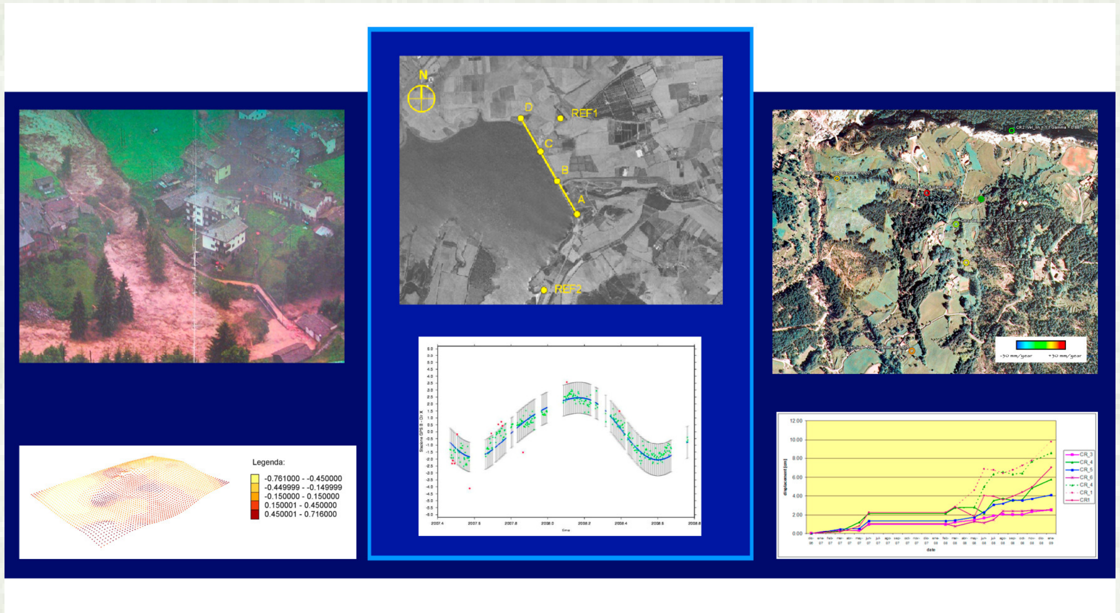
Monitoraggio del rischio ambientale: fotogrammetria, GPS ed Interferometria Radar



