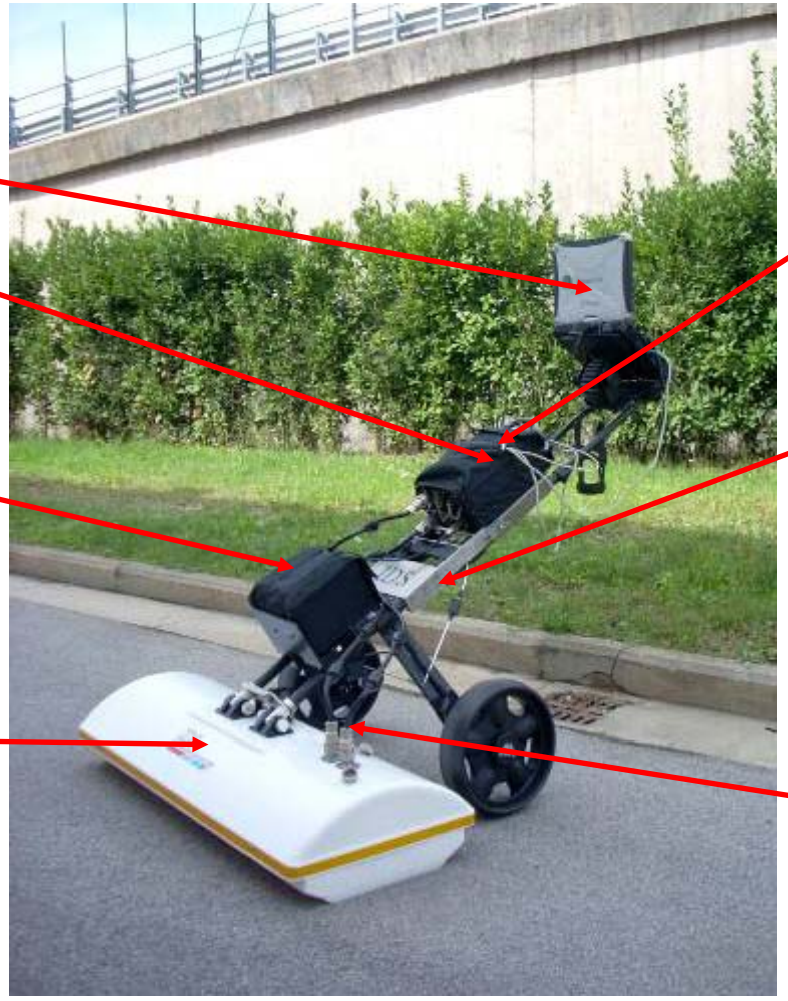
System composition



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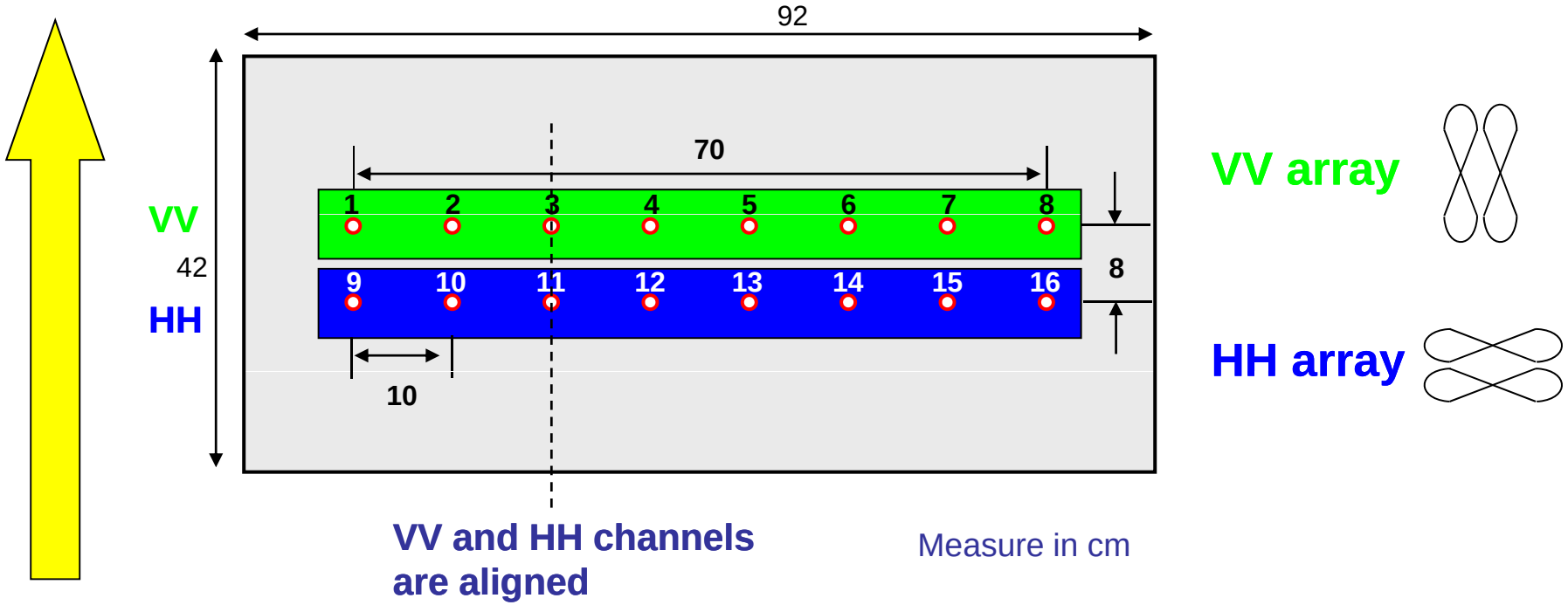
Antenna array: layout

- Total channels: 16
- Channels spacing: 10 cm
- Alignment of different polarized channels
- Aligned channels offset: 8 cm
- Swept width: 70 cm



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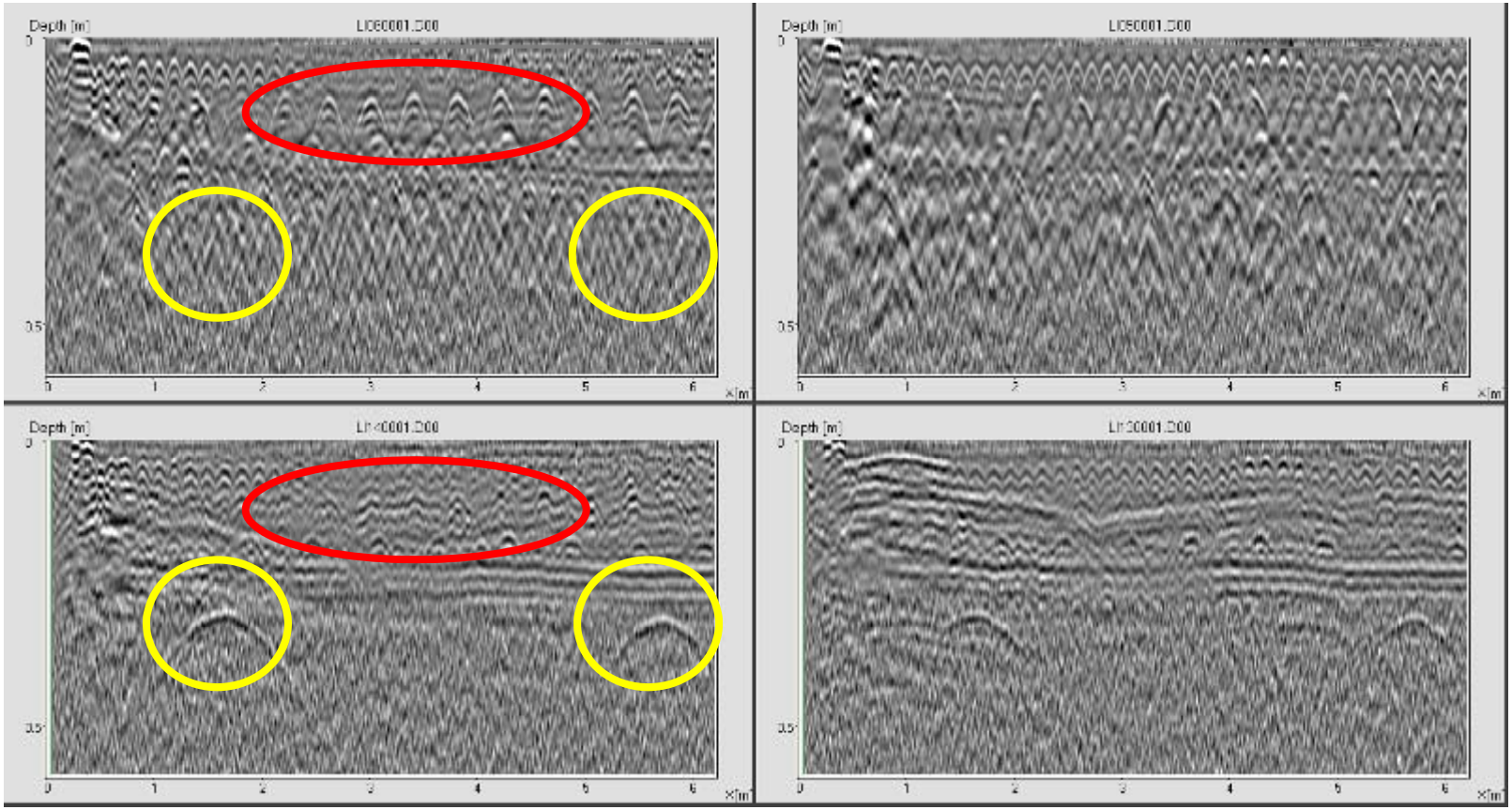
Benefit from double polarization

- Hyperbolas produced by shallower rebars can be detected in HH data only
- Hyperbolas produced by deeper objects/rebars can be detected in VV data only

HH channels

VV channels



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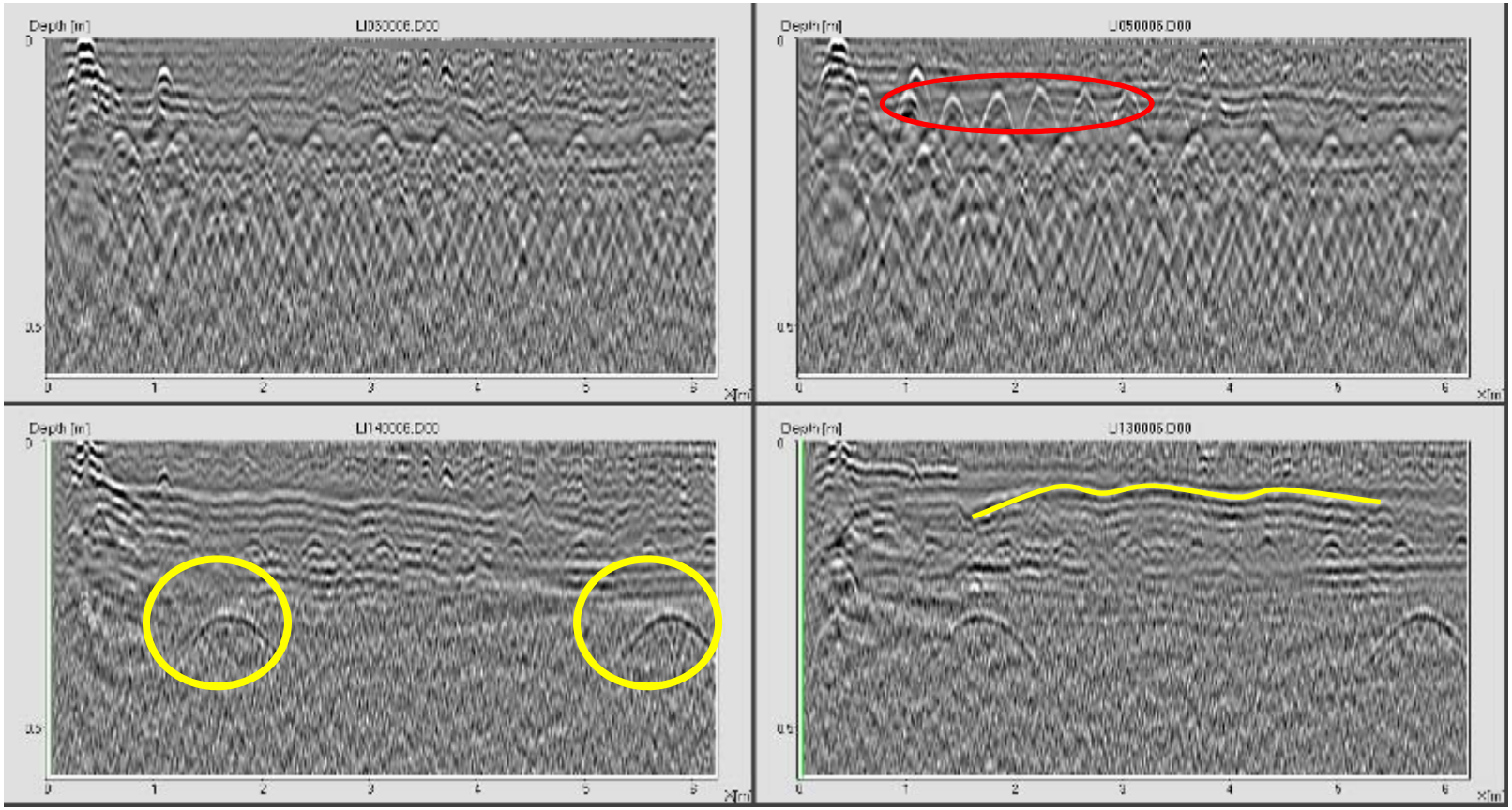
Benefit from double polarization

- VV data show a better resolution of layers (no interference from shallower hyperbolas)

HH channels

VV channels



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Data collection with the Hi-BrighT

- Usually just longitudinal profiles are executed

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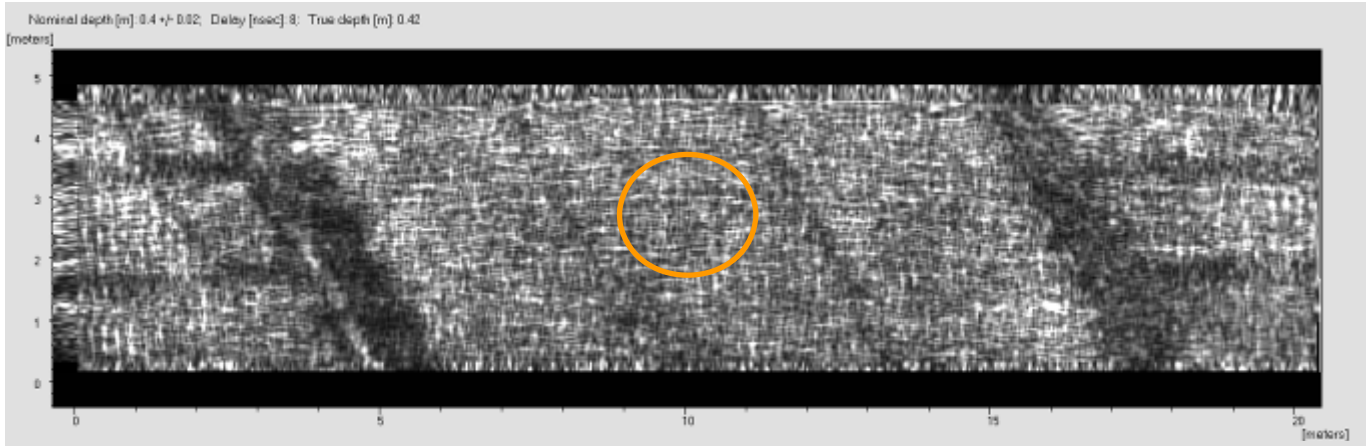
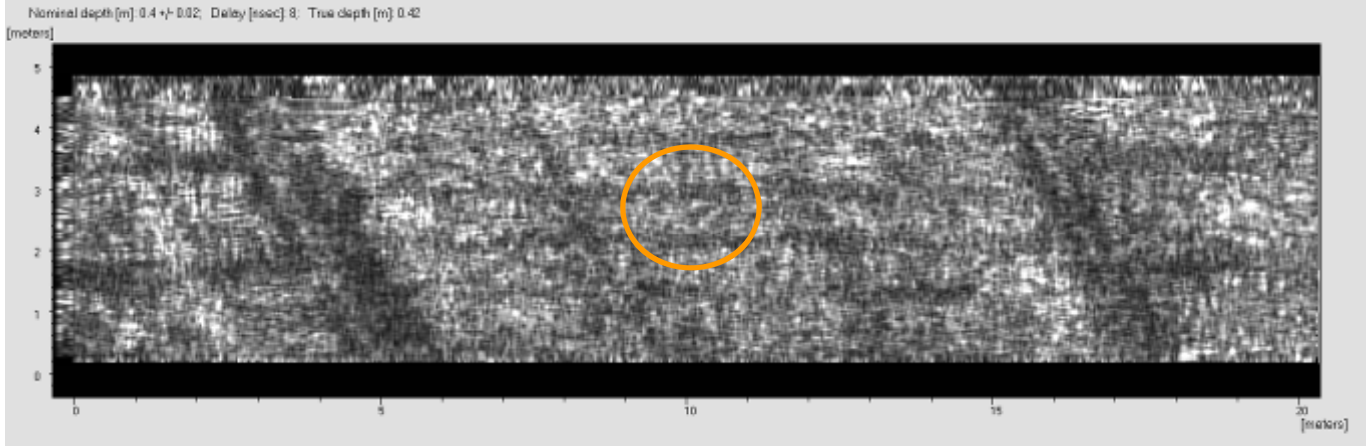
Standard output: Time Slice View

- The area marked in orange shows some possible moisture retention

L+T: HH Polarization



L+T: VV Polarization



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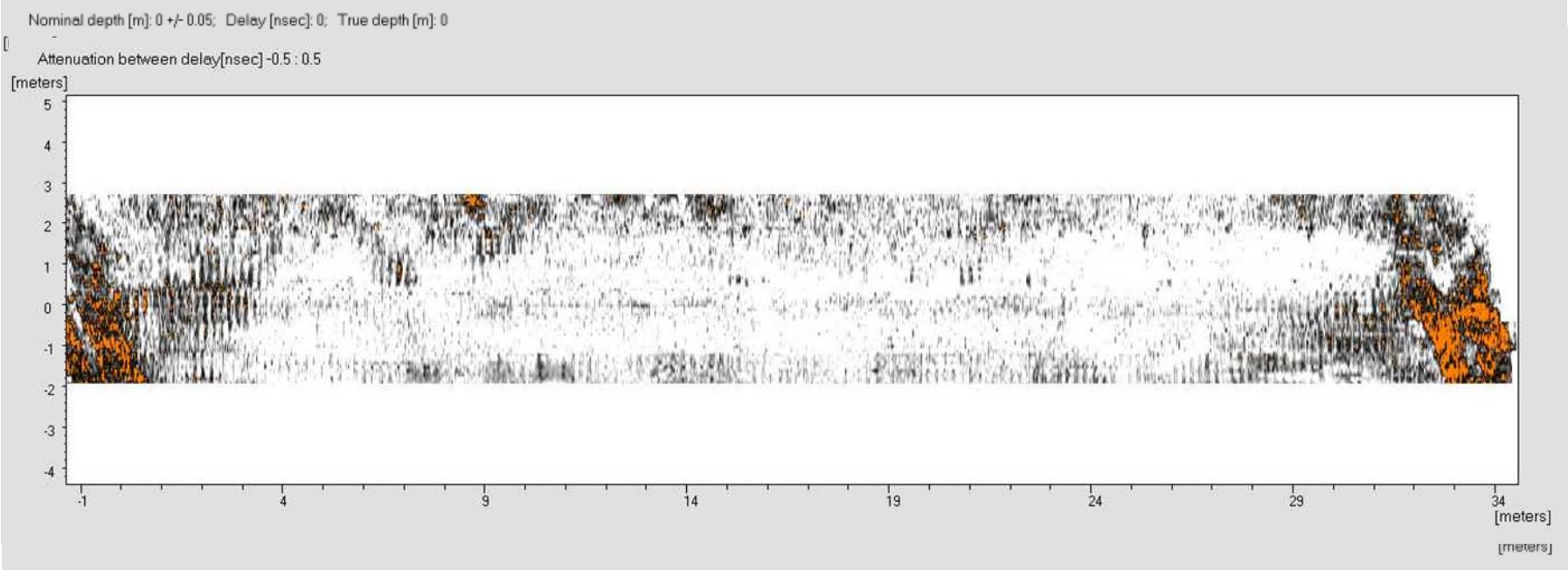
Advanced output

Le zone rosse indicano zone anomale che sono indice di zone affette da difettosità.