Alice Pozzoli

Dott. in Geodesia e Geomatica ed
in Informatique et Information
pour la Societé

Venezia, 15 Marzo 2011

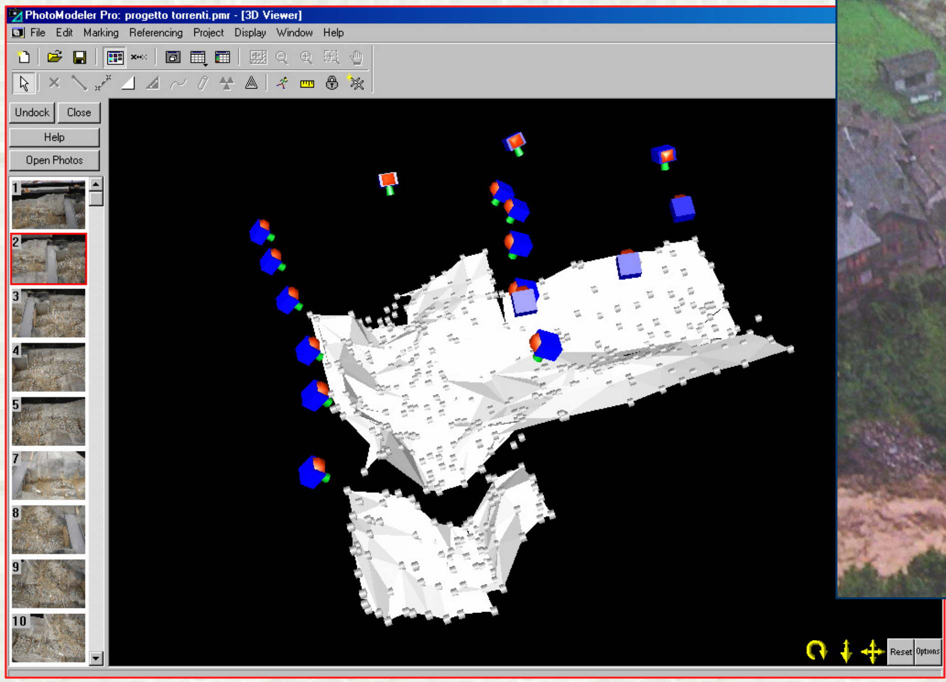
Organizzazione della Presentazione

- Tesi di Dottorato: *"Data and Quality Metadata for continuous field: Terrain and Photogrammetry"*
  - *Geo-data*
  - *Fotogrammetria analitica*
  - *Applicazione di monitoraggio ambientale*

- Assegno di ricerca al DIIAR del Politecnico di Milano: *"Analisi di serie temporali di dati finalizzate al monitoraggio ambientale"*

- Contratto di ricerca presso l'Institut de Geomatica di Castelldefels: *"Interferometria radar per il monitoraggio ambientale"*

Data and Quality Metadata for continuos Fields: Terrain and Photogrammetry



INTRODUCTION

This thesis deals on data processing applied to photogrammetric image analysis. Therefore some aspects of geo-data and environmental monitoring (and photogrammetry) are not so deeply investigated.

The frame of the work is a Ph. D. curriculum in the macro area Environment and Security, set up by the Interpolytechnic School among the TU's of Turin, Milan and Bari.

Thanks to a co-tutoring agreement between the Politecnico di Milano and INSA de Lyon, the work improved Geodesy and Geomatic knowledge (Milan) with Computer Science and Geographic Information one (Lyon).

- INTRODUCTION
- PART I. THE GEO DATA
  - Part I Conclusion
- PART II. DATA ACQUISITION AND PROCESSING
  - Part II Conclusion
- PART III. AN APPLICATION
  - Part III Conclusion
- FINAL CONCLUSIONS

ORGANIZATION OF THE PRESENTATION

Part I. Geo-Data

Part II. Data Acquisition and Processing

Part III. Application

Final Conclusions

Part I – GEO-DATA

- Geo-data and interoperability
- Standard for geographic information
- XML Extensions
- GML
- Conceptual schema – UML/INTERLIS
- Model Driven Approach
- Data and metadata

GEO-DATA and INTEROPERABILITY

In our work we started from geographic data coming from photogrammetric survey to generate digital surface models either static or dynamic.

Some geographic data are continuous ones, and their codification has to consider all the process that brings to the reconstruction of their continuity.

Large amount of devices for surveying and monitoring

↓

Geographic data are very different among them

↓

Difficult to have data standard formats

Really important to pay attention in the:

- in the storage process
- in the model transfer
- in the standard used
- in the existence and quality data and metadata

GEO-DATA and INTEROPERABILITY

A data transfer method has to be adaptable for a real interoperability.

A model based transfer could be useful for the exchange between different software, local or regional extensions and for the mutations through the time (products and technology).

For a **model based transfer** we need:

- a standard language for **conceptual description** of data, defining univocally and consistently the data structure to transfer
- a procedure to obtain the **transfer standard** of data structure

ISO Norm for Data Transfer

Actual Status (2008)

Norm	Title	Status	Description
OMG UML	Unified Modeling Language	Different versions. 191xxx are based on UML 1.3	Class diagrams
ISO 19103	Conceptual Schema Language	DTS	UML restrictions + basic data type (text, numbers, etc.)
ISO 19109	Rules for application schema	DIS	Metamodel (=modeling language). Confused because UML and 19103 define the model language
ISO 19107	Spatial Schema	IS	Geometric data type (topology included)
ISO 19108	Temporal Schema	IS	Temporal data type (topology included)
ISO 19111	Spatial Referencing by coordinates	IS	Data model for spatial reference system for coordinates
ISO 19112	Spatial referencing by geographic identifiers	IS	Data model for geographic names
ISO 19123	Schema for coverage geometry and functions	DIS	Data model - Coverage
ISO 19115	Metadata	IS	Data model for Metadata
ISO 19118	Encoding	DIS	Codification rules for data transfer. Must be univoque and complete for interoperability
W3C XML	XML	1.0 (rarely 1.1)	Flexible text format
W3C XML-Schema	XML-Schema	1.0	Description language for XML data
ISO 19136	Geography Markup Language	IS (GML 3.2)	Common specification of OGC and ISO for data transfer

ISO Norms (WD: Working Daft; CD: Committee Draft; DIS/DTS: Draft International Standard/Drat; Technical Specification; FDIS: Final Draft International Standards; IS: International Standard)

XML – Extensible Markup Language

- Independence of data from software and platforms
- It is a modular language and it can be easily adapted
- Permits definition of new entities and attributes
- It is the syntactic and grammatical base of other formats and it is very spread for the geographic data
- It is associated to a robust protocol like http

XML is a really good starting point for other more specific languages with more utilities for the geo-data. XML can be extended to territorial data, and needs to be extended for more complex applications.

XML Extensions

- SVG
- GML
- LandXML
- CityGML
- FieldXML

XML Extensions

- SVG
- GML
- LandXML
- CityGML
- FieldXML

- Universal use of GML as a standard for geo-referenced data (recommended by ISO)
- Base for Internet GIS
- Integration with XML data
- Geometry codification
- Integration of spatial and non-spatial element

GML is a powerful format for geographic data

GEO-DATA ORGANISATION

Model Approaches

GML for data modeling could be used:

- as storage application → information are stored directly in GML
- only for schema and data transport → information are converted from some other storage format on demand and GML is used only for schema and data transport

With the introduction of GML, we have two different approaches for data modeling:

- UML model as visualization tool + GML Schema as reference standard
- UML model as reference standard + GML Schema as transfer format

GEO-DATA ORGANISATION
Model Approaches

GML for data modeling could be used:

- as storage application → information are stored directly in GML
- only for schema and data transport → information are converted from some other storage format on demand and GML is used only for schema and data transport

With the introduction of GML, we have two different approaches for data modeling:

- UML model as visualization tool + GML Schema as reference standard
- UML model as reference standard + GML Schema as transfer format

UML model is decisive and the GML Schema is automatically derived from it

GEO-DATA ORGANISATION

Model Approaches

GML for data modeling could be used:

- as storage application — information are stored directly in GML
- only for schema and data transport — information are converted from some other ...

The UML model describes only the data structure, while the format used is created automatically from the encoding rules

Some GML functionalities could not be used because in the ISO 19136 (Annex E) some encoding rules from UML to GML are missing

Other transfer formats could be generated from the same UML model

A UML model translation is needed for the real format transformation. (UML model, transfer format and translation rules)