- By using dedicated algorithms, the software can produce further output, as
  - The map showing the areas where the the thickness of the protecting concrete is below the nominal value (red areas)
  - The map showing the areas where a poor reflection from rebars is present (that is correlated to the corrosion) (red areas)
  - The map showing the possible presence of moisture (orange areas)



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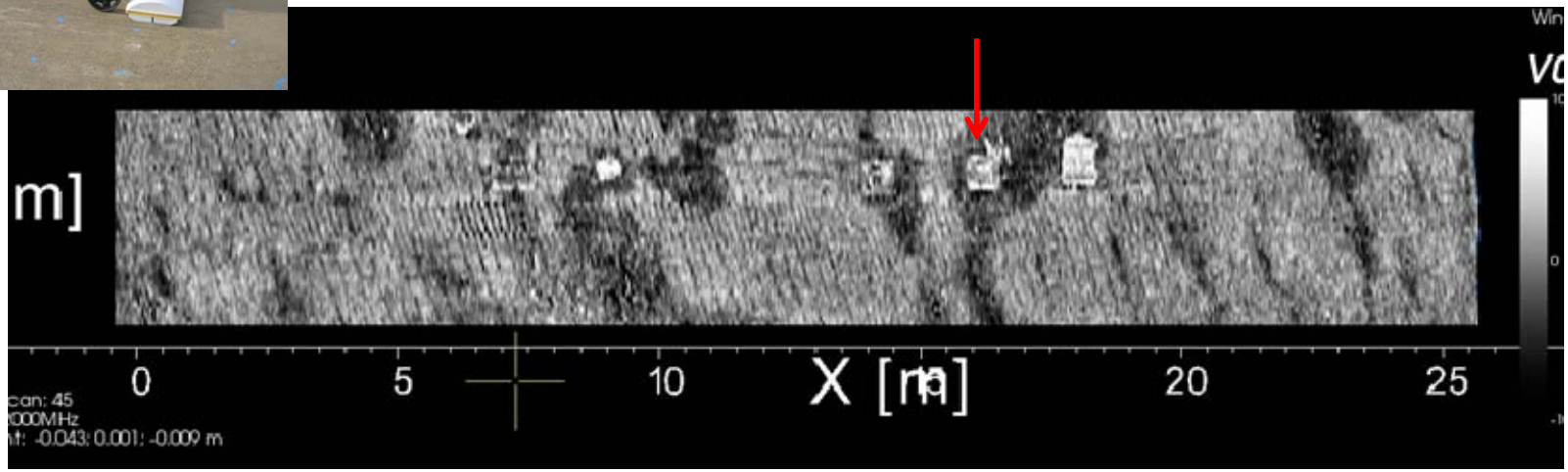
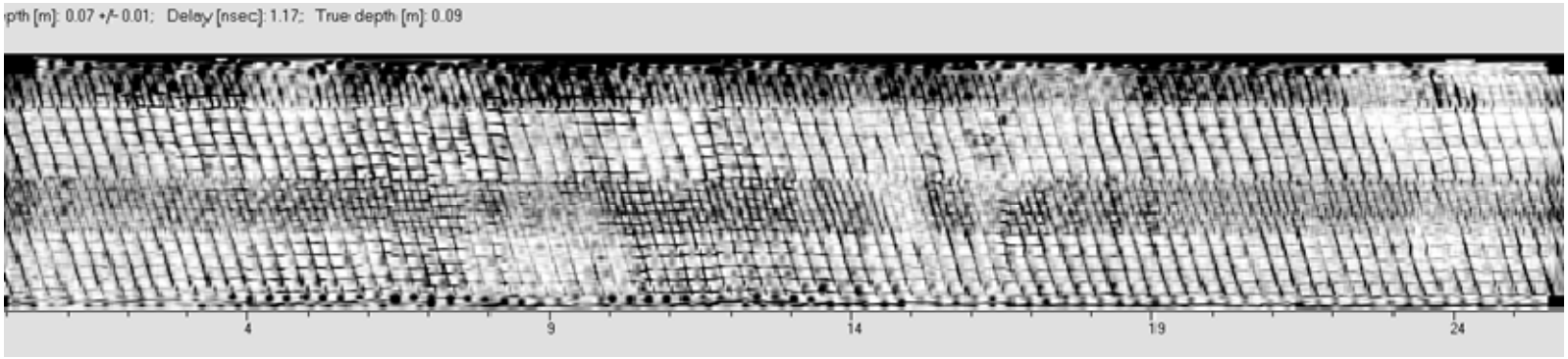
Case histories:

I-66 Interstate Highway, Virginia -USA





On top patches below asphalt (not visible at the surface) and rebars mesh (picture below)

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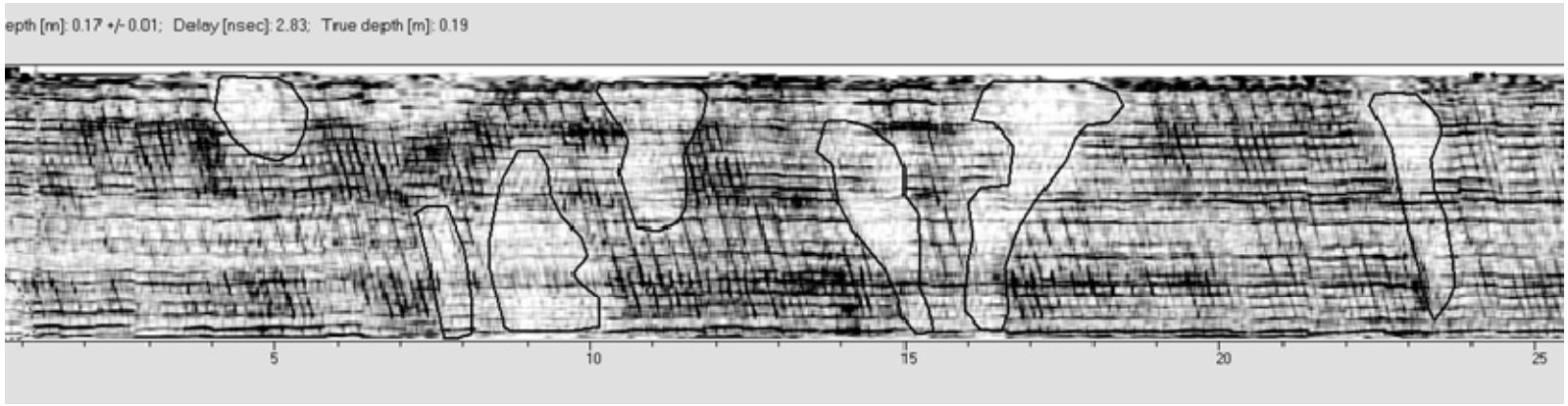
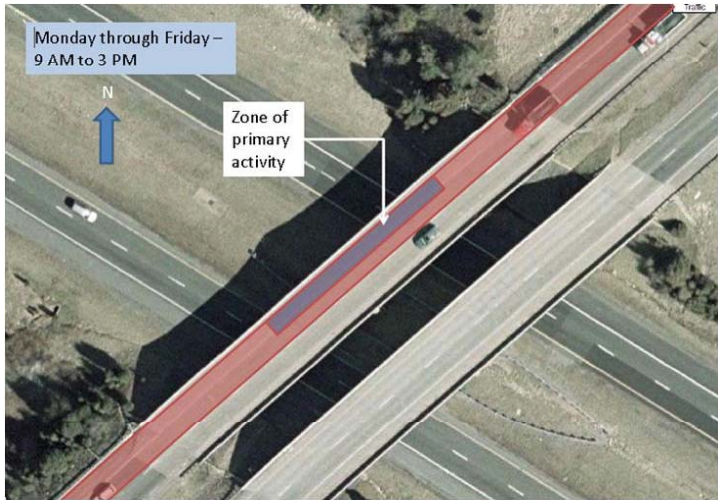
Case histories:

I-66 Interstate Highway, Virginia -USA





Position of defective areas (corrosion) was confirmed by results from impact echo survey

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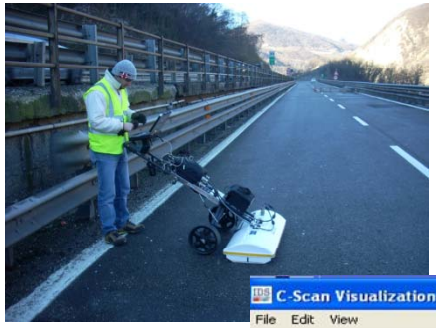
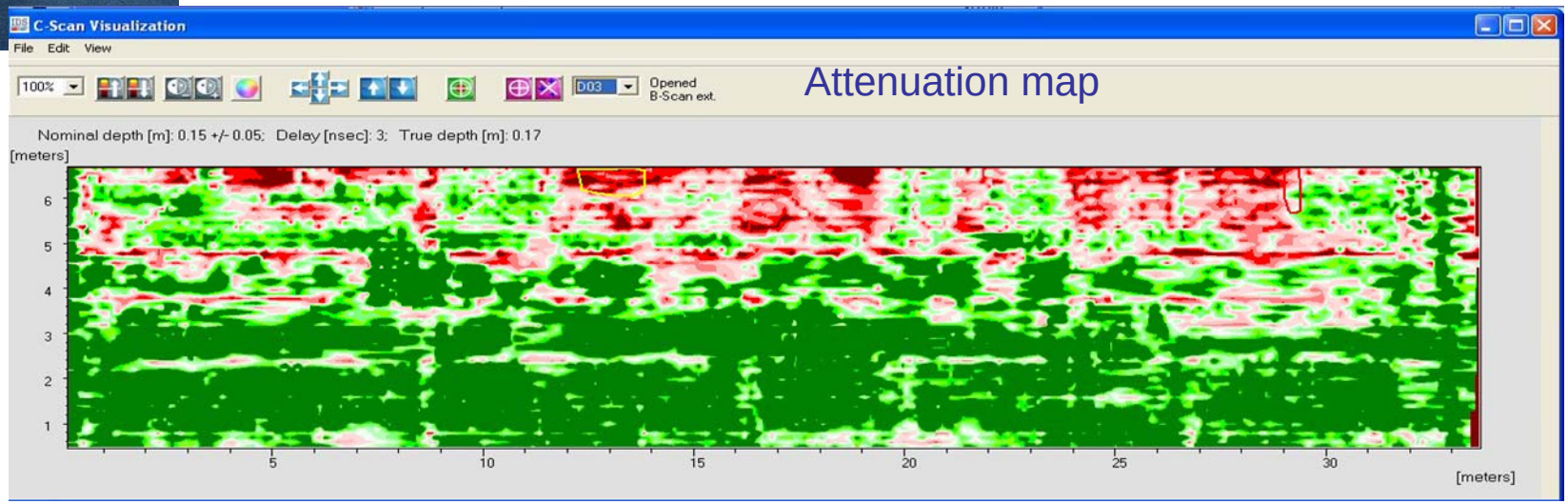


Case histories: Italy



Attenuation map

Areas marked in red are most likely affected by corrosion; it has been confirmed by executing some inspection trenches

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Applicazioni stradali

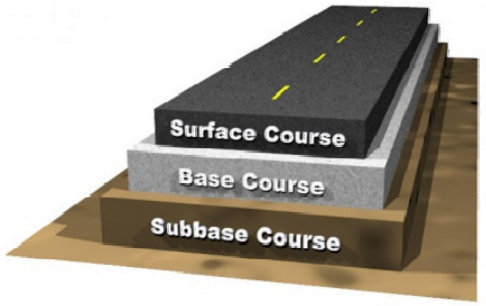
RIS Hi-Pave

The "*faster*" and most flexible solution for

Road Assessment Survey

All rights reserved to IDS

RIS Hi-Pave: application



High speed multichannel radar system for Road Assessment Survey:

- **Measure pavement thickness**
- **Assess surface, base and subbase road course**
- **Detection of cavities voids and delamination**
- **Location of cracks**
- **Detection of wet area**
- **Airport runaway condition assessment**

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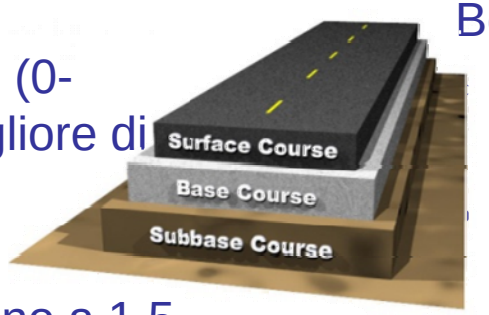
RIS Hi-Pave

Applicazioni

- Rileva gli strati superficiali (0-50cm) con risoluzione migliore di 4 cm ed accuratezza sub centimetrica
- Rileva gli strati profondi (fino a 1.5 – 2 metri) con accuratezza e risoluzione superiore a 15 cm
- Rileva la presenza di cavità, ferri di armatura e umidità
- Localizza la presenza dei tubi con elevata precisione



Benefits

- Acquisizione veloce dei dati (oltre 125 Km/h) radar
- Facile interpretazione dello spessore mediante un software specializzato con tracking semiautomatico dei layer
- Migliora l'efficienza nella pianificazione della riabilitazione della pista
- Riduce i costi per la manutenzione
- Supporta gli strumenti HWD per la misurazione del modulo di elasticità.

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Architettura del sistema RIS Hi-Pave

Unità di controllo radar (DAD MCh Fastwave)

PC (Data Logger)

GPS antenna + Video Camera (option)

Ruota metrica di posizione

Horn antenna 1000 o 2000MHz

Kit meccanico di installazione dell'antenna

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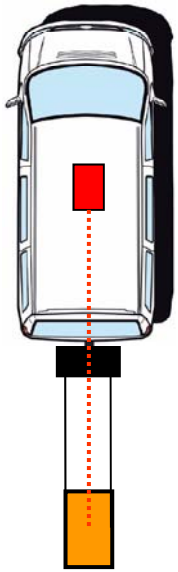
GeoRadar

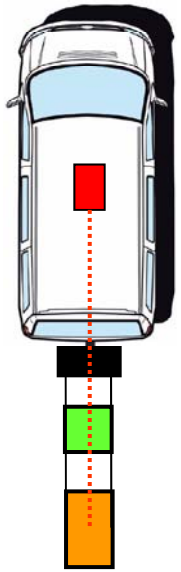
RIS Hi-Pave: possible configurations



RIS Hi-Pave HR1

The single-antenna, entry-level configuration for road and runaway pavement evaluation:
- 1 DAD FastWave control unit

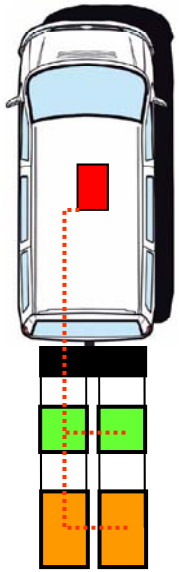
- 1 HR2000 antenna (2 GHz horn) for road survey
or
1 HR1000 antenna (1 GHz horn) for runaway survey



RIS Hi-Pave HT2

The double-antenna configuration for complete road and runaway evaluation (pavement, grade, subgrade):
- 1 DAD FastWave control unit

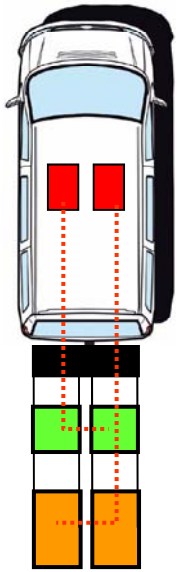
-1 HR2000 antenna (2 GHz horn) for road pavement survey
or
- 1 HR1000 antenna (1 GHz horn) for runaway survey
-1 TR600 antenna (600 MHz) for grade and subgrade evaluations



RIS Hi-Pave HT4

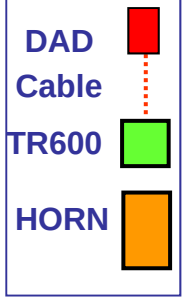
The four-antenna configuration for complete and wide road and runaway evaluation:
- 1 DAD FastWave control unit

-2 HR2000 antennas (2 GHz horn) for road survey
- 2 HR1000 antenna (1 GHz horn) for runaway survey
-2 TR600 antennas (600 MHz) for grade and subgrade evaluations



RIS Hi-Pave HT4 HS
or
RIS Hi-Pave HT2 HS

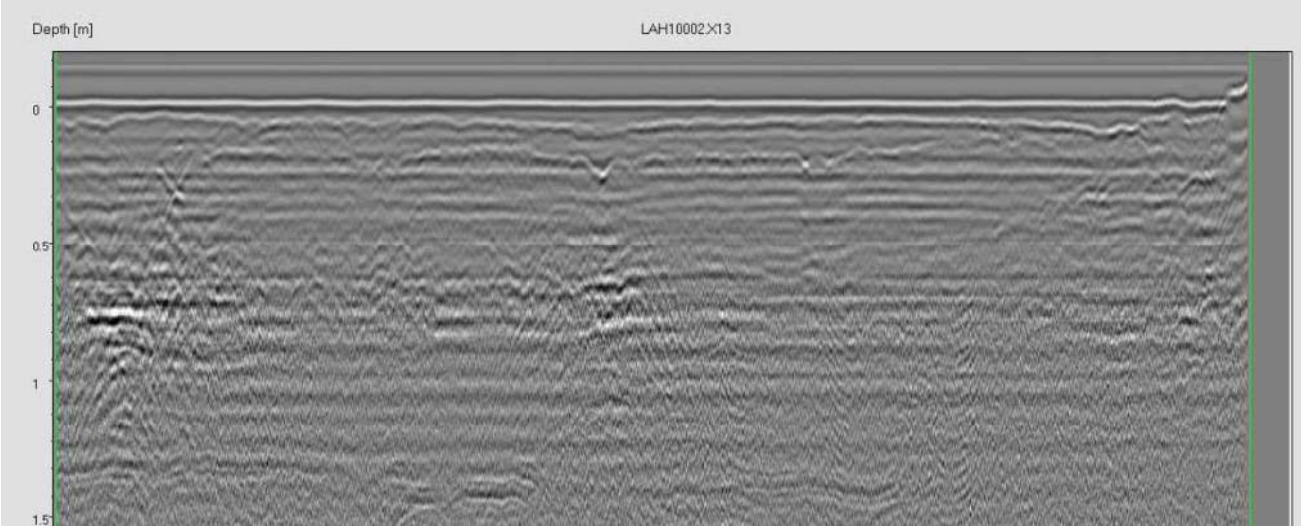
The same as the HT4 or HT2 configuration but with 2 synchronised DAD control units for maximum speed (over 200 Km/h) or very dense sampling (5 cm. at 125 km/h)



RIS Hi-Pave: le antenne

Antenne Horn : acquisiscono non a contatto

- **TR 1000 (1000 MHz)**
- **TR2000 (2000 MHz)**



Radar map with 1000 MHz Horn antenna.

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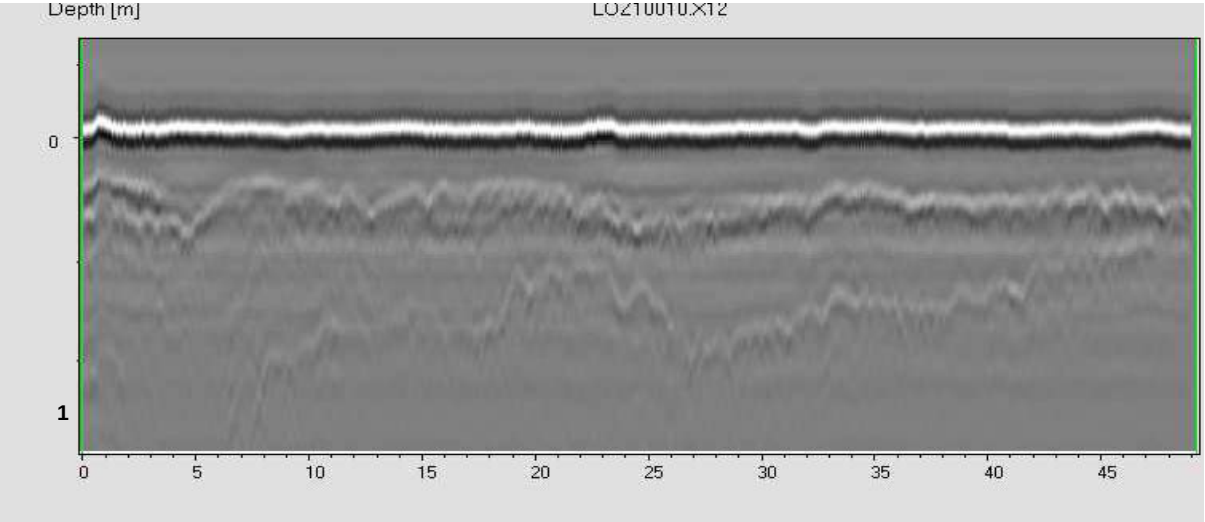
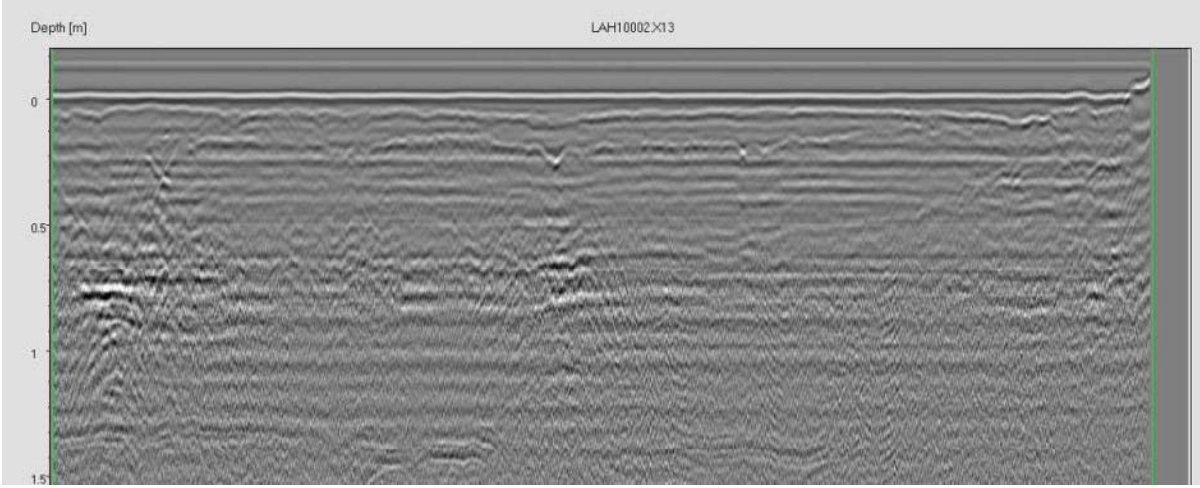
Antenne Horn : esempio mappe radar



Radar map with 2000 MHz Horn antenna.



Radar map with 1000 MHz Horn antenna.

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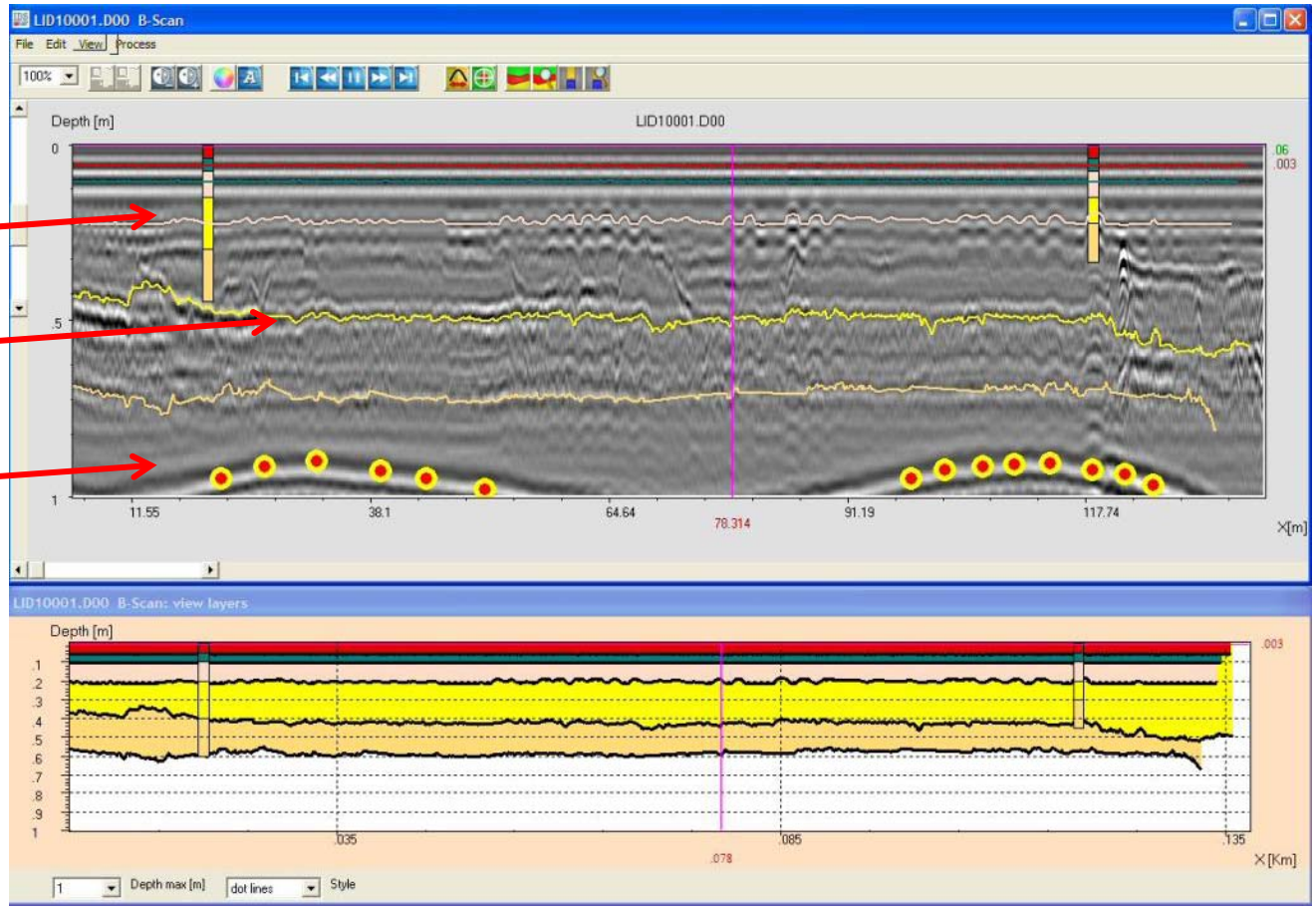
RIS Hi-Pave: esempio di risultato

Core test

Stratigraphic levels

Cavities



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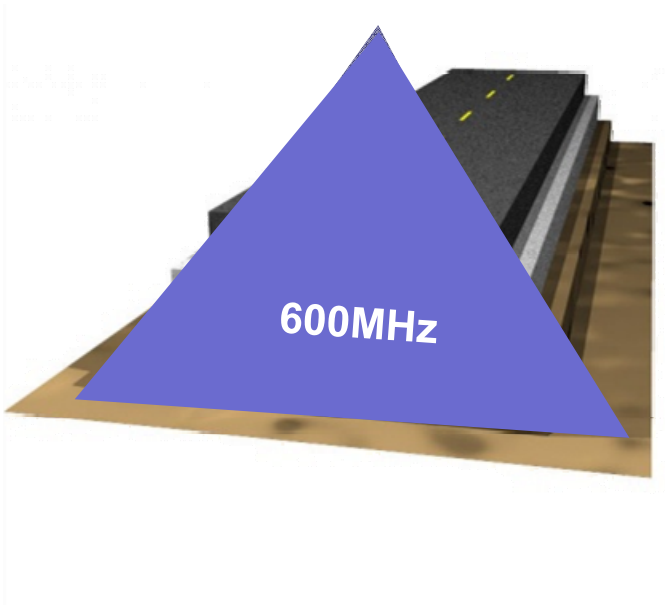
Caratteristiche del sistema RIS Hi-Pave

- RIS Hi-Pave può acquisire simultaneamente a 4 antenne con una velocità di 125 Km/h (10 cm di campionamento)
- Acquisizione contemporanea di dati multifrequenza per una analisi completa degli strati più superficiali e profondi..



System	**Collection Speed (Km/h)** ***(@10 scan/meter, 512 samples)***
RIS Hi-Pave with 2 antennas	125 km/h
RIS Hi-Pave with: 4 antennas (configuration with 1 Control Unit)	125 km/h (interlaced channels)

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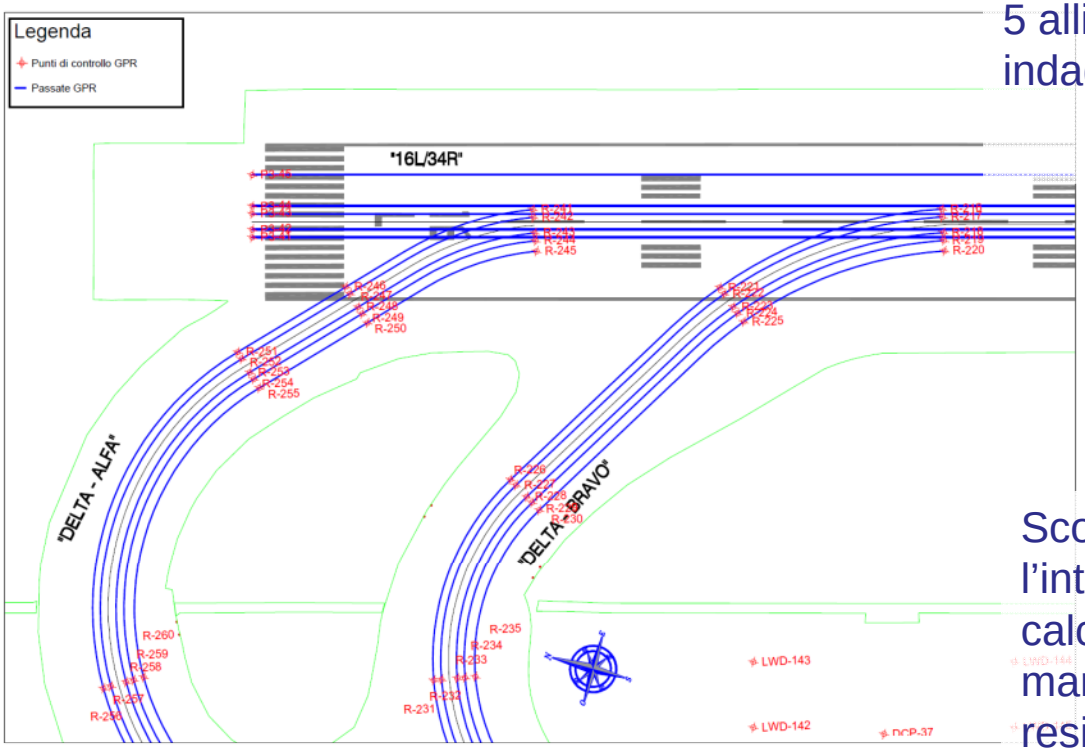
Case study

Campagna di indagini GPR delle sovrastrutture nell'intero sedime aeroportuale pavimentato dell'aeroporto "Leonardo Da Vinci di Fiumicino, per conto di ADR S.p.A. .



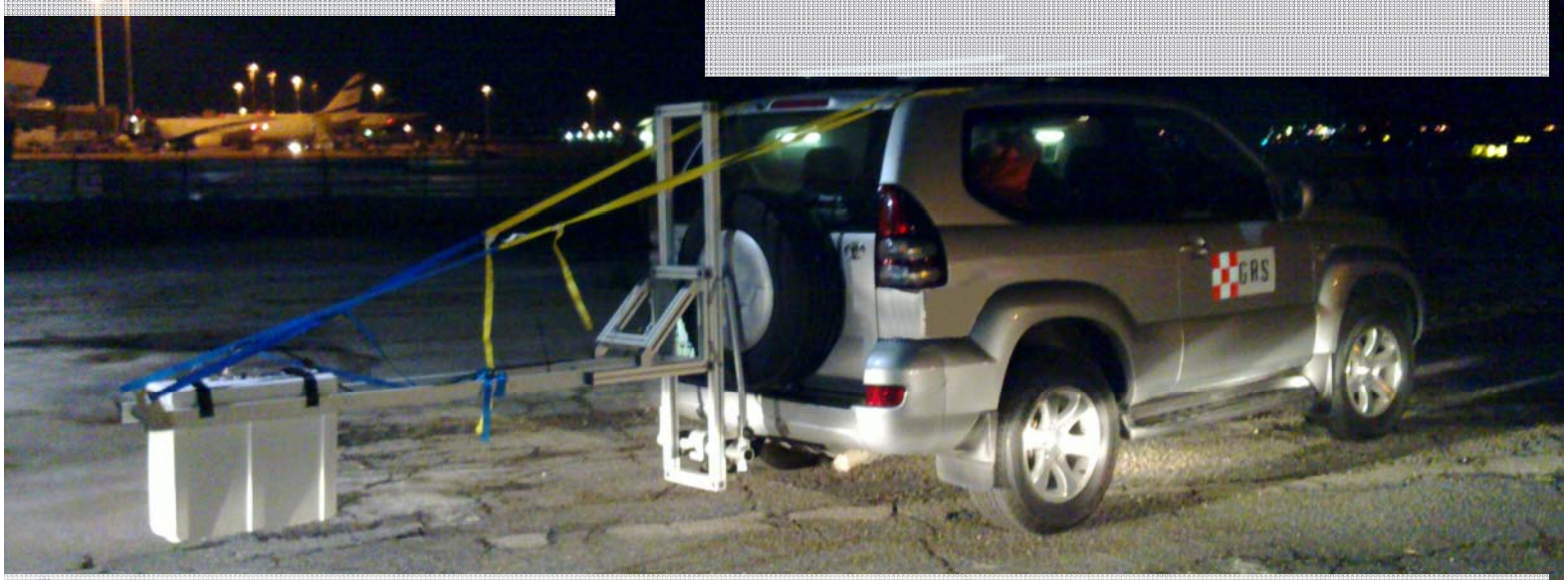
Le indagini sono state eseguite lungo 5 allineamenti in modo da non indagare la sola fascia portante.

Scopo delle indagini era verificare l'integrità della sovrastruttura e calcolare lo spessore degli strati, in maniera da conoscerne la vita residua.

Realizzazione

Per l'esecuzione delle indagini è stato utilizzato il sistema RIS Hi-Pave interfacciato ad un GPS Topcon GR3 .

Tale sistema utilizza un antenna Air Launched con frequenza di 1000MHz e permette una rapidità di acquisizione compatibile con le velocità di un veicolo.

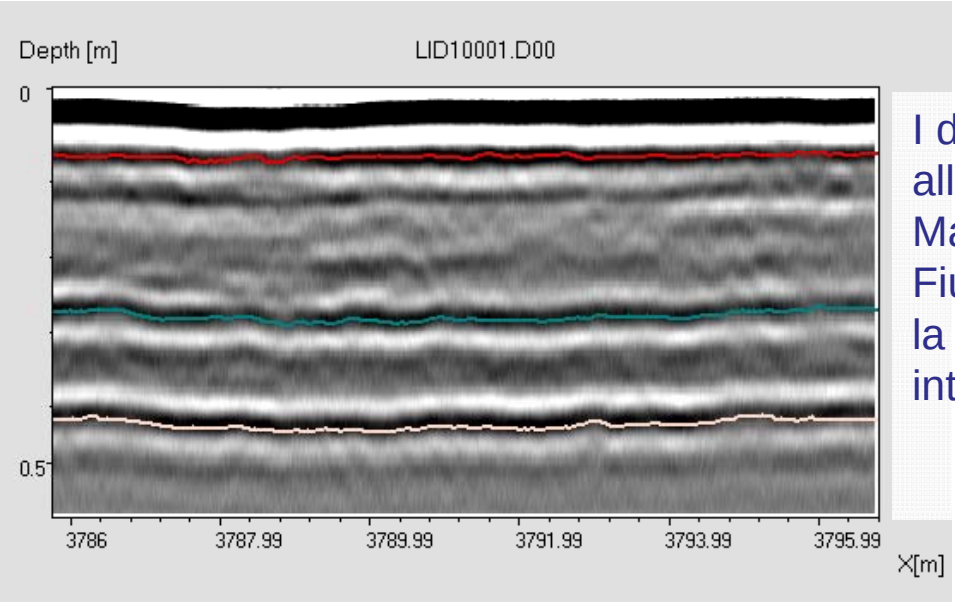


Nei tempi stabiliti, nonostante le penalizzazioni ed i limiti derivanti dall'esecuzione di rilievi durante orari notturni e in zone sensibili, è stato possibile completare l'intera campagna di rilievo, per uno sviluppo totale di oltre 2000 Km.

Risultati

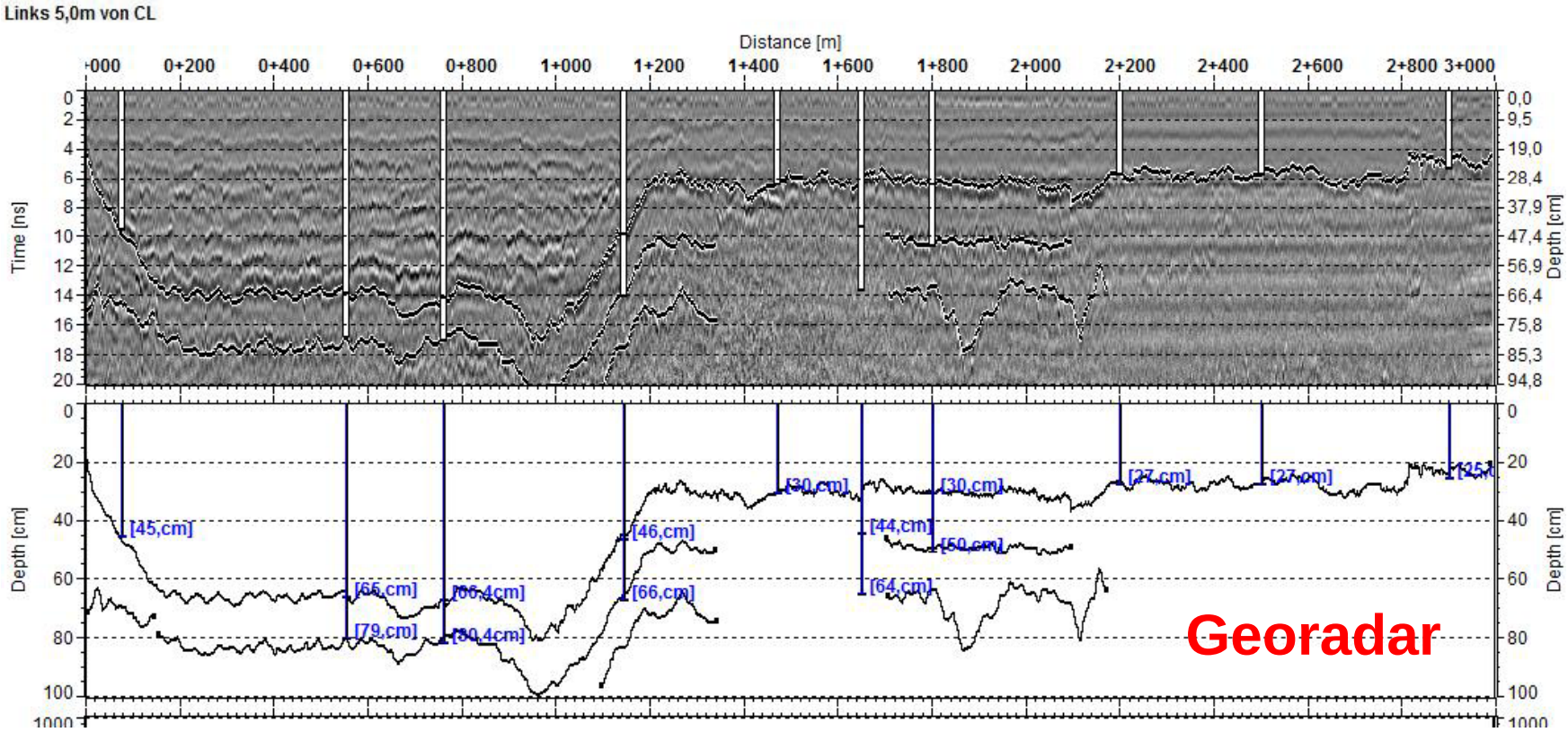
Utilizzando il software GRED 3d IDS è stato possibile valutare gli spessore dei diversi strati componenti la sovrastruttura in maniera da individuare poi i tratti omogenei ed in seguito determinare i punti dove eseguire i carotaggi.

Dall'interpretazione dei dati GPR, unitamente ai dati deflettometrici ottenuti attraverso l' Heavy Weight Deflectometer "Dynatest 8081" e ai dati di traffico, è possibile stimare il modulo elastico e la vita residua delle sovrastrutture indagate.



I dati ottenuti saranno poi implementati all'interno del PMS (Pavement Management System) dell'aeroporto di Fiumicino, in maniera da pianificare sia la tipologia che la tempistica degli interventi.

Airport Linz - Austria


Links 5,0m von CL
Distance [m]
0+000
0+200
0+400
0+600
0+800
1+000
1+200
1+400
1+600
1+800
2+000
2+200
2+400
2+600
2+800
3+000
Time [ns]
Depth [cm]
0,0
9,5
19,0
28,4
37,9
47,4
56,9
66,4
75,8
85,3
94,8
[45,cm]
[65,cm]
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[46,cm]
[66,cm]
[30,cm]
[44,cm]
[64,cm]
[50,cm]
[27,cm]
Georadar

ALADDIN

an advanced radar based sensor for Non-Destructive structural analysis

Civil engineering & Cultural heritage applications

- 3D imaging of shallow and deep rebars in concrete;
- Inspection of concrete for location of voids;
- Inspection of concrete thickness, integrity;
- 3D imaging of pre-tension and post-tension cables;
- Inspection and analysis of old structures and monuments;
- Inspection of walls and floors for the location of pipes, objects, caches, etc..

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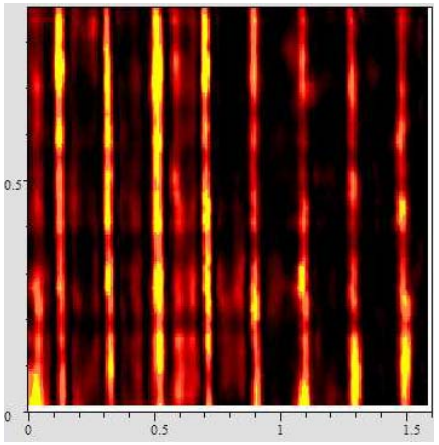
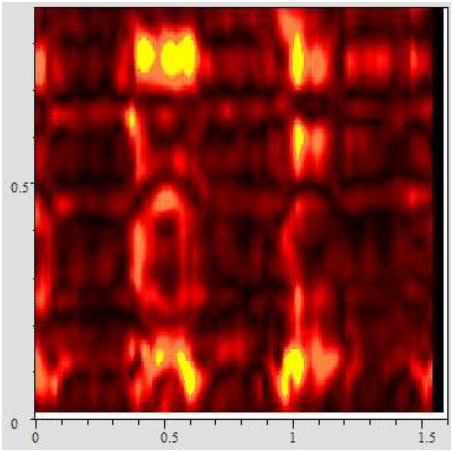
Standard Products

Depth: 0.10m



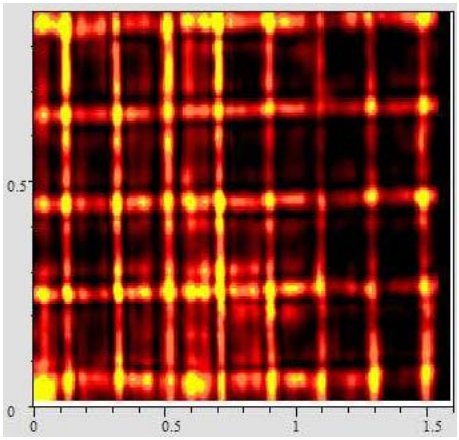
Depth: 0.40m



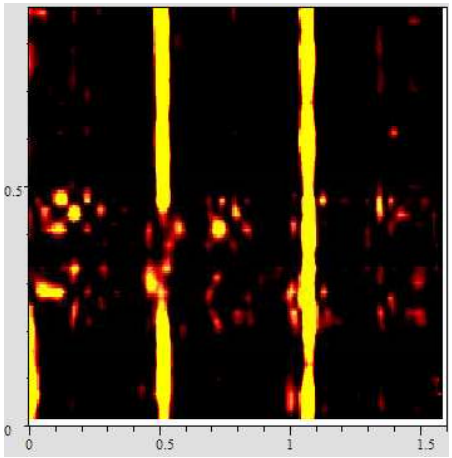
The standard antenna can read the shallow targets (rebars), but is not able to reveal the lower structures

ALADDIN

Depth: 0.10m

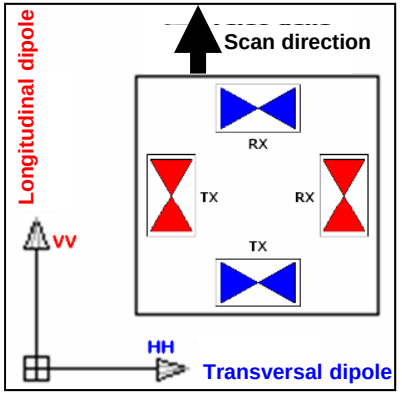


Depth: 0.40m



Instead, the FULL-POLAR antenna is able to identify both targets (shallow and deep) in just one scan.

The **SPECIAL FULL-POLAR** high-frequency (2 GHz) antenna combined with the **patented Pad Survey Guide (PSG)** permit joint orthogonally polarized scans to be acquired in a single pass, detecting shallow and deep structures and halving acquisition time compared to standard methods.



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No-destructive tool for structural analysis.