- UML model as reference standard + GML Schema as transfer format

UML model is decisive and the GML Schema is automatically derived from it

GEO-DATA ORGANISATION
Model Driven Approach

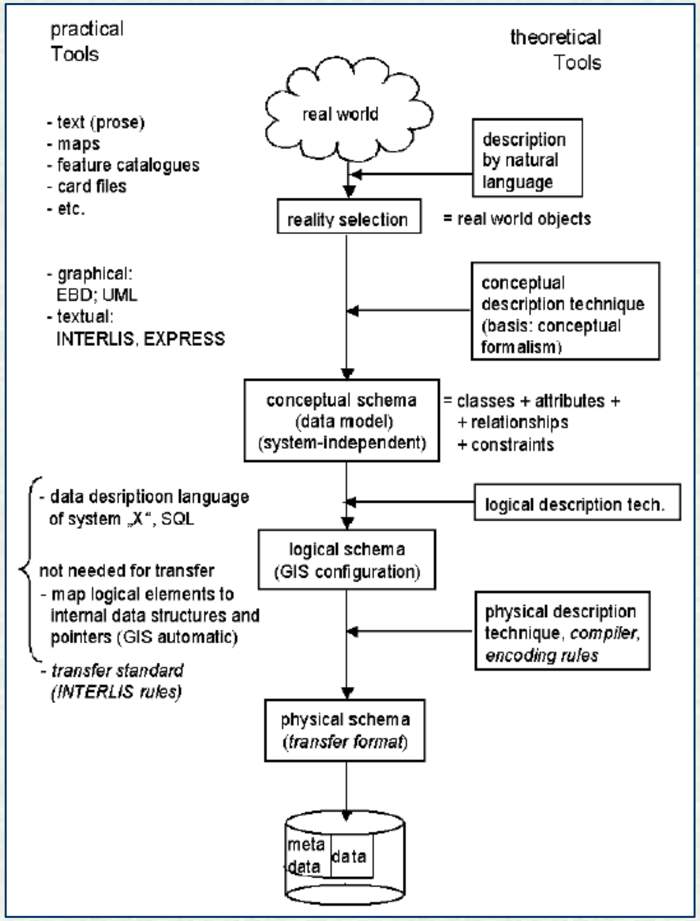
The model-driven approach (MDA) is a really useful strategy for data transfer independent from the used format or system.

Based on a first exact description of the structure of the data to be transferred

Conceptual database model or conceptual schema

The transfer format can then automatically be derived from the conceptual schema according to rules (once fixed a standard) by a compiler.

Transfer format (e.g. GML Schema)



GEO-DATA ORGANISATION

ISO/TC211 experience shows that geographic information standardization is only possible at the system-independent conceptual level and focuses on a model-driven approach for mapping these to XML

Conceptual database schema

The conceptual level describes what kind of information is stored in the database.

At this level we define accurately what the data contents are, the relationships among the data, and the constraints they should hold on this data.

Unified model language (UML) has been selected as the normative specification language within ISO/TC211 since 1998 [ISO19103]

UML model description in ISO 19115/2003 is **too general for a real application.**

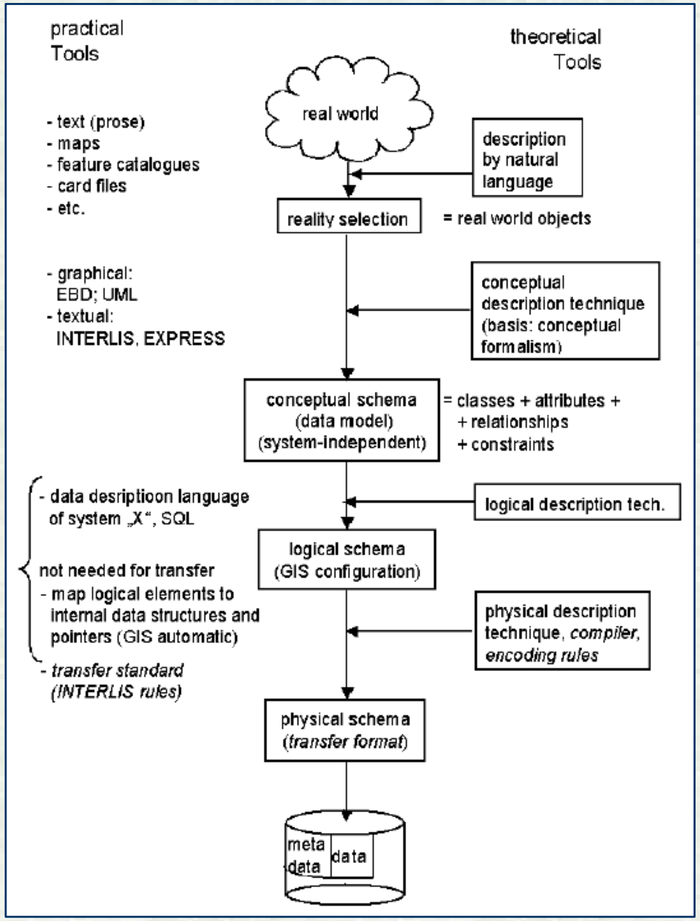
Switzerland detailed the UML model creation in a **standard language INTERLIS2**.

GEO-DATA ORGANISATION
UML and INTERLIS

INTERLIS is a **textual form of UML**, very similar to a programming language and easy to improve and integrate with different utilities.

It contains encoding rules for the automatic generation of XML and GML Schema.

INTERLIS is one among few available and operative solution with all the necessary tools that **permits the realization of the model-driven approach**.



GEO-DATA DESCRIPTION
Metadata

- Increasing quantity of data coming from different and non-conventional sources
- GPS networks more and more widespread
- a wide sensor's network control and exchange geographic data for different and non-homogeneous applications
- GIS as basic support for many decisions in social fields
- …

Non-quality data

To reduce the risk of redundancies and waste (of time and money) a standard definition and evaluation of data and metadata quality become necessary

GEO-DATA DESCRIPTION

Metadata

- Increasing quantity of data coming from different and non-conventional sources
- GPS networks more and more widespread
- a wide sensor's network control and exchange geographic data for different and non-homogeneous applications
- GIS as basic support for many decisions in social fields
- …

Non-quality data

ISO number	Name	Year	EN ISO
ISO 19113	*Geographic Information – Quality principles*	*2002*	*EN ISO 19113:2005*
ISO 19114	*Geographic Information – Quality evaluation procedures*	*2003*	*EN ISO 19114:2005*
ISO 19115	*Geographic Information - Metadata*	*2003*	*EN ISO 19116:2005*

Conclusion of *PART I*

- Model-driven approach is a good option for the description and the transfer of geo-data, it is the only operative solution for an interoperable data transfer
- Using INTERLIS there are many advantages about the consistency of the model description and it becomes easier to pass from the conceptual model (in UML) to a GML schema and if it is necessary to go back
- Thanks to all the norms and specifications about geo-data the procedure for data transfer is well documented and has a high control even for the quality of the data, including a large amount of metadata

Part II – Data Acquisition and Processing

- Automatic procedure for external orientation of 3 images (ORTRE)

  This procedure it is relevant when we are working with big unknown rotation angles (e.g. Police image in car crash)

- Rigorous adjustment (CALGE)
- Integrated approach (Dynamic behavior)
- Post-analysis

Three Image Orientation (ORTRE)

The main function of Photogrammetry is the transformation of data from the image space to the object space.

- **One step** procedure (collinearity equations)
- **Two steps** procedure (Relative Orientation + Absolute Orientation)

Three Image Orientation (ORTRE)

The main function of Photogrammetry is the transformation of data from the image space to the object space.

- One step procedure (collinearity equations)

Position and attitude angle parameters of two images

12 parameters

$(X_i \; Y_i \; Z_i \; \omega_i \; \phi_i \; k_i)$

Three Image Orientation (ORTRE)

The main function of Photogrammetry is the transformation of data from the image space to the object space.

- One step procedure (collinearity equations)

- **Two steps** procedure

(Relative Orientation) **5 parameters**

$b_y\ b_z\ \omega_2\ \phi_2\ k_2$ *(asymmetric)*

$\phi_1\ k_1\ \omega_2\ \phi_2\ k_2$ *(symmetric)*

+

(Absolute Orientation) **7 parameters**

$t_x\ t_y\ t_z\ \lambda\ \Omega\ \Phi\ K$

Three Image Orientation (ORTRE)

- The main function of Photogrammetry is the transformation of data from the image space to the object space.