High frequency antennas

3D processing software

APPLICATIONS

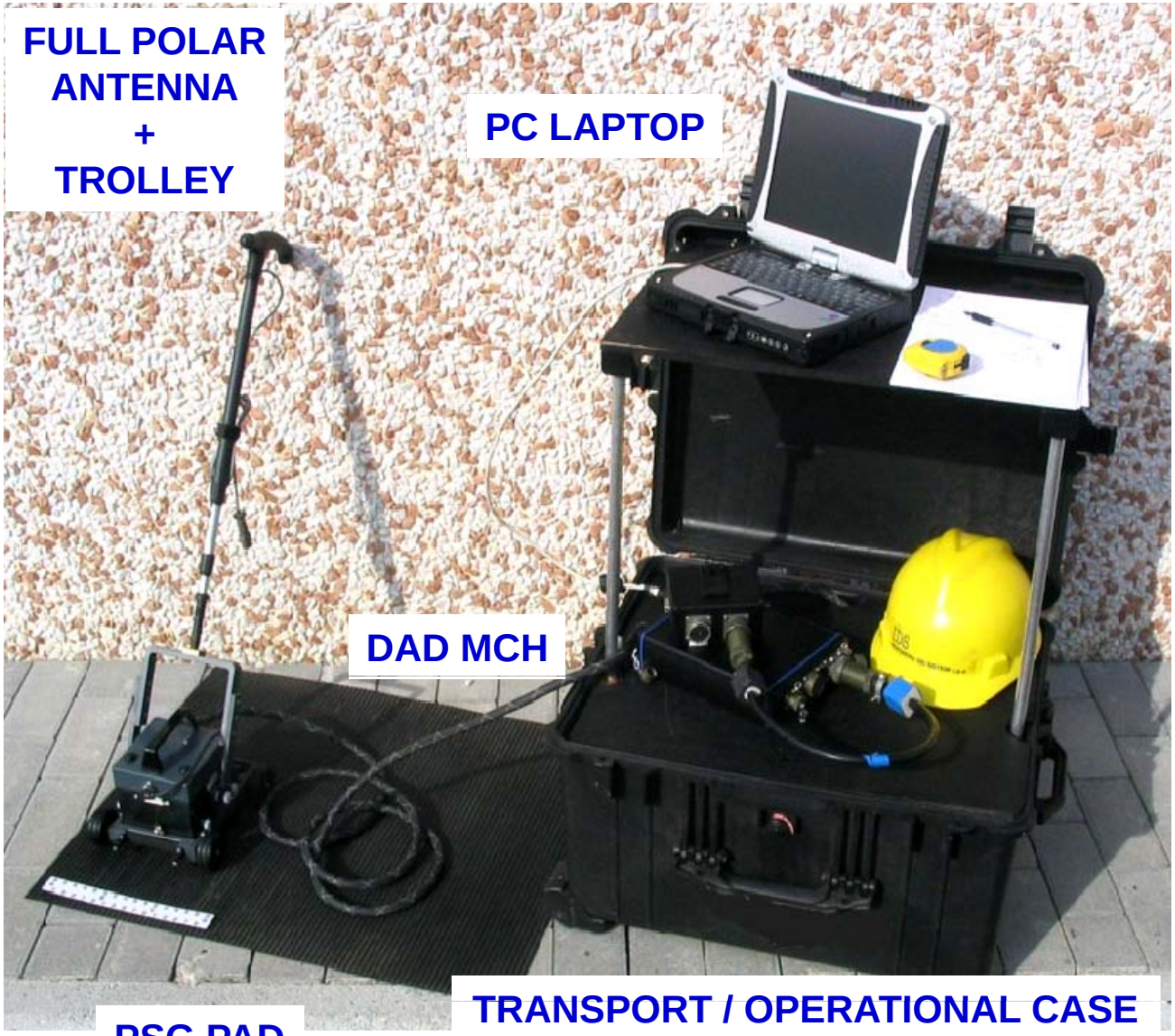
- Locate rebar, tension cables, conduits, voids and measure slab thickness.
- Inspection of walls, floors, decks, slabs, tunnels, balconies and garages.
- Detect and map the relative concrete condition for rehab planning.
- Detect and map cavities inside walls
- Concrete thickness, water and inner rebar structure inspection
- Reconstruction of wall inner structure detection of structural defects

USER BENEFITS

1. EASY TO USE
2. ACQUISITION TIME OF RADAR DATA REDUCED DRASTICALLY
3. FLEXIBLE CONFIGURATION FOR ANY USE: PAD or OPTICAL READER
4. 3D DATA COLLECTION BY PERFORMING ONLY PARALLEL SCANS
5. AUTOMATIC START/STOP OF DATA COLLECTION SYNCHED UP WITH PAD LENGTH
6. REMOTE CONTROL ON THE STICK
7. DUE TO POLARISED CHANNEL, IT UNVEALS DEEP TARGETS SHADOWED BY SHALLOWER ONE
8. EXPANDIBLE CONTROL UNIT (DAD) CAN BE USED WITH ALL IDS ANTENNAS FOR USE IN OTHER APPLICATIONS
9. DEDICATED 3D SW INCLUDED IN THE PACKAGE
10. HIGH RESOLUTION DATA
11. DETECTION AND MAPPING OF THINEST CABLES

ALADDIN

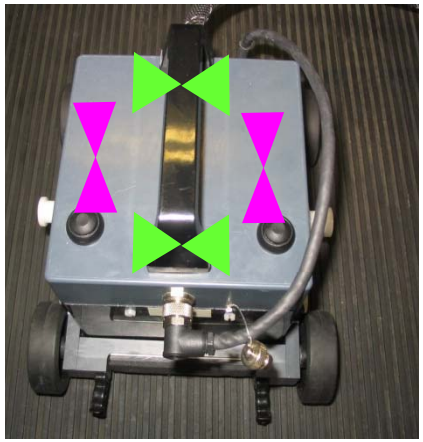
COMPOSITION



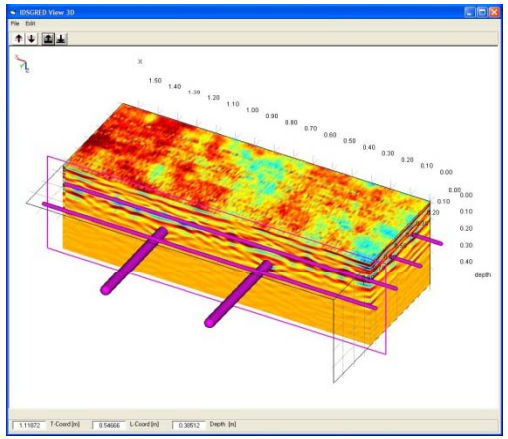
ADVANTAGES

1
OPERATIONAL CASE

2
PSG: INNOVATIVE SURVEY KIT



3
FULL POLAR ANTENNA



4
3D SW FOR ON-SITE PROCESSING

1. DEDICATED TRANSPORT/OPERATIONAL CASE
2. PSG: INNOVATIVE SURVEY KIT FOR AN EASY AND TOTAL 3D ACQUISITION DATA
3. FULL POLAR ANTENNA (2 GHz): IMPROVES THE IMAGING OF SHALLOW AND DEEP REINFORCING BARS
4. QUICK ON-SITE DATA PROCESSING
5. OPTION: OPTICAL READER SURVEY KIT POINTER

Full line of high frequency antennas

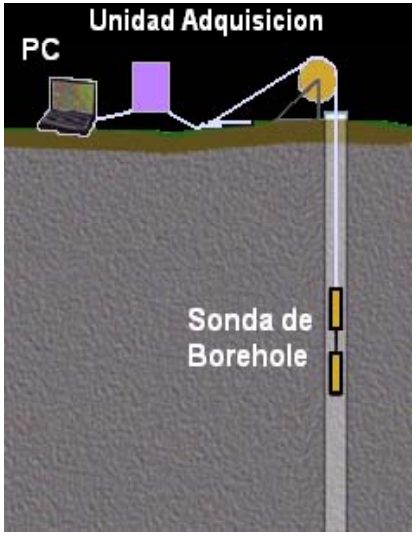
DAD MCH (Aladdin radar control unit): is compatible with all the IDS antennas

Borehole antenna for no destructive test

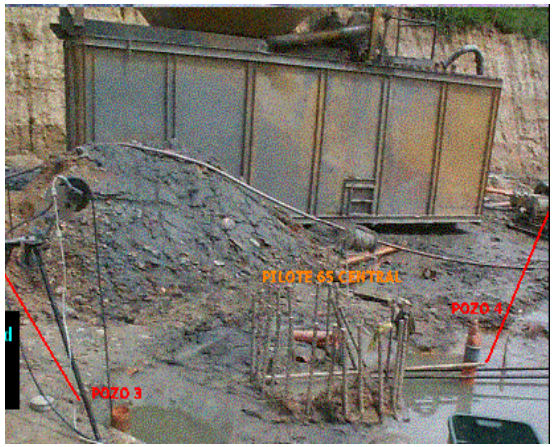
DAD MCH (Aladdin radar control unit): is compatible with all the IDS antennas

Available models/frequency antennas :

- BA 600 MHz



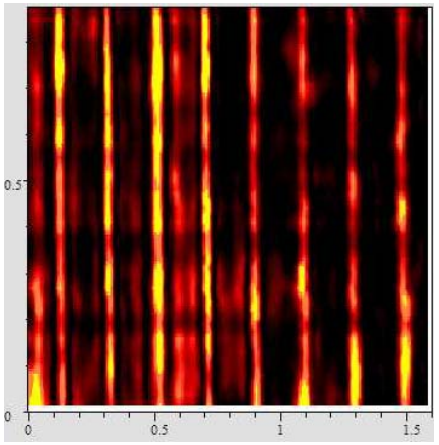
- Borehole antenna cable (40 m) (BAC 4000)
- Antenna Type: Unshielded Dipole
- Nominal Frequency: 600 MHz
- Operation Mode: Single hole reflection, Cross-hole tomography
- Length: 1.6 or 1.0 meter
- Diameter: 40 mm
- Weight: 1.5 Kg
- Water-proof: up to 5 bar



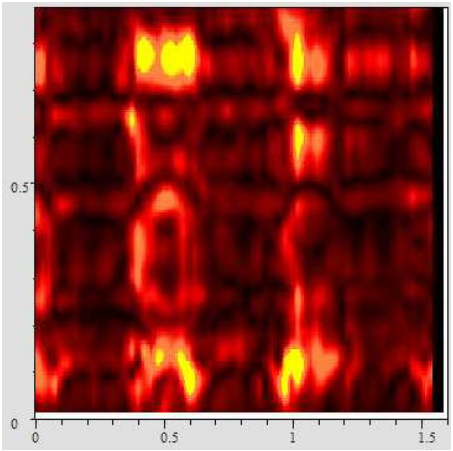
Grazie per l’ascolto

Standard Products

Depth: 0.10m



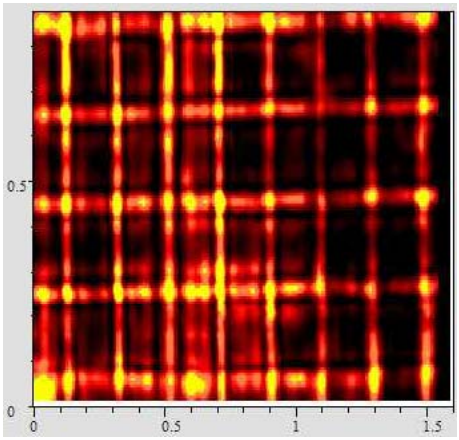
Depth: 0.40m



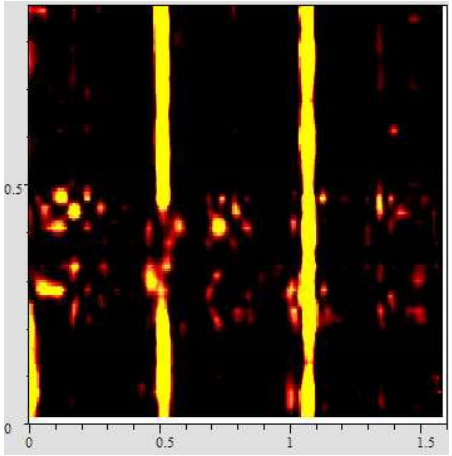
The standard antenna can read the shallow targets (rebars), but is not able to reveal the lower structures

ALADDIN

Depth: 0.10m

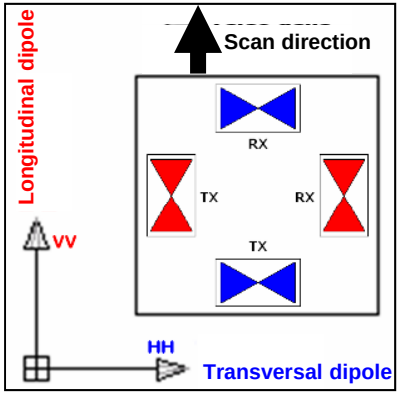


Depth: 0.40m



Instead, the FULL-POLAR antenna is able to identify both targets (shallow and deep) in just one scan.

The **SPECIAL FULL-POLAR** high-frequency (2 GHz) antenna combined with the **patented Pad Survey Guide (PSG)** permit joint orthogonally polarized scans to be acquired in a single pass, detecting shallow and deep structures and halving acquisition time compared to standard methods.



ANTENNA FEATURES

Antenna Frequency	2 GHz Bipolare
Offset RX and TX	6 cm
Antenna dimension	12×12 cm

Indagine GPR con antenne ad alta frequenza
Test site in Cemento
Highways Department - Bangkok – Thailand (1/4)

Indagine GPR con antenne ad alta frequenza per localizzare vuoti sotto lo strato di cemento (2/4):

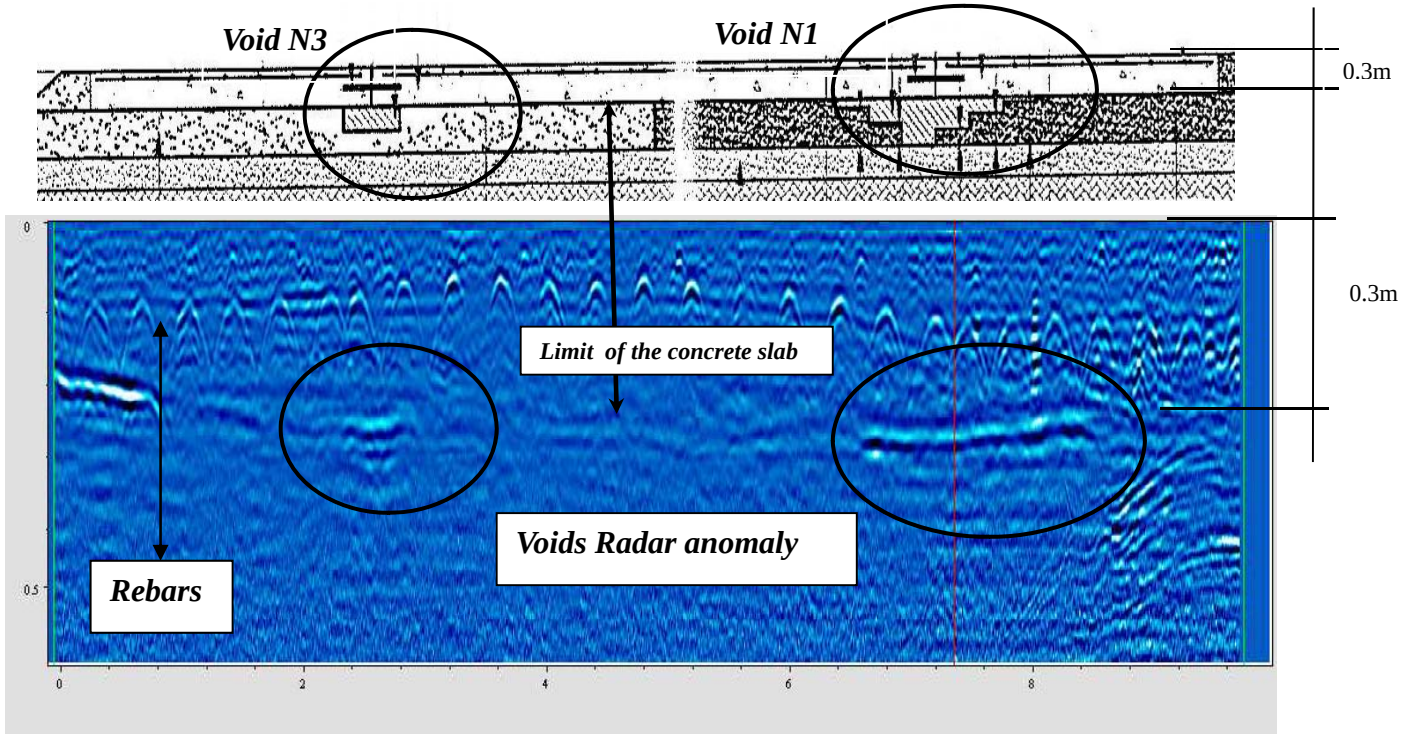
Tets site in the *Asian Institute of Technology*

Indagine GPR su un test site in cemento della *Highways Department of Bangkok* per valutare:

- La presenza e la posizione di vuoti sotto lo strato di cemento
- La presenza e la posizione dei ferri di armatura nello strato di cemento

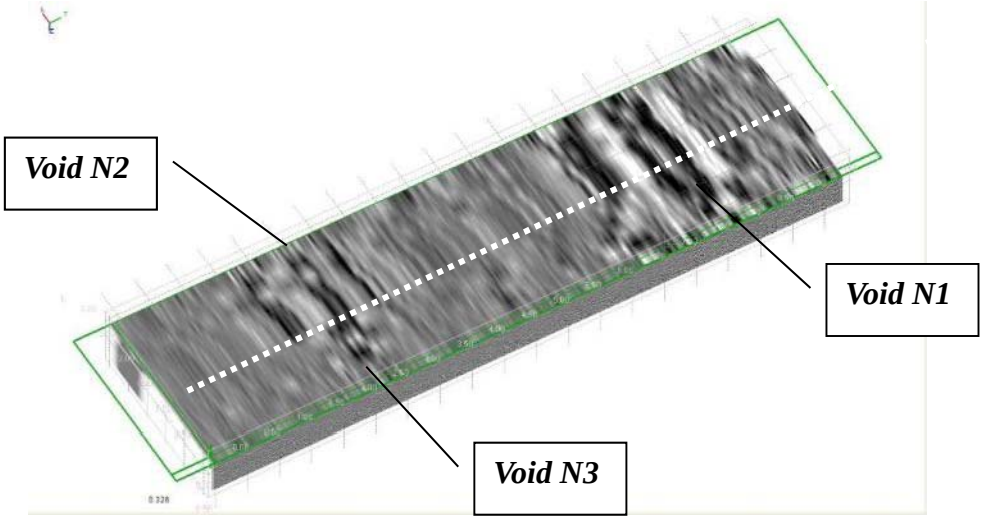
Configurazione Usata: Sistema con antenna a 2 GHz

Indagine GPR con antenne ad alta frequenza per localizzare vuoti sotto lo strato di cemento (3/4):



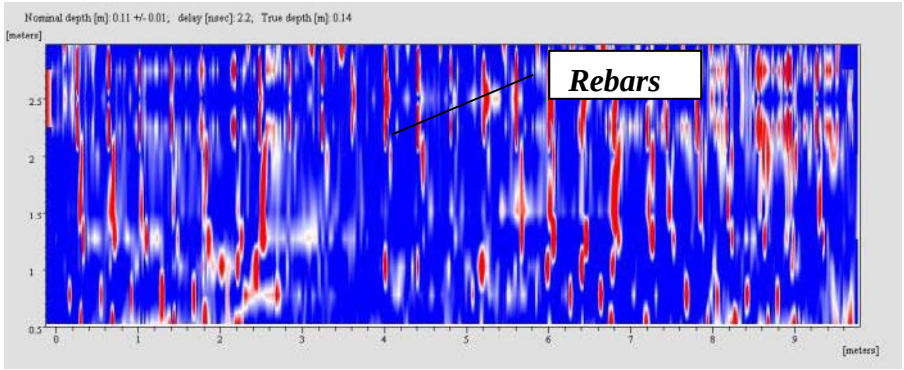
Mappa radar a 2Ghz comparata con il disegno schematico della struttura;

Indagine GPR con antenne ad alta frequenza per localizzare vuoti sotto lo strato di cemento (4/4):



Vista 3D tagliata a 32cm di profondità che mostra la presenza di 3 anomalie create da vuoti

Time slice con le anomalie create dai ferri nel cemento



Indagine GPR ad alta frequenza in AOT

Airports of Thailand Public Company (1/4)

Indagine GPR ad alta frequenza per la localizzazione dei ferri nel cemento (2/4):

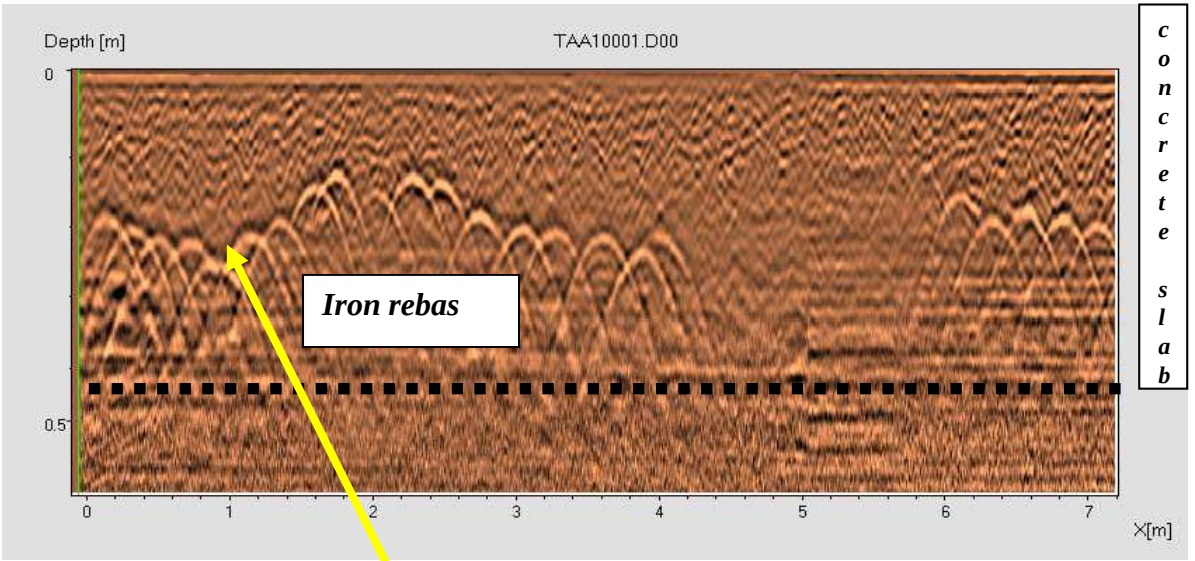
Test site in the International Airport of Bangkok

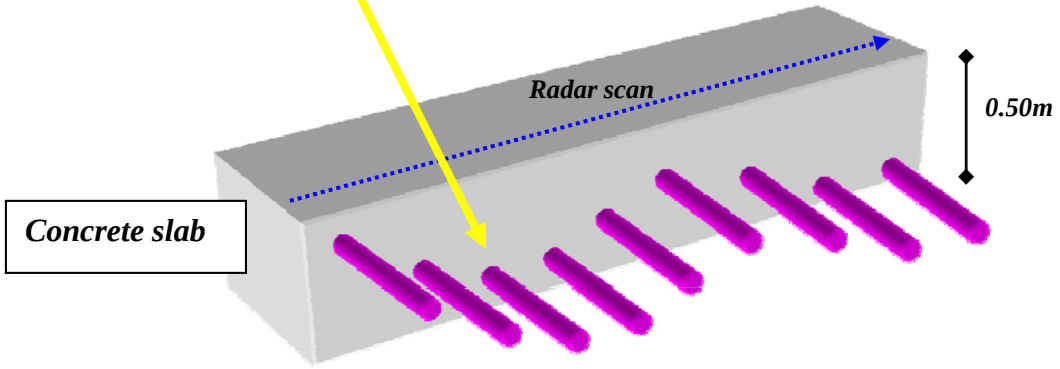
Indagine GPR nell'area test di *Airports of Thailand Public Company* **per valutare**:

- La presenza e la posizione dei ferri nel cemento

Configurazione Usata: Sistema con antenna a 2 GHz

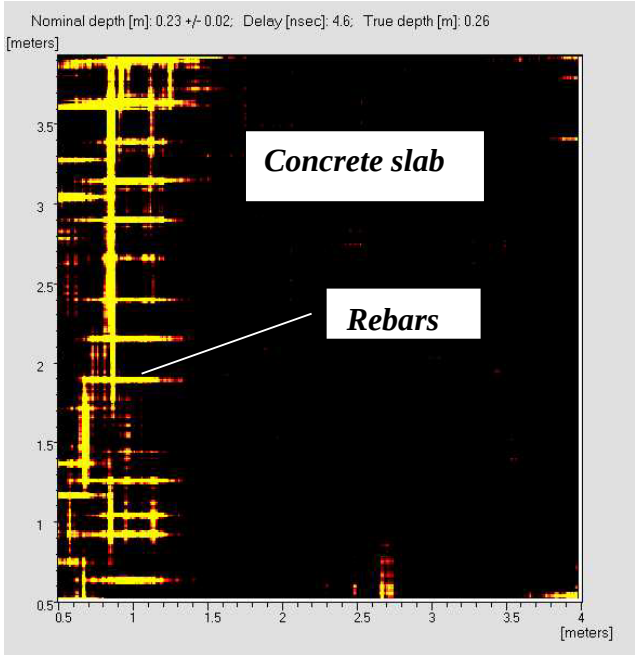
Indagine GPR ad alta frequenza per la localizzazione dei ferri nel cemento (3/4):





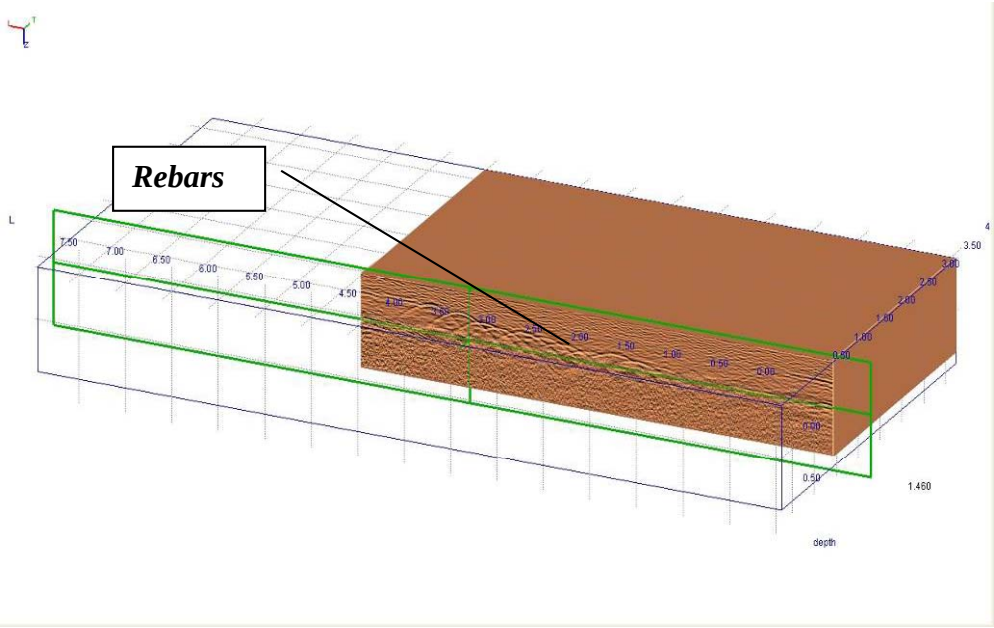
Mappa radar a 2GHz acquisito lungo la giunzione di due slab di cemento; ferri a diversa profondità

Indagine GPR ad alta frequenza per la localizzazione dei ferri nel cemento (4/4):



Time slice, anomalie generate dai ferri nel cemento

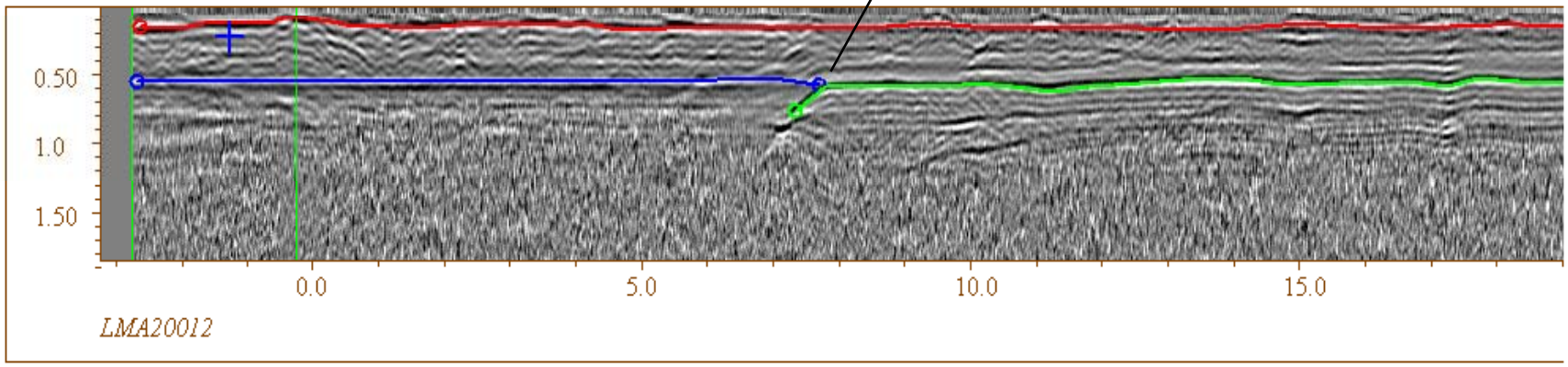
Viosta 3D con le anomalie generate dai ferri



Maiquetía Airport - VENEZUELA

Fratture nell'asfalto

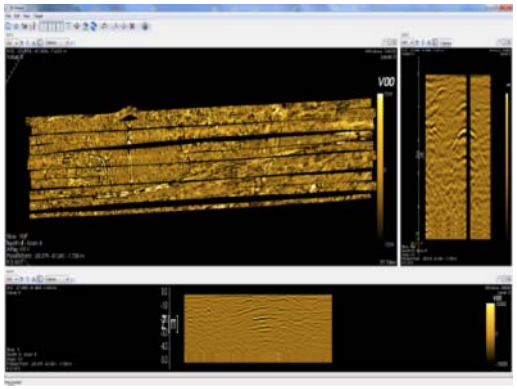
La mappa radar mostra la presenza di fratture nell'asfalto e nello strato sottostante (fino ad 1 m di profondità)



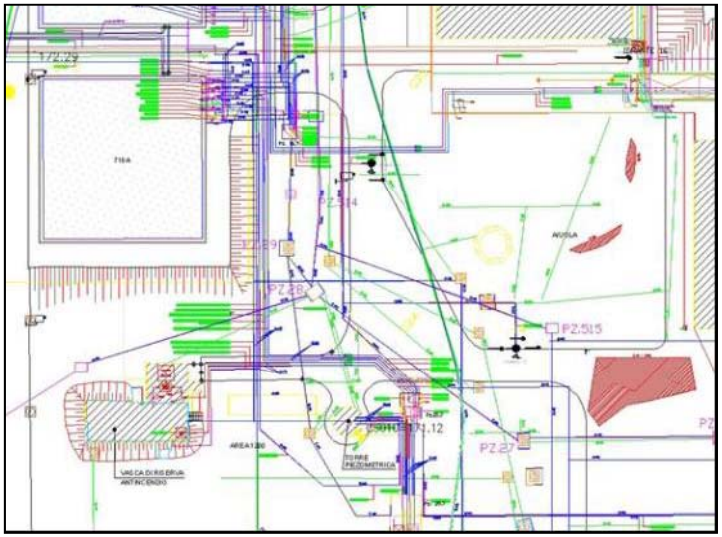
Mappatura estesa delle reti sottoservizi: Stream-EM

Un sistema georadar trainato da veicolo (fino a 15 km/h) consente la mappatura veloce delle reti sottoservizi senza degrado delle prestazioni

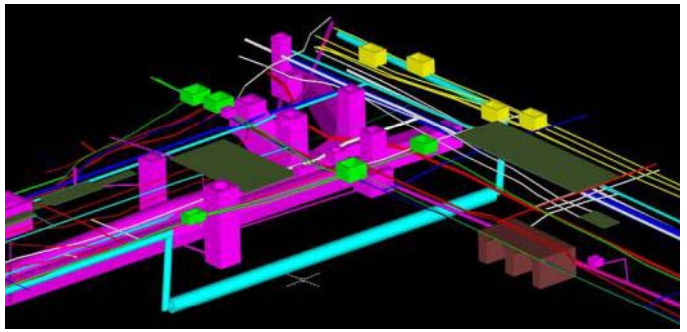
1. Stream EM per l'acquisizione dei dati radar



2. Elaborazione di dati



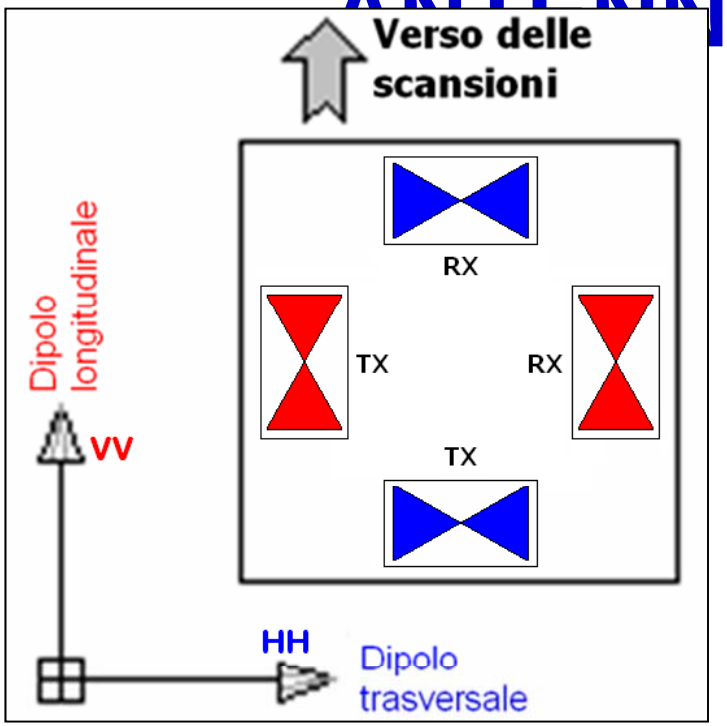
3. Cartografia delle reti esistenti

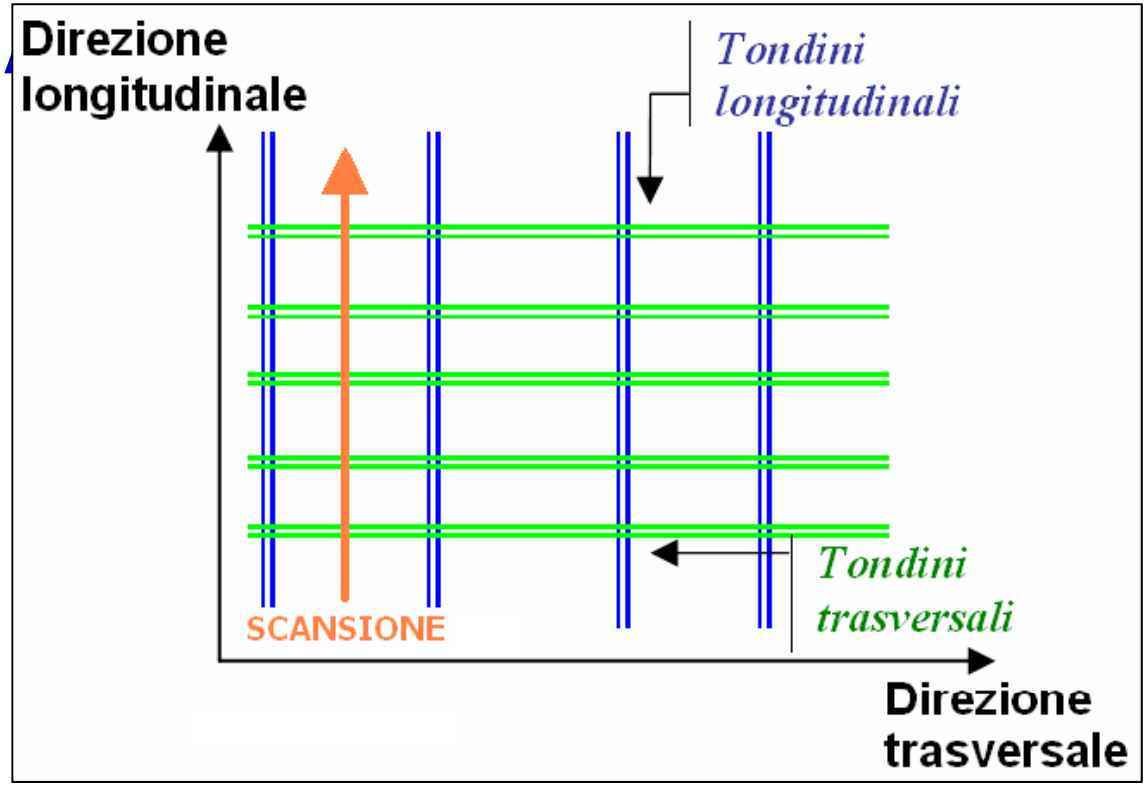


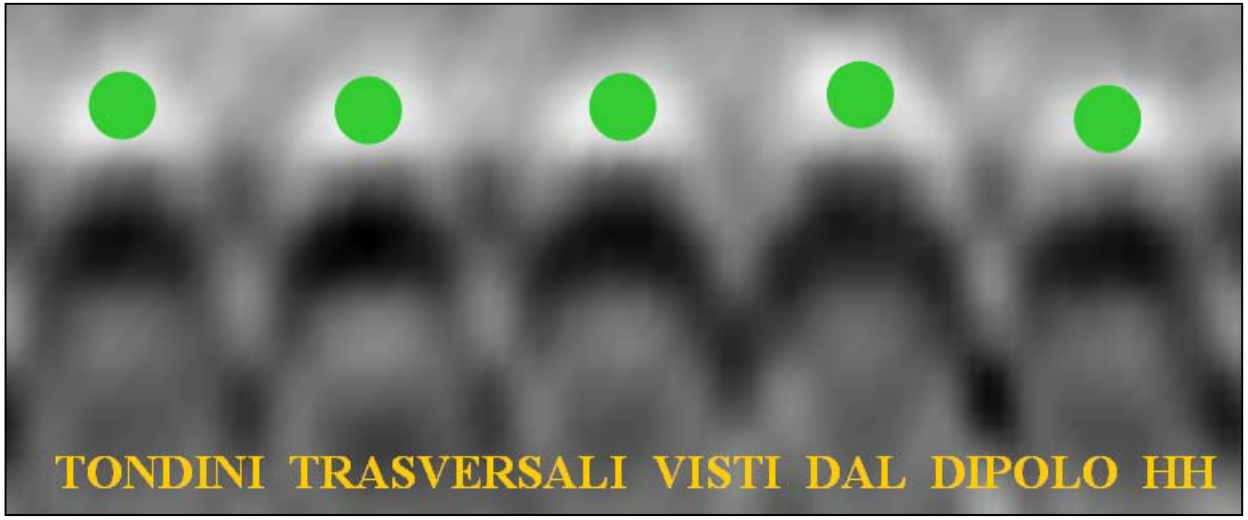
3. Rappreseentazione 3D delle reti rilevate

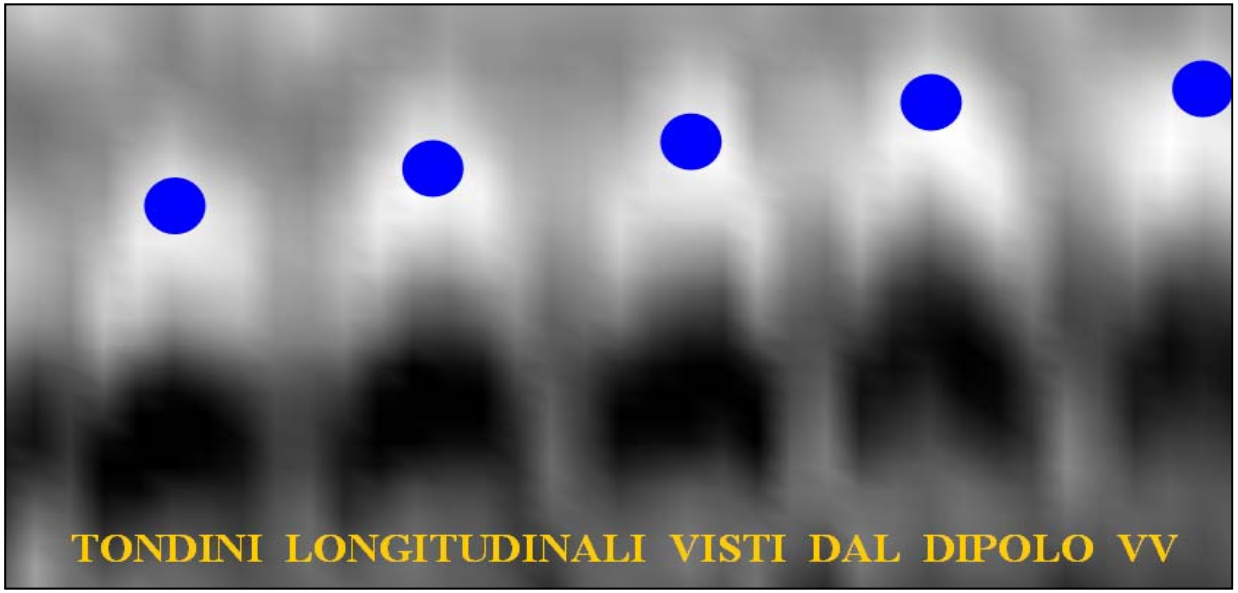
APPLICAZIONI PER L’ INGEGNERIA CIVILE

Luglio 2010

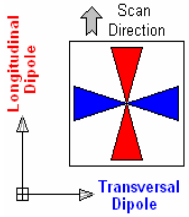

Verso delle scansioni
RX
TX
RX
TX
Dipolo longitudinale
VV
HH
Dipolo trasversale


Direzione longitudinale
Tondini longitudinali
SCANSIONE
Tondini trasversali
Direzione trasversale

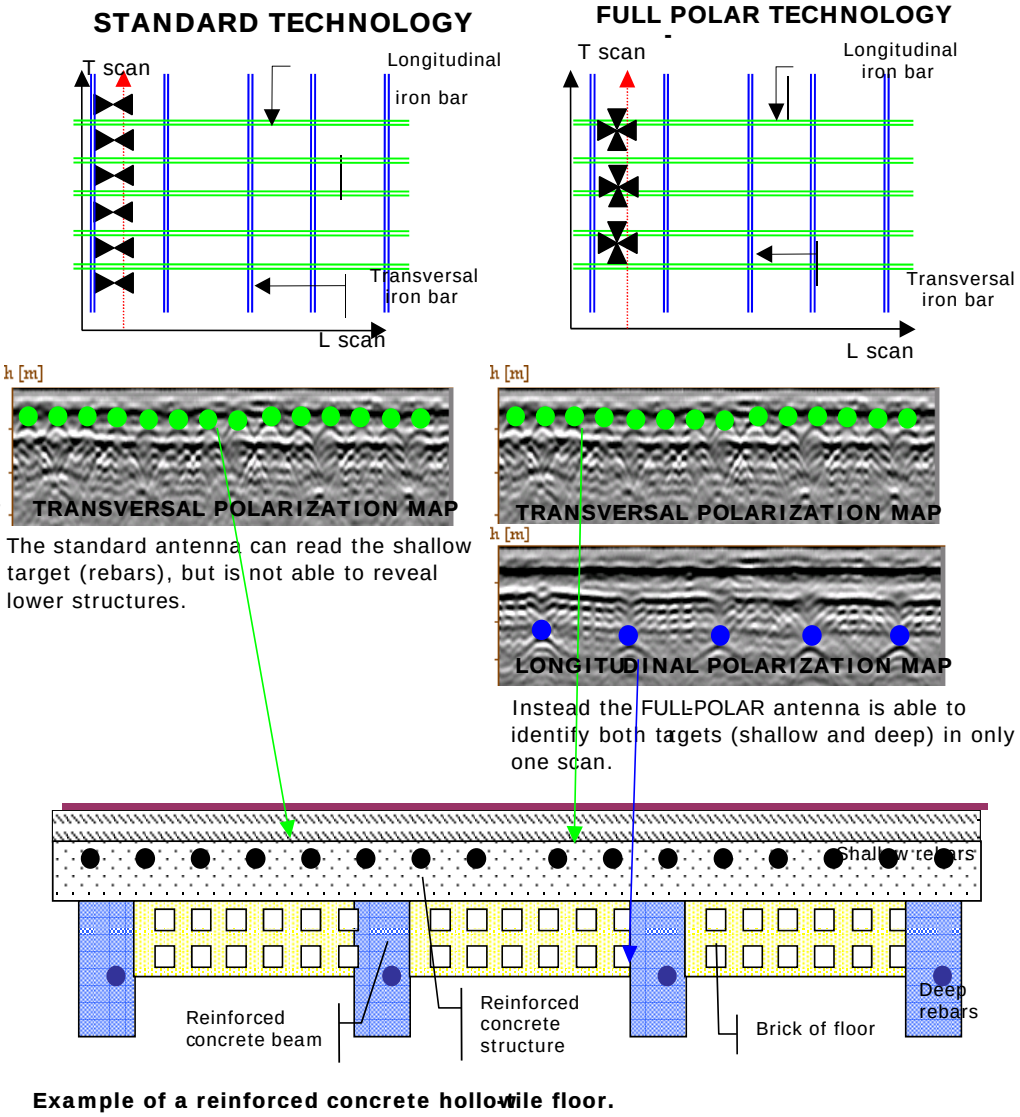

TONDINI TRASVERSALI VISTI DAL DIPOLO HH


TONDINI LONGITUDINALI VISTI DAL DIPOLO VV

FULL POLAR antenna (2000 MHz)



The **ALADDIN** features the **unique** high-frequency (2 GHz) antenna **with two polarizations** (transversal and longitudinal).
It permits to acquire joint orthogonally polarized scans in one pass, improving images of the shallow and deep structures.
ALADDIN includes the multi-channels radar control unit that can be connected with all the IDS antennas



Example of a reinforced concrete hollow-tile floor.

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (1/4):

Sao Paulo (Brasil)

Indagini GPR su strutture nella stazione Metro di Sao Paulo (Brasil) Metro per valutare:

- La presenza e la spaziatura dei ferri nelle colonne.
- La presenza e la spaziatura dei ferri e/o tiranti.