- One step procedure (collinearity equations)

- Two steps procedure

Position and attitude angle parameters of the second image, compared to the first image

Position and attitude angle parameters of the two images

(Relative Orientation) **5 parameters**

$b_y\ b_z\ \omega_2\ \phi_2\ k_2$ *(asymmetric)*

$\phi_1\ k_1\ \omega_2\ \phi_2\ k_2$ *(symmetric)*

+

(Absolute Orientation) **7 parameters**

$t_x\ t_y\ t_z\ \lambda\ \Omega\ \Phi\ K$

Three Image Orientation (ORTRE)

The main function of Photogrammetry is the transformation of data from the image space to the object space.

- One step procedure (collinearity equations)
- Two steps procedure

(Relative Orientation) **5 parameters**

$b_y \; b_z \; \omega_2 \; \phi_2 \; k_2$ *(asymmetric)*

$\phi_1 \; k_1 \; \omega_2 \; \phi_2 \; k_2$ *(symmetric)*

+

(Absolute Orientation) **7 parameters**

$t_x \; t_y \; t_z \; \lambda \; \Omega \; \Phi \; K$

Shift vector, scale factor and attitude angle parameters of the model

Three Image Orientation (ORTRE)

- The main function of Photogram... ...ion of data from the image space to the object space

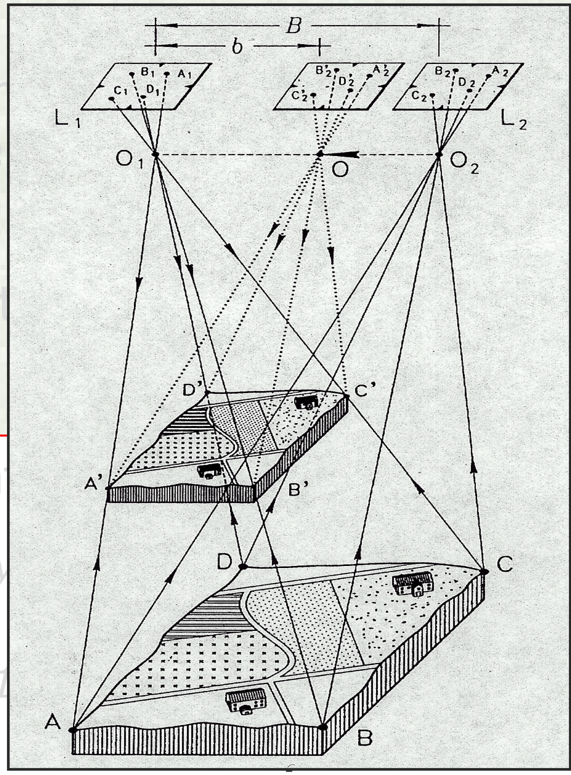
- One step procedure (collinearit...

- Two steps procedure

(Rela... ...eters

b_y ... c)

ϕ_1 ... ic)



(Absolute Orientation) **7 parameters**

$t_x\ t_y\ t_z\ \lambda\ \Omega\ \Phi\ K$

A variation of b_x produces only a scale variation and not a shape one

Three Image Orientation (ORTRE)

- The main function of Photogrammetry is the transformation of data from the image space to the object space.

- One step procedure (collinearity equations)

- Two steps procedure (Relative Orientation + Absolute Orientation)