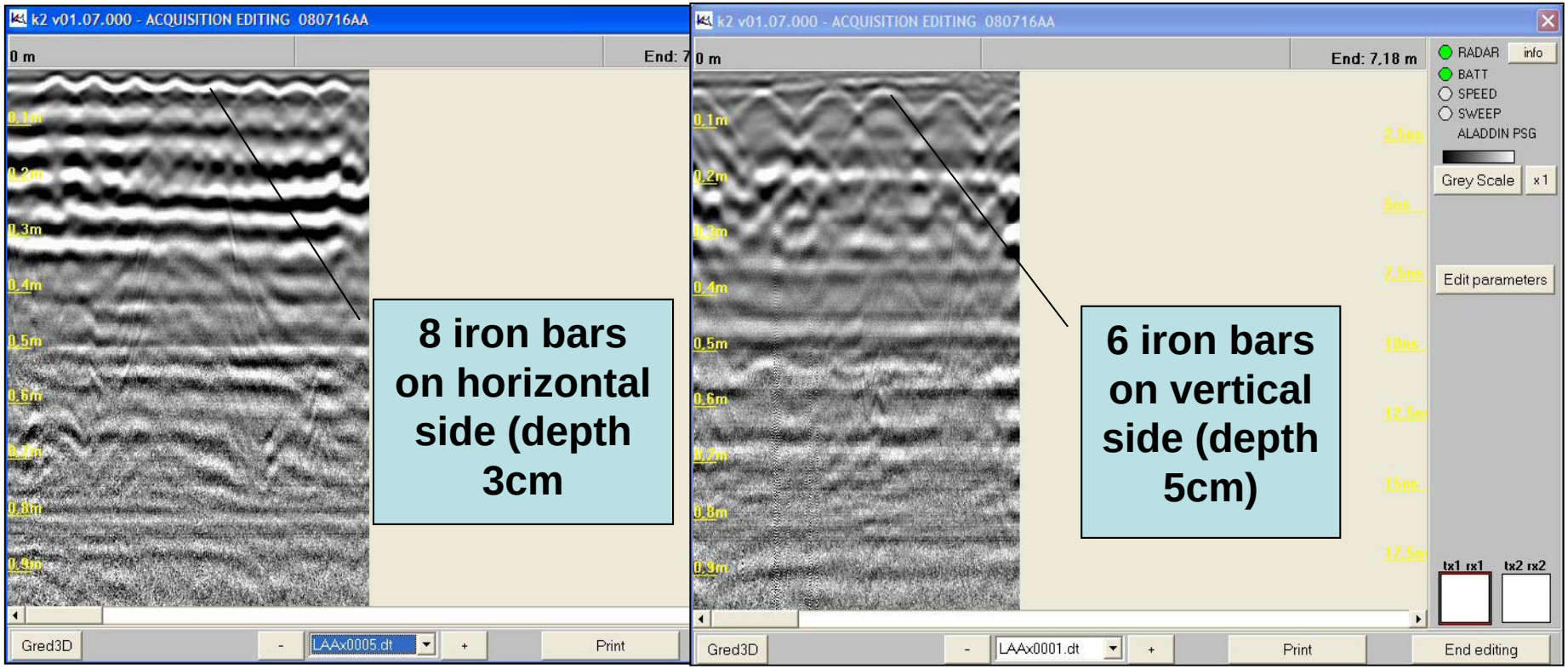
Strumentazione utilizzata: Sistema con antenna Bipolare a 2 GHz

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (2/4):

Fase di acquisizione: Sao Paulo (Brasil) Metro Line

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (3/4):

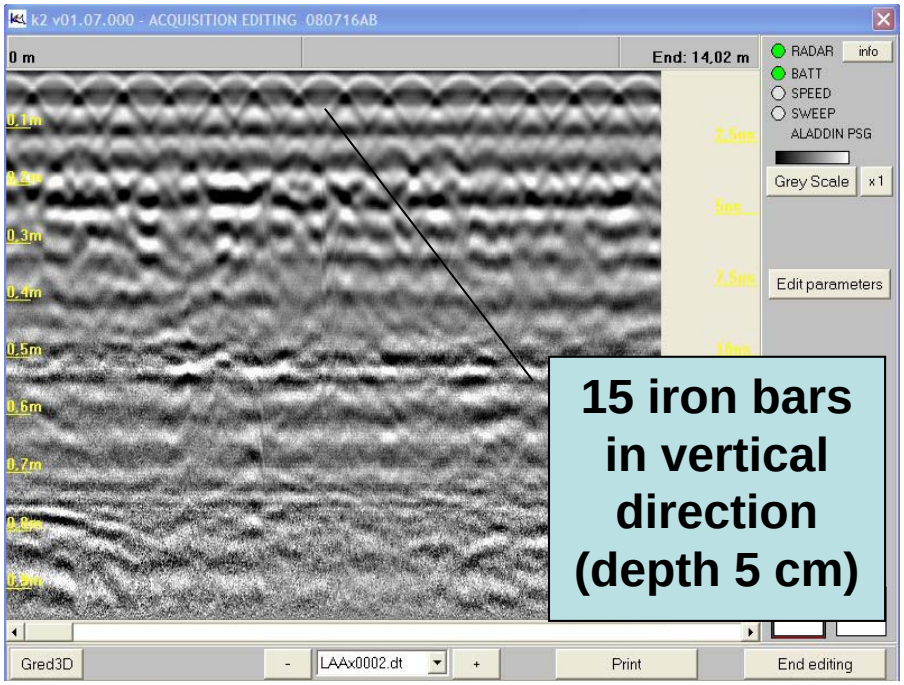
Mappe Radar che evidenziano la presenza e la spaziatura dei ferri di armatura

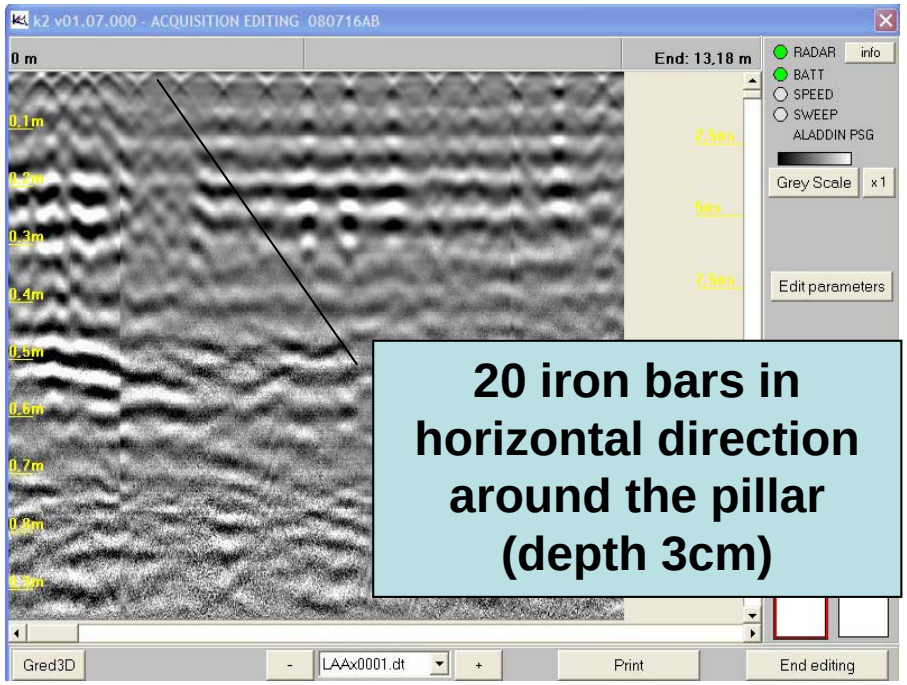


Spaziatura orizzontale tra i ferri: 20-25cm

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (4/4):

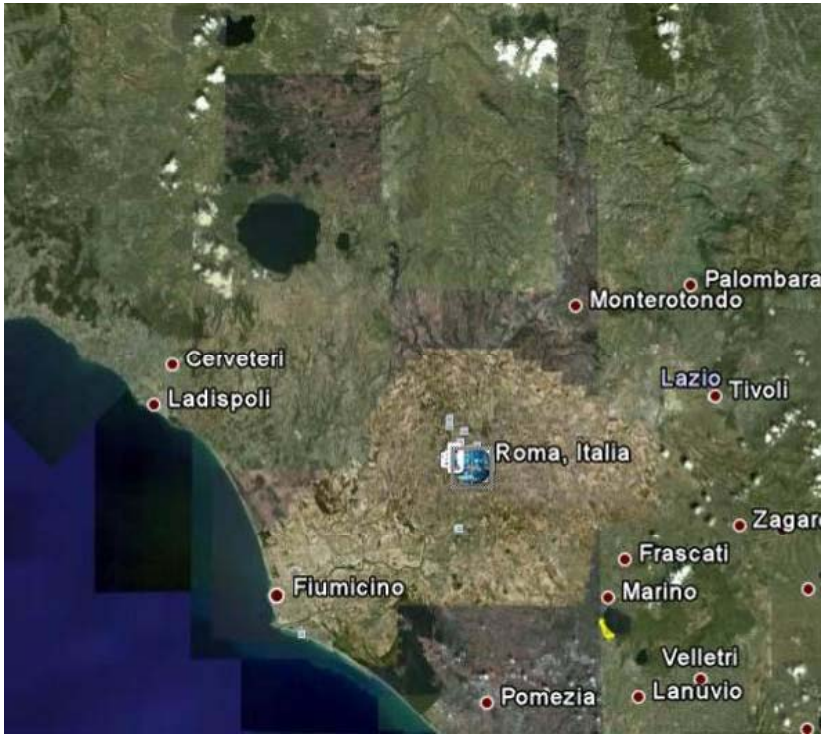
Mappe Radar che evidenziano la presenza e la spaziatura dei ferri di armatura nella colonna





Doppia linea di armature. Spaziatura orizzontale: 10-20cm

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (1/3):



Rome, Italy

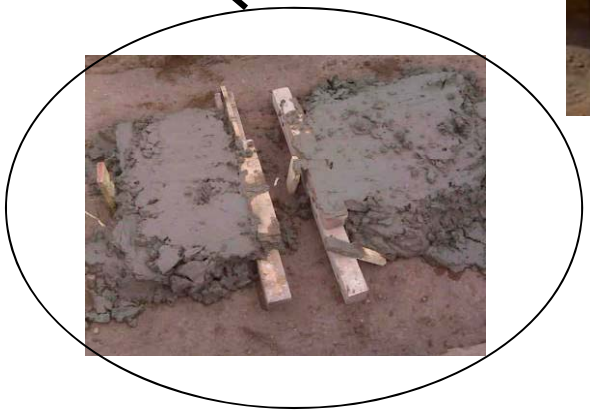
Indagini GPR su un sito test lungo la linea Metro di Roma per valutare:

- La presenza di vuoti e cavità dietro lo strato di cemento.

Configurazione usata: sistema con antenne a 900MHz e 2GHz

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (2/3):

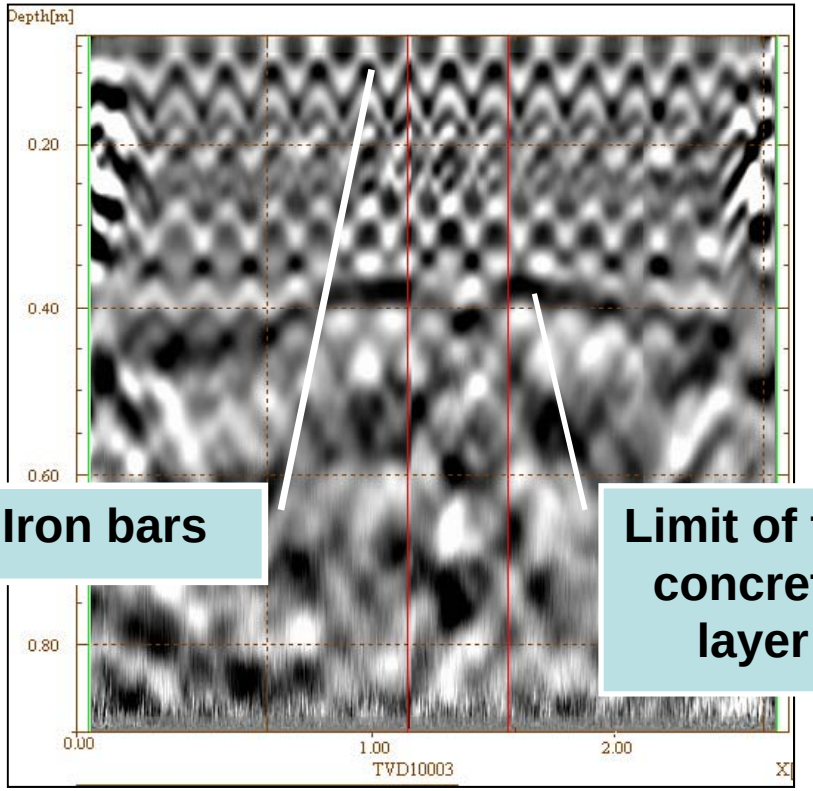
Fase di acquisizione: test site lungo la linea Metro di Roma (nuova linea)

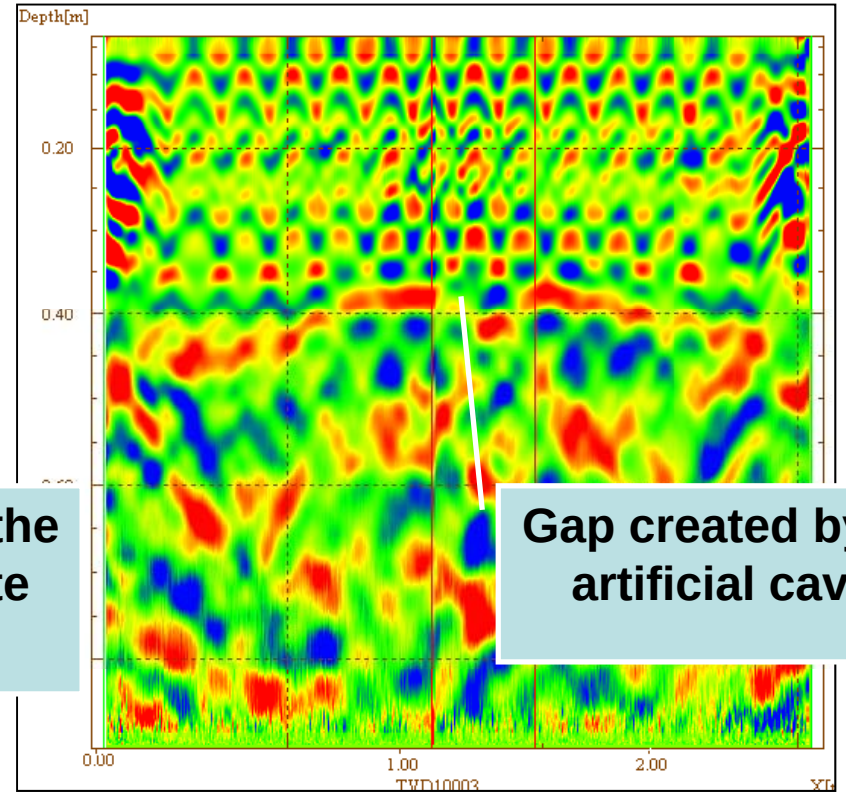


Artificial cavity

Indagini GPR con antenne ad alta frequenza per applicazioni strutturali (3/3):

Risultati



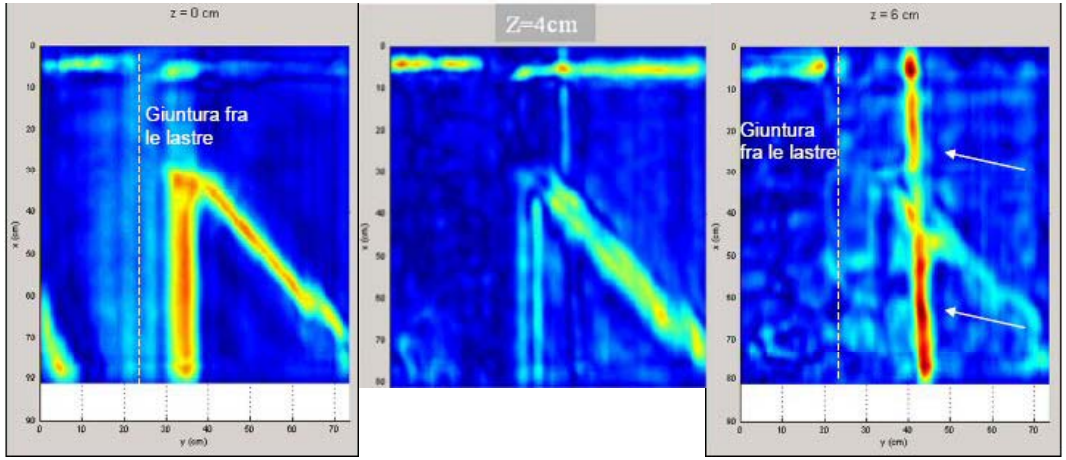


Teatro DONIZZETTI- Bergamo (Italy)

(by Polytechnic of Milan)

Indagine strutturale sulla facciata del teatro per la localizzazione di un sistema di fratture.

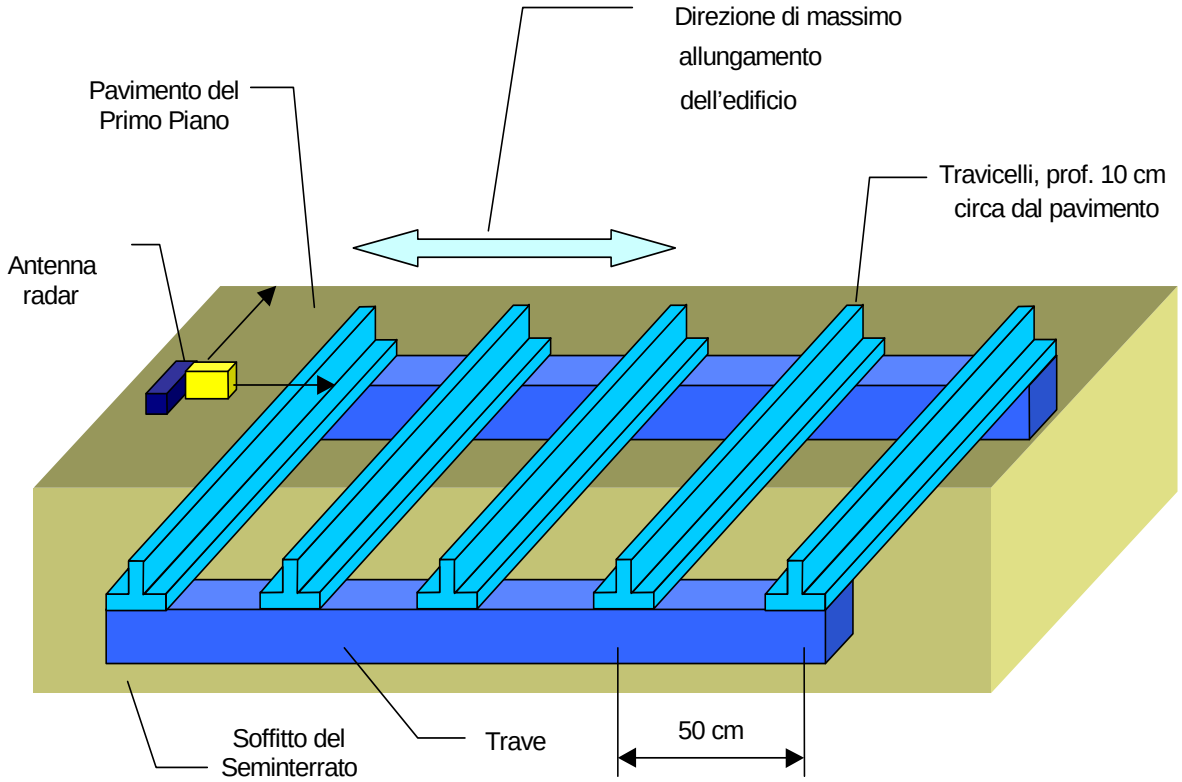
Sistema utilizzato: georadar con antenna bipolare a 2 GHz.
Dimensioni dell'area test: 1 x 2 m
Tempo di acquisizione 20 min .



Z = 0 cm **Z = 4 cm** **Z = 6 cm**

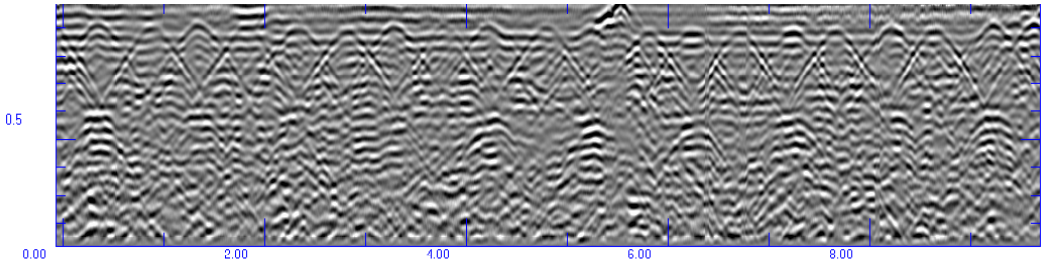
UN EDIFICIO DELL'AEROPORTO DI MILANO - LINATE:

- esempio di verifica della disposizione degli elementi strutturali



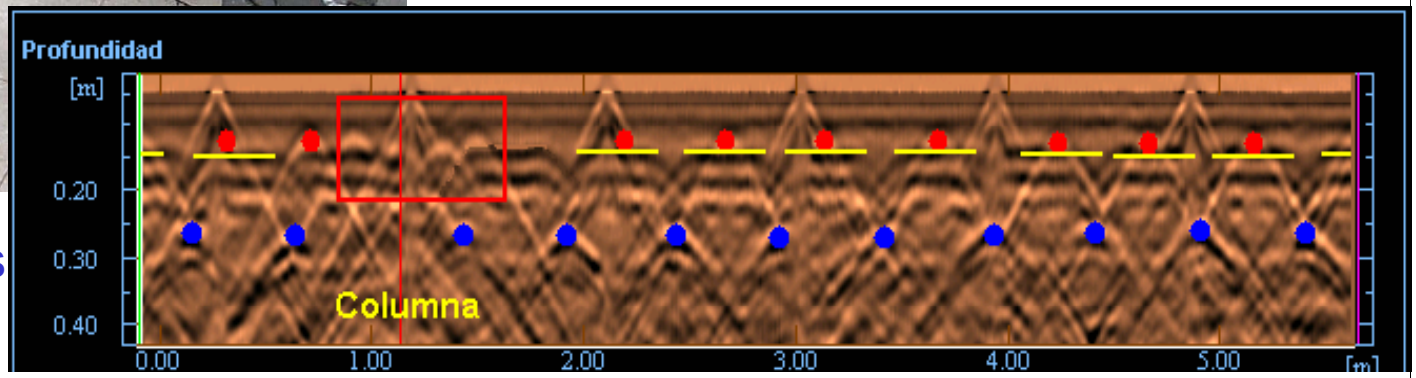
Ricostruzione 3D della disposizione degli elementi

Sezione radar di riferimento



Indagini GPR su pavimento

Localizzazione di due livelli di armatura



REINFORCED BARS

Indagini GPR con antenna da foro per il controllo di Dighe (1/2):

Badana Dam – Genova Italy

Problemi strutturali sulla Diga di Badana Genova -Italy:

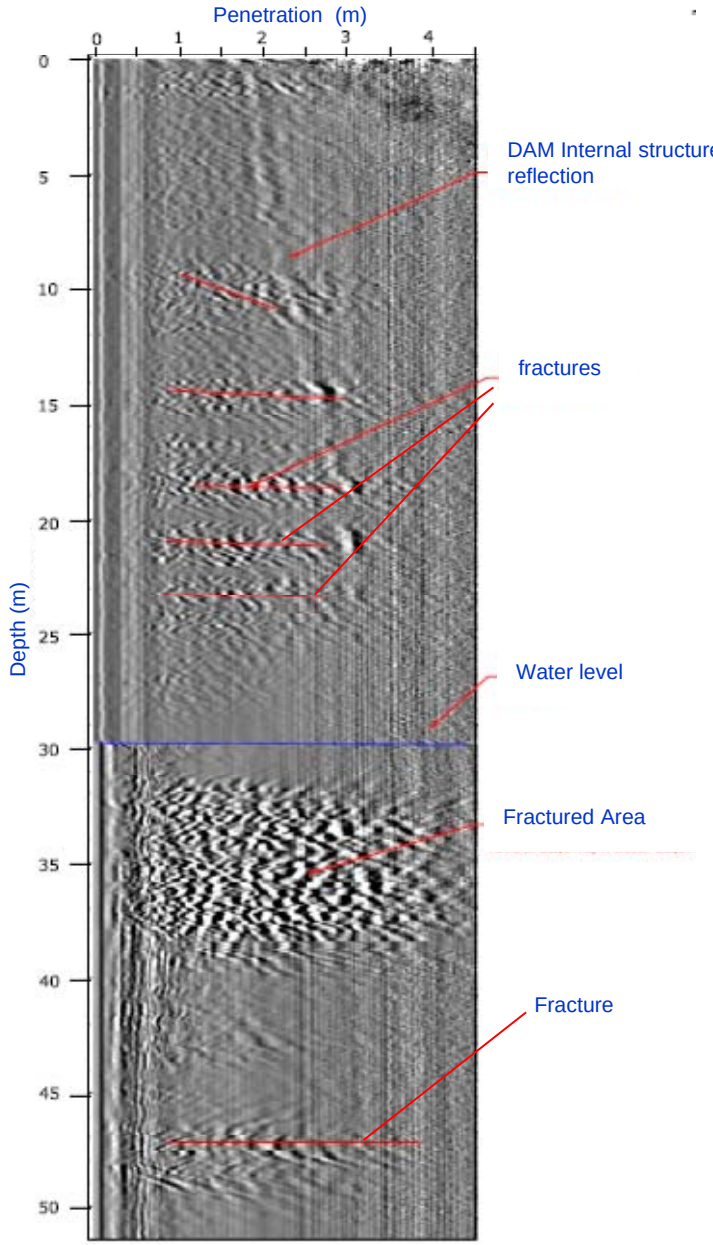
- Presenza di fratture nella diga.
- Infiltrazione di acqua.