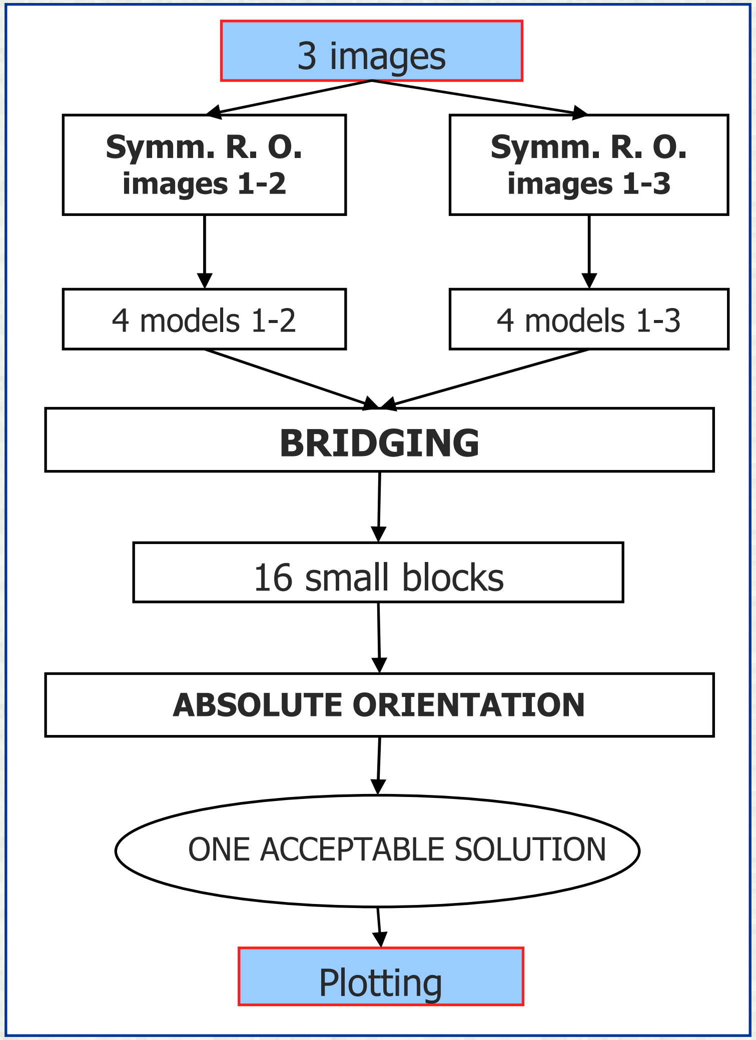
It is not always so easy to have the preliminary values of the unknown parameters. Especially in non-conventional photogrammetry (non professional images, image coming from unknown or old sources, equipped vehicles, robots...)

Our method does NOT need preliminary values

ORTRE - Three Image Orientation

Global Procedure

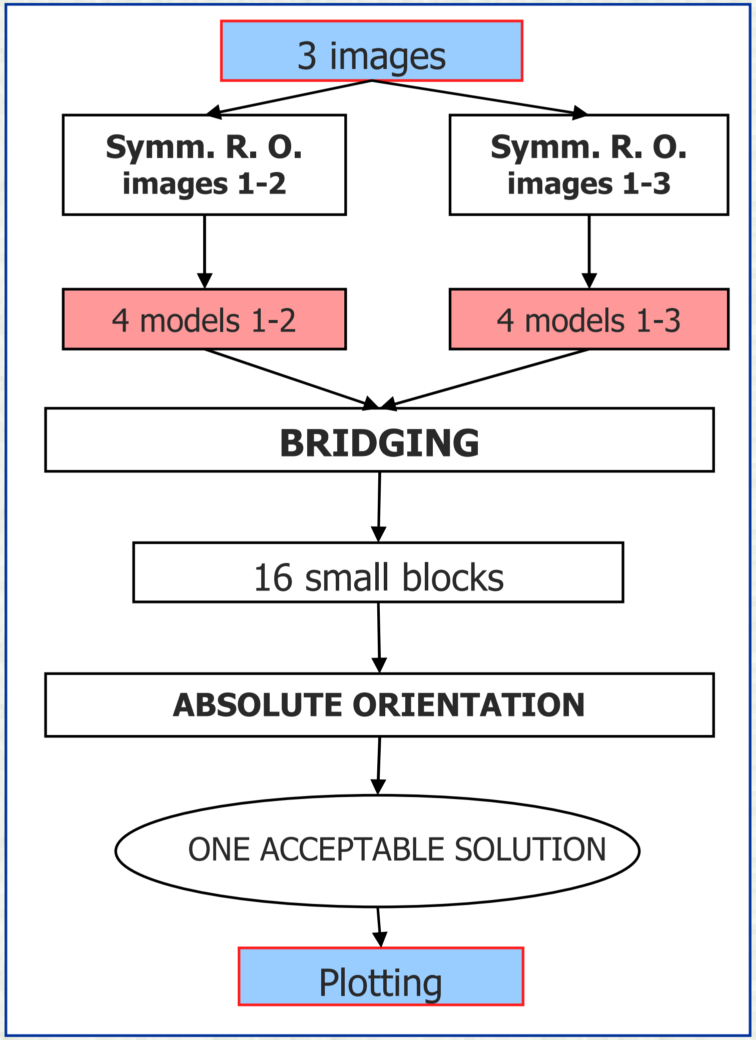
- 3 images
- Symmetric Relative Orientation
- 4 models
- Bridging
- 16 blocks
- Absolute Orientation
- One solution