- Configurazione Usata; sistema GPR con antenna BoreHole da 300 MHz

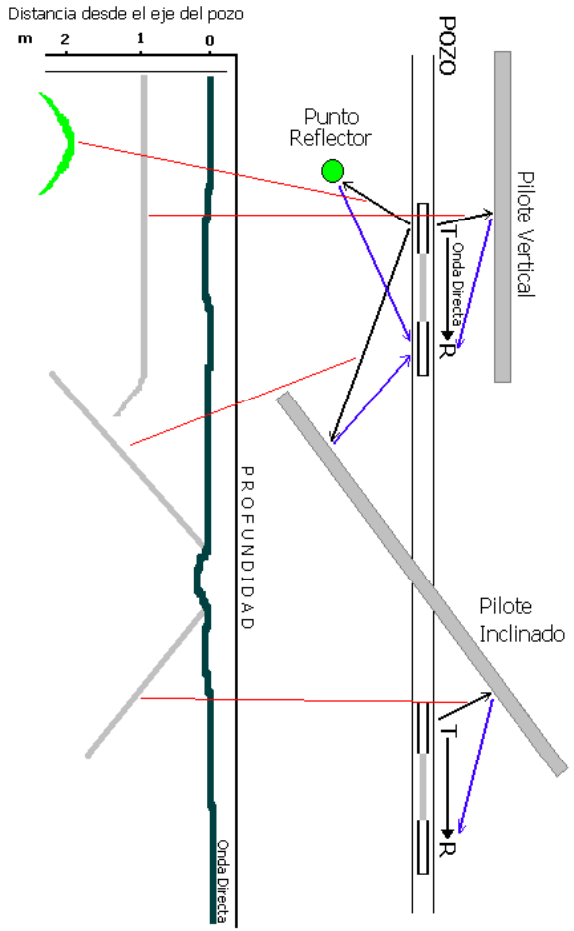
Badana Dam – Genova Italy

Indagini GPR con antenna da foro per il controllo di Dighe (2/2):

Field Acquisition Phase



Indagini Borehole per applicazioni geotecniche (1/2)



Sketch of GPR Bore Hole Technique

Indagini Borehole per il controllo di pali in Caracas – Venezuela:

- Valutazione della profondità del palo.
- Valutazione dell'integrità del palo.

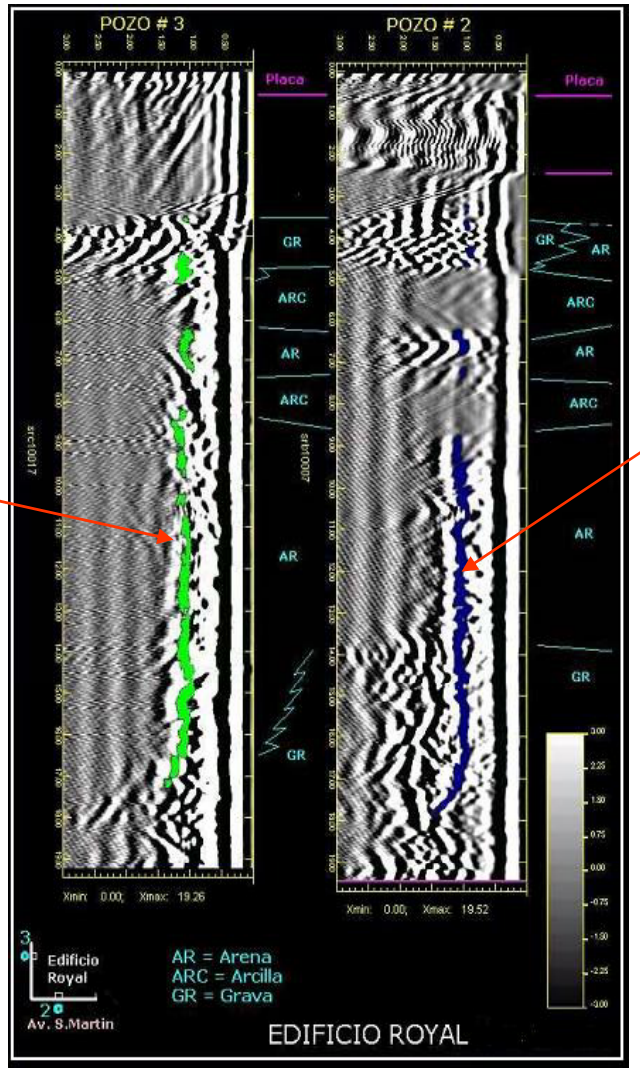
- Configurazione usata: sistema GPR con antenna borehole da 300 MHz

Caracas - Venezuela

Indagini Borehole per applicazioni geotecniche (2/2)

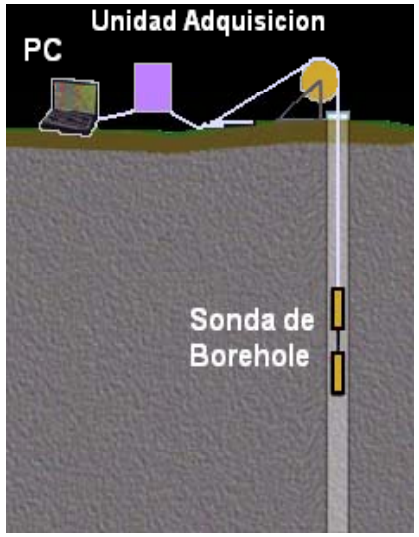
Hole for GPR investigation

Edificio Royal



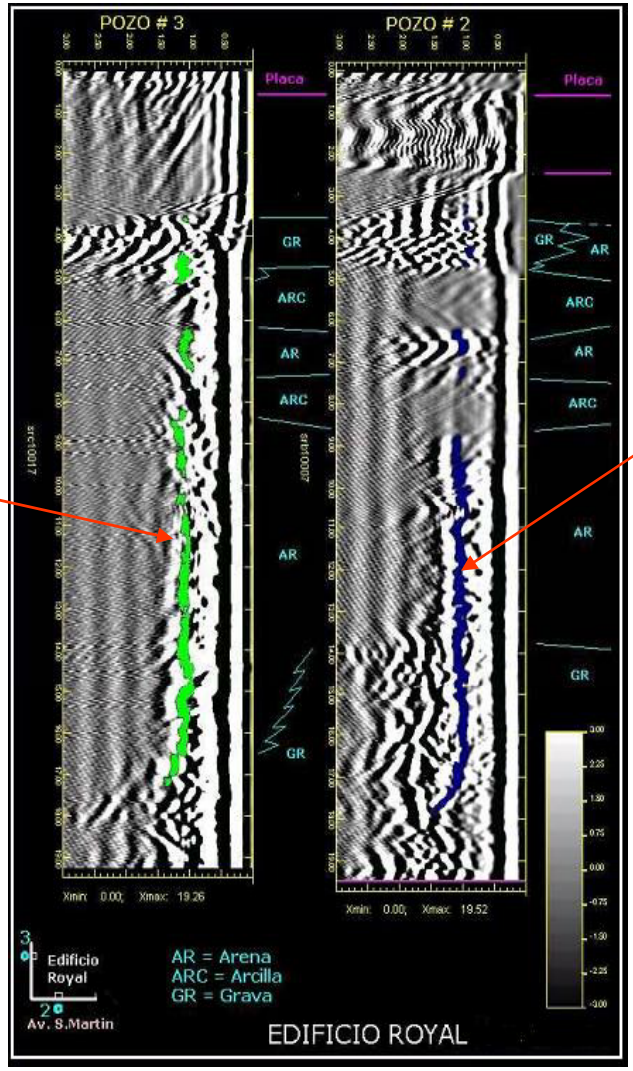
Bore Hole Results

Profondità ed integrità dei pali



hole

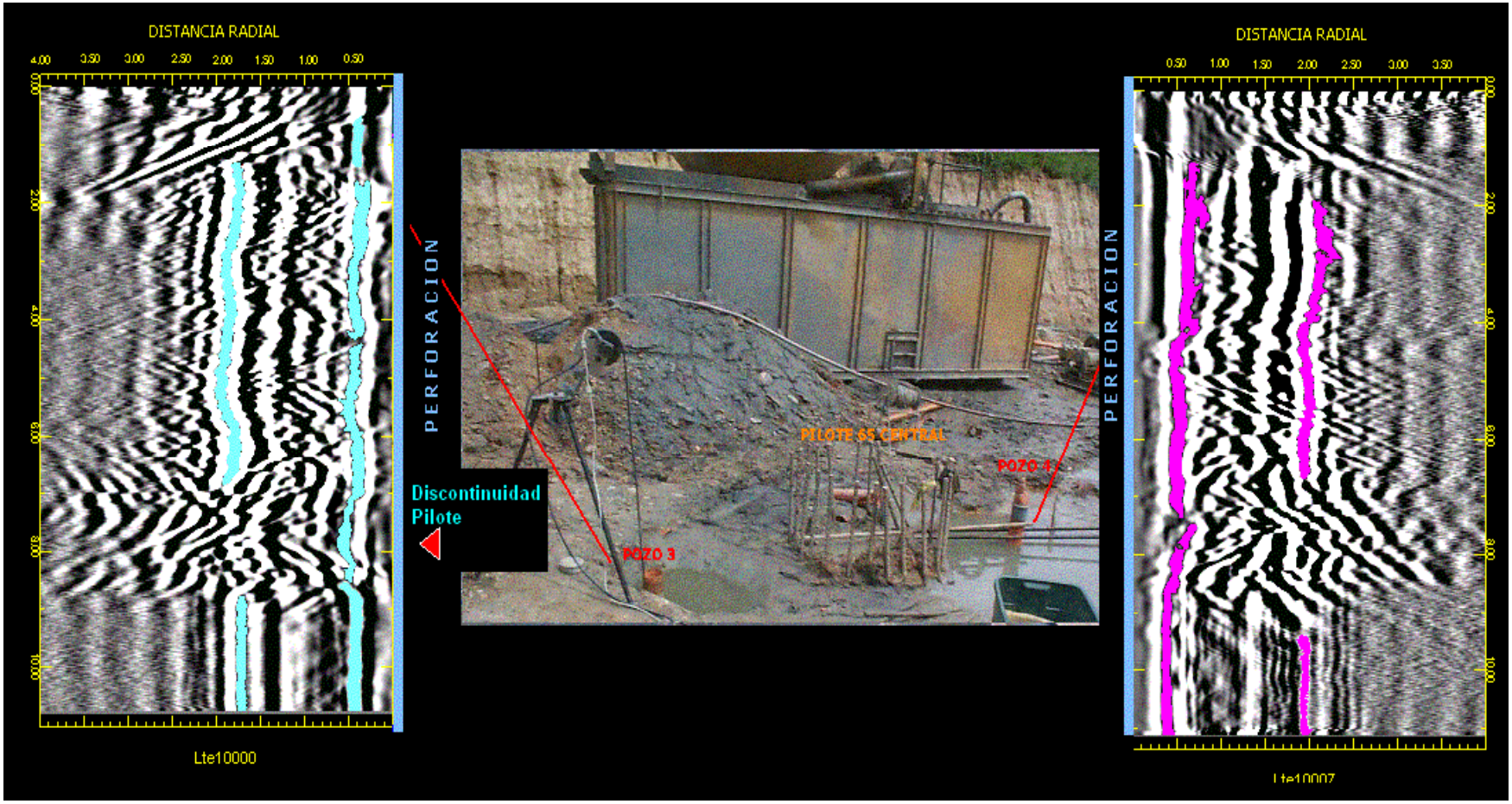
Pile wall



Pile wall

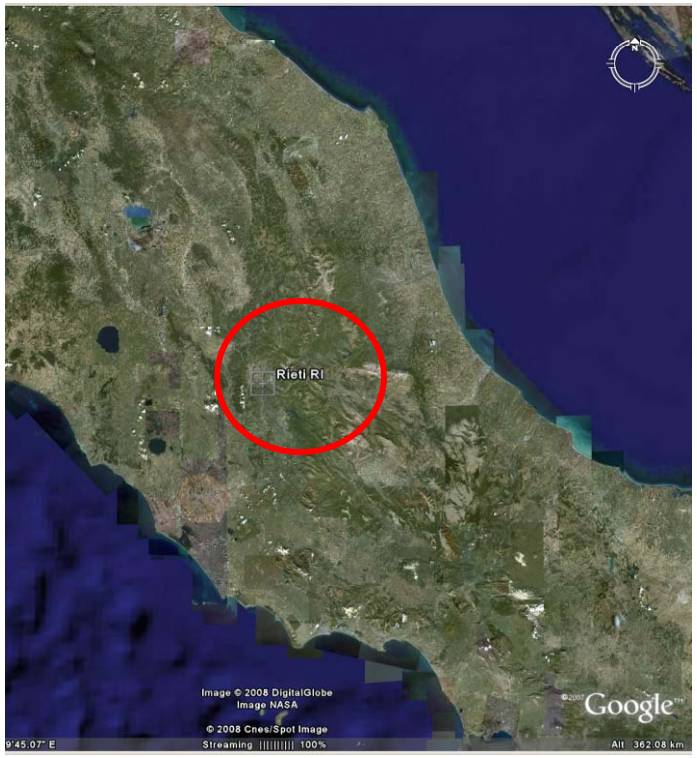
Profondità ed integrità dei pali

Ricostruzione della Parete dei pali e localizzazione di eventuali discontinuità



TUNNEL e PONTI

Indagini GPR Borehole in tunnel (1/2):



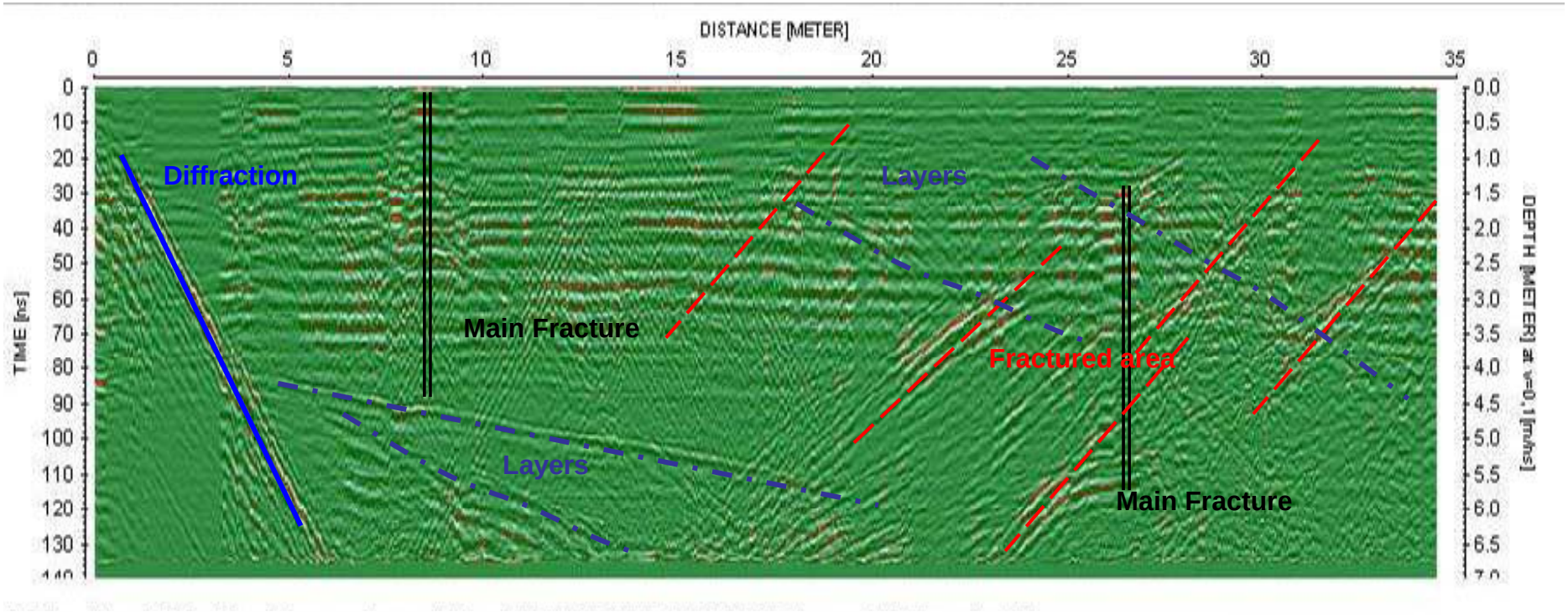
Rieti area-Italy

Presenza di problemi strutturali in un tunnel lungo la linea ferroviaria tra Terni e Rieti - Italy:

- Preseza di fratture nella struttura del ponte e nella roccia
- Presenza di stratificazione nella roccia

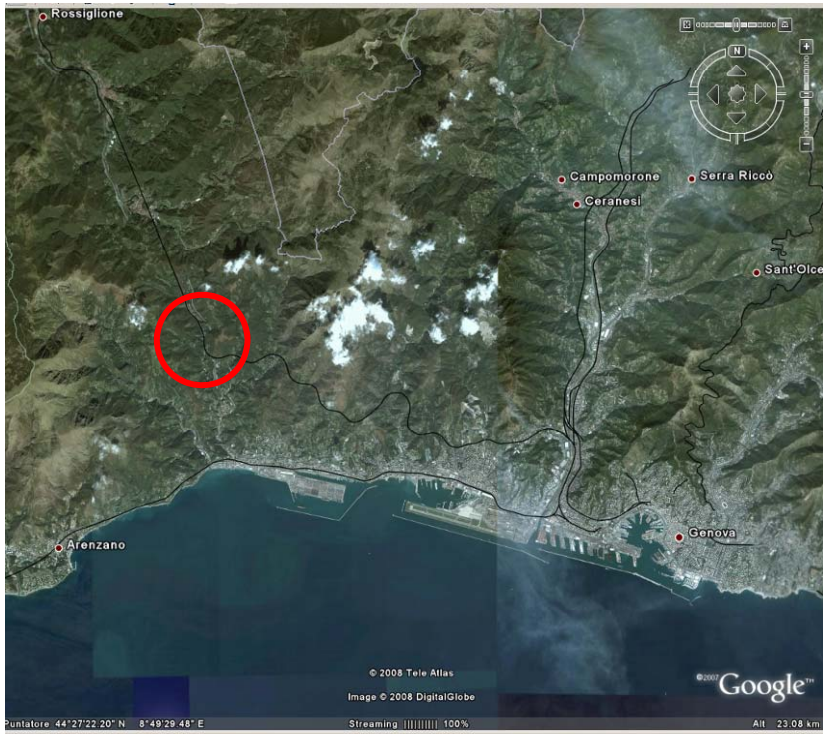
- Configurazione usata: Antenna Borehole a 150 MHz – Acquisizione Orizzontale

Indagini GPR Borehole in tunnel (2/2):



Bore Hole Results

Indagini GPR in un Tunnel ferroviario (1/2)



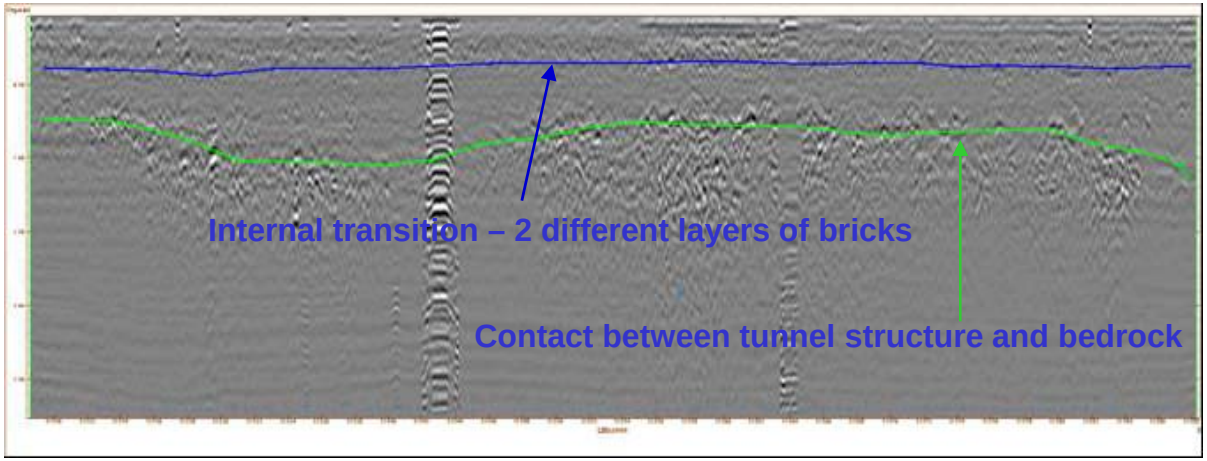
Gorsexio tunnel along the rail line Genova-Ovada (Italy)

Applicazione Geotecnica nel Tunnel di Gorsexio lungo la tratta ferroviaria Genova-Ovada (Italy):

- Studio delle fratture, della stratigrafia e delle anomalie per valutare la stabilità della struttura e le aree a rischio di infiltrazioni di acqua.
- Configurazioni usate: Sistema GPR con antenne a 200MHz e 600 MHz

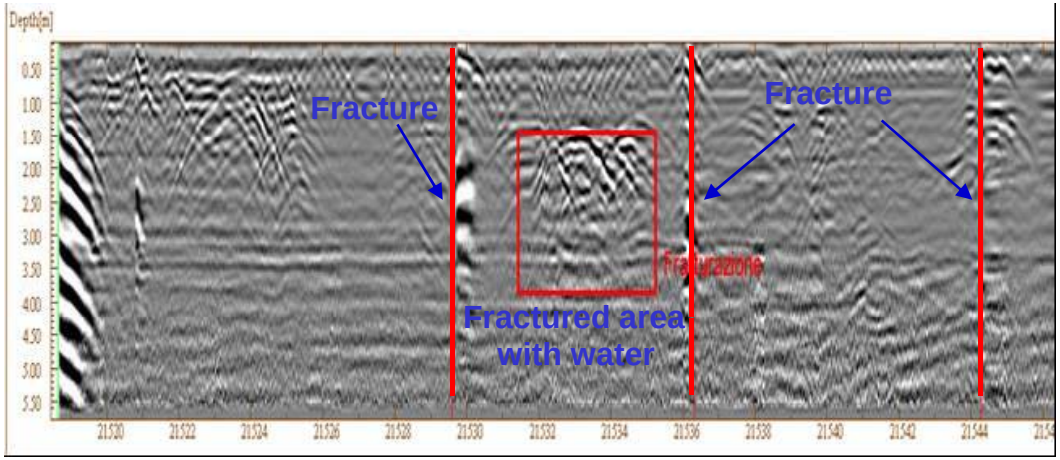
Gorsexio Tunnel – Acquisition phase

Indagini GPR in un Tunnel ferroviario (2/2)



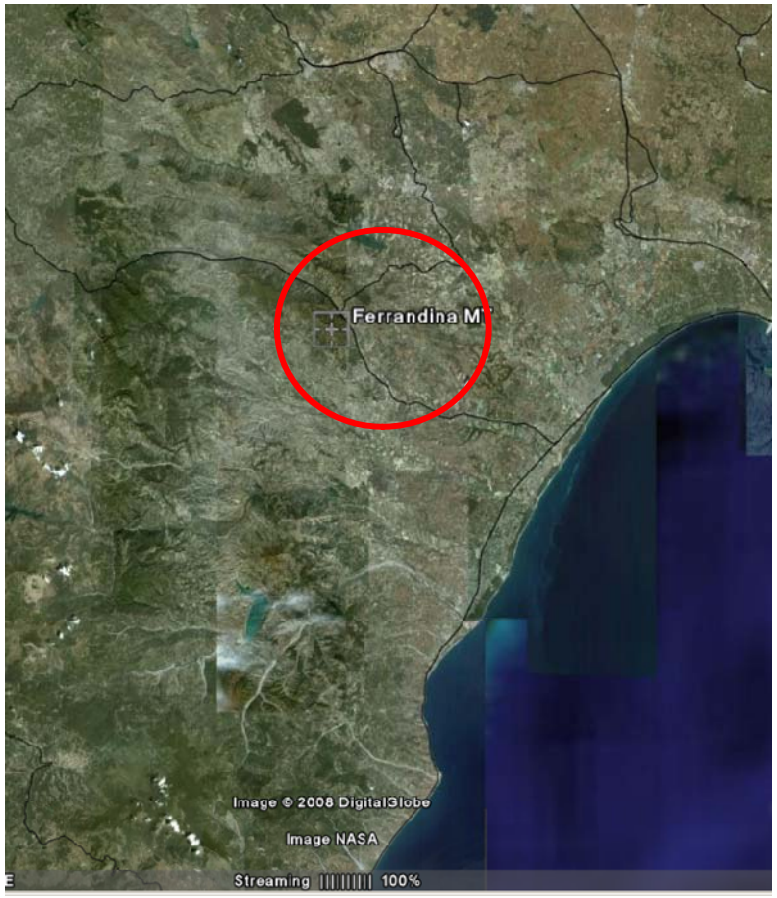
600 MHz Results

Gorsexio Tunnel
Acquisition phase



200 MHz Results

Indagini GPR in un Tunnel ferroviario (1/2)



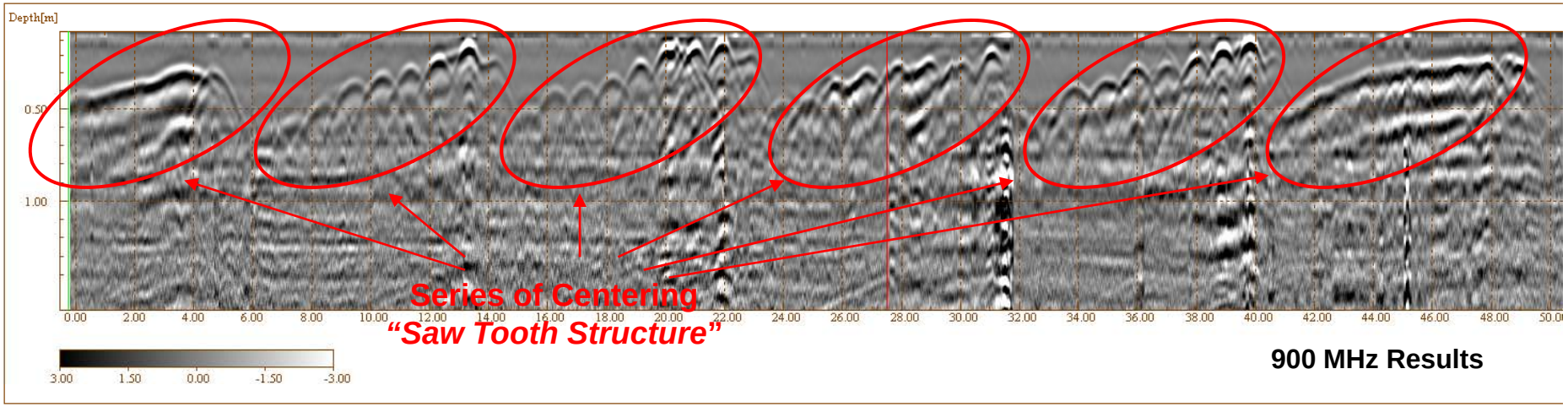
Ferrandina rail line (Italy)

Applicazioni Geotecniche in un Tunnel in costruzione lungo la tratta ferroviaria Ferrandina - Matera (Italy). La tecnica GPR ha permesso di valutare:

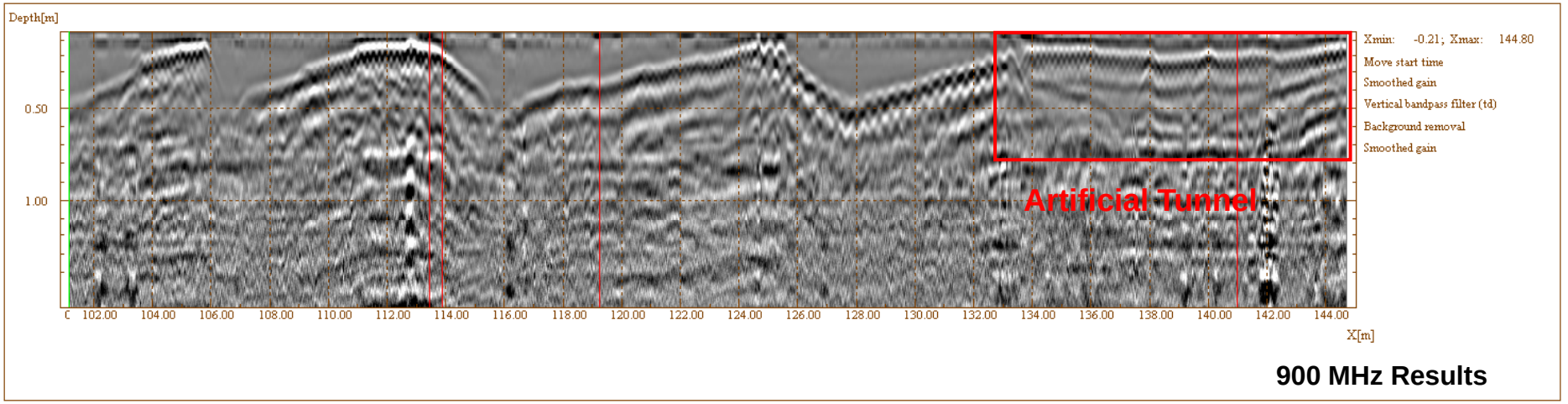
- La presenza di centine nel tunnel (numero e profondità) con una struttura a “dente di sega”
- La presenza della galleria artificiale

Configurazione Usata: Sistema GPR con antenna a 900MHz

Indagini GPR in un Tunnel ferroviario (2/2)

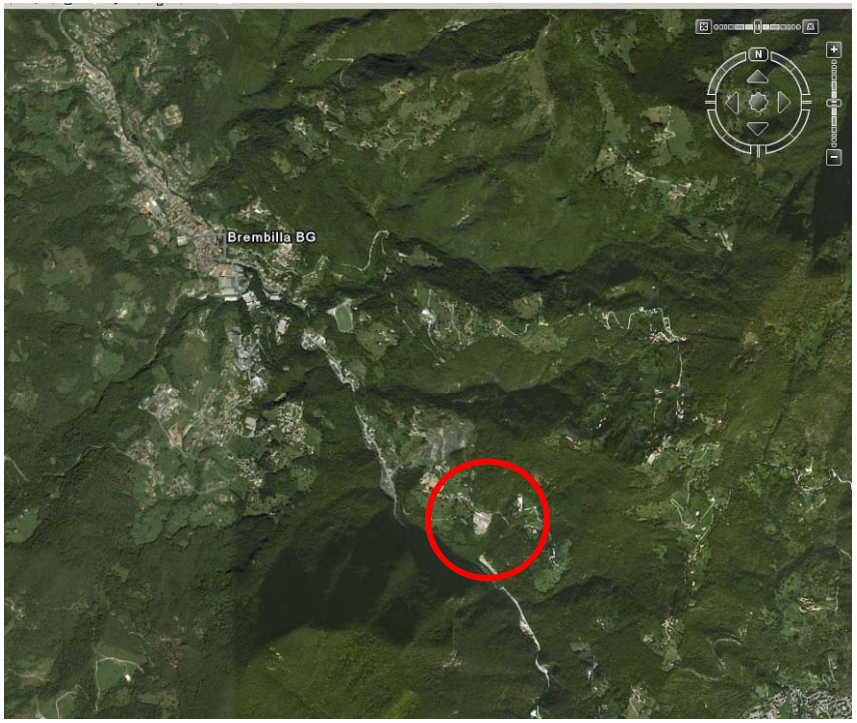


900 MHz Results



900 MHz Results

Indagine GPR a bassa frequenza in una galleria di servizio di una cava (1/2)



Brembilla Quarry -Italy

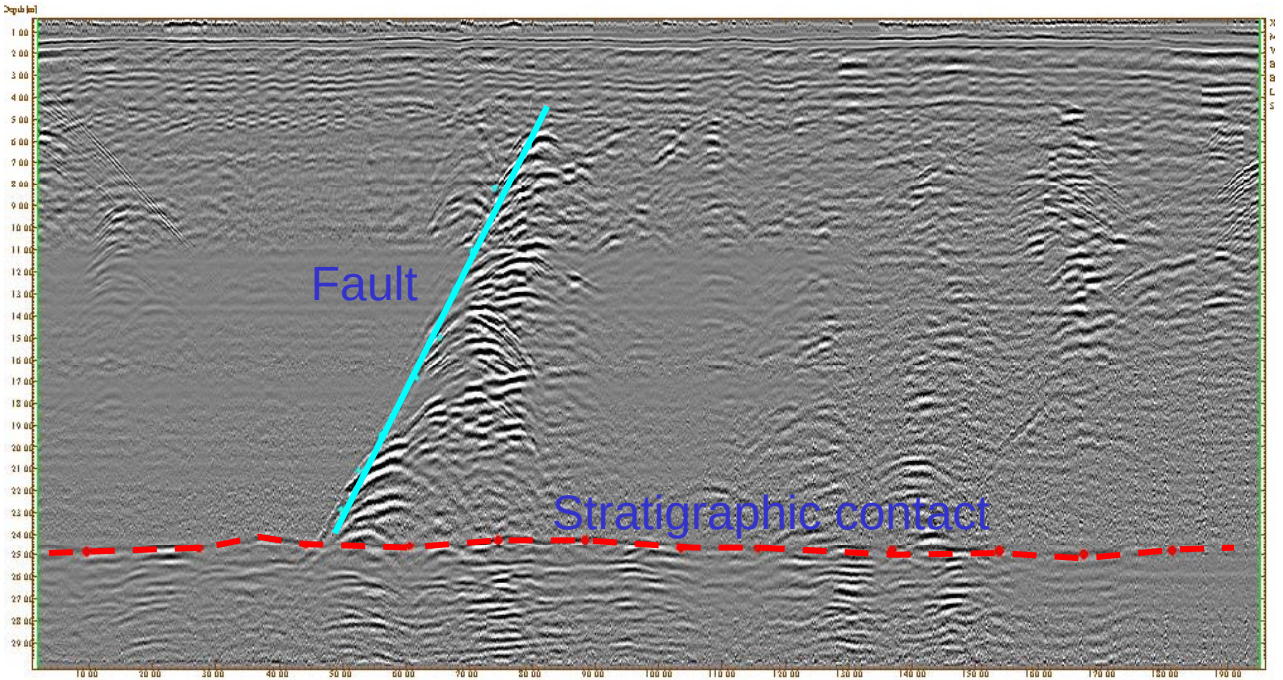
Applicazione Geotecnica in un tunnel nella cava di calcare di Brembilla (Bergamo)-Italy:

- Studio delle fratture e della stratigrafia in un tunnel per la valutazione della stabilità delle pareti.
- Configurazione Usata: Sistema con antenna ad 80MHz

Brembilla Quarry – Italy

Indagine GPR a bassa frequenza in una galleria di servizio di una cava (2/2)

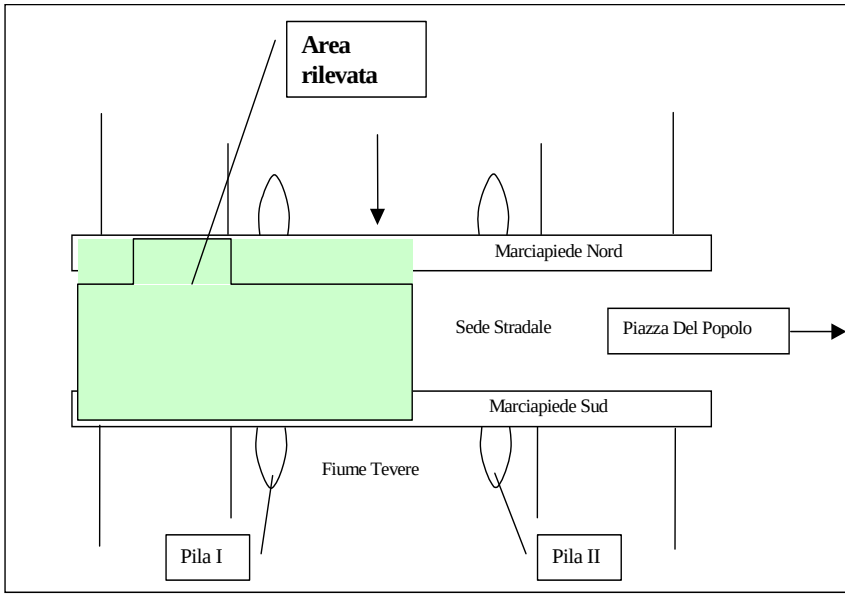
RIS Configuration with 80 MHz Shielded Antenna- Acquisition Phase



80 MHz Antenna Results

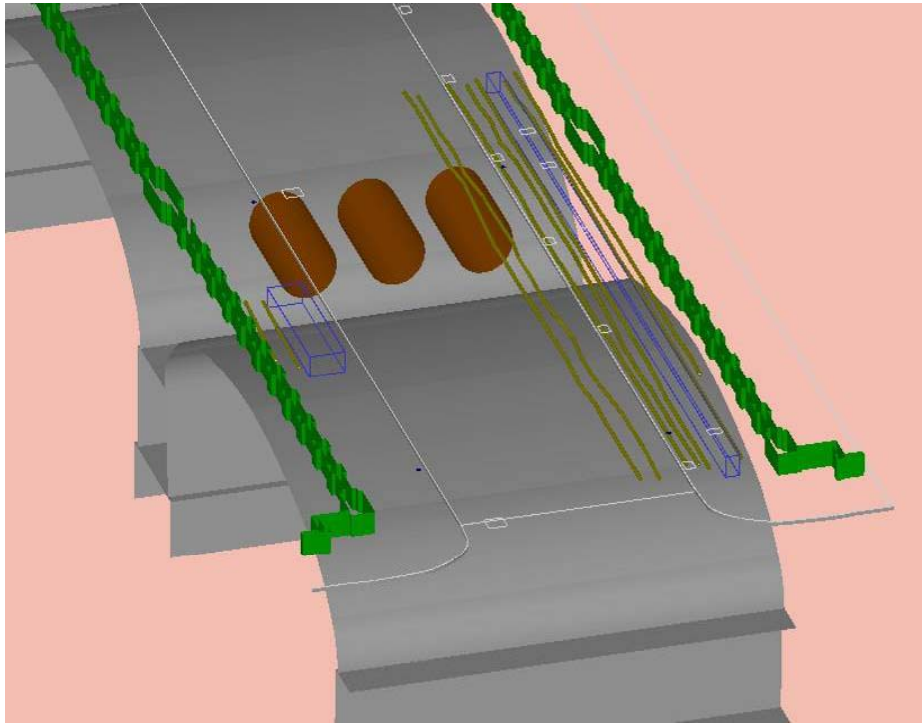
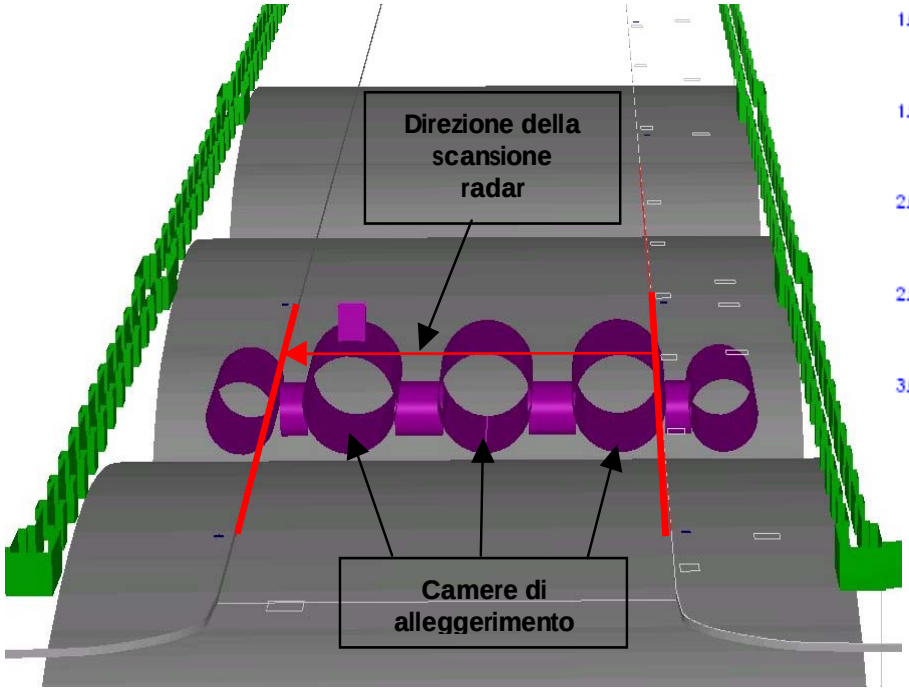
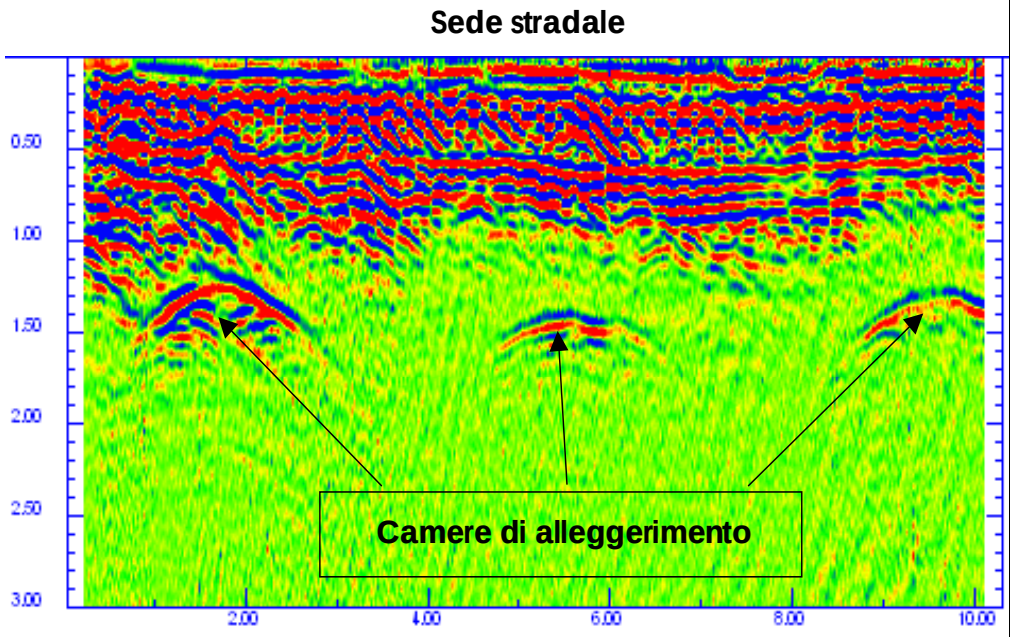
PONTE: REGINA MARGHERITA – ROMA (ITALY)

L’indagine sul ponte Regina Margherita



L’area di indagine sul ponte

I target rilevati



L’indagine sul ponte Regina Margherita