ORTRE – Three Image Orientation

Global Procedure

- 3 images
- Symmetric Relative Orientation
- 4 models
- Bridging
- 16 blocks
- Absolute Orientation
- One solution



ORTRE – Model Formation

Thanks to an exhaustive research of all the possible preliminary values we manage to solve a linear system for each of the 12800 founded cases.

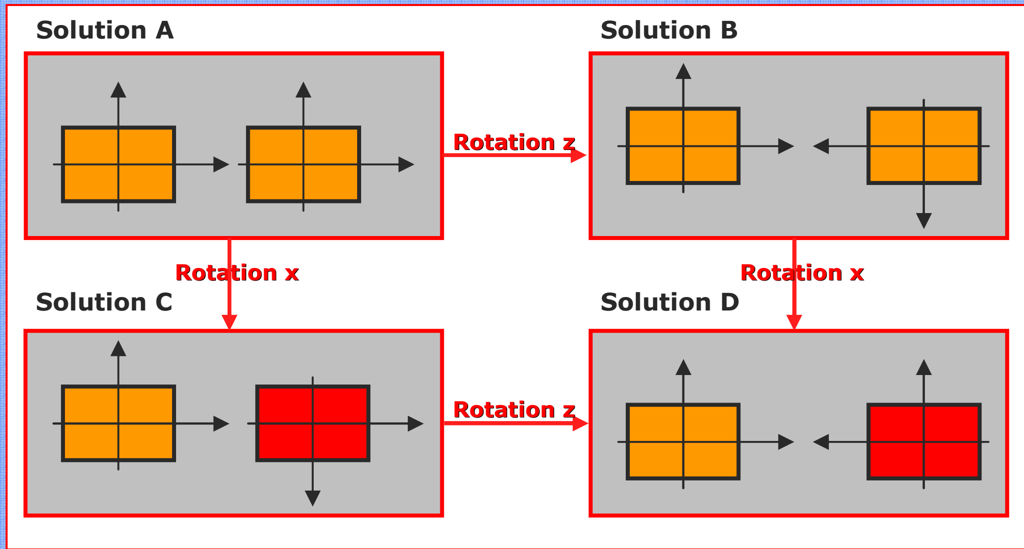
Convergence of linearization of trigonometric function is acceptable as far as values lower or near $\pi/4$.

Each linear system give us the estimated parameters for the Symmetric Relative Orientation to be converted in those of the Asymmetric Relative Orientation.

We found four analytical acceptable configurations for each pairs of images.

	φ_1	$k1$	ω_2	φ_2	$k2$
–Π/2	o			o	
–Π/4	•			•	
0	•	•	•	•	•
Π/4	•	•	•	•	•
Π/2	o	•	•	o	•
3Π/4		•	•		•
Π		•	•		•
5Π/4		•	•		•
3Π/2		•	•		•
7Π/4		•	•		•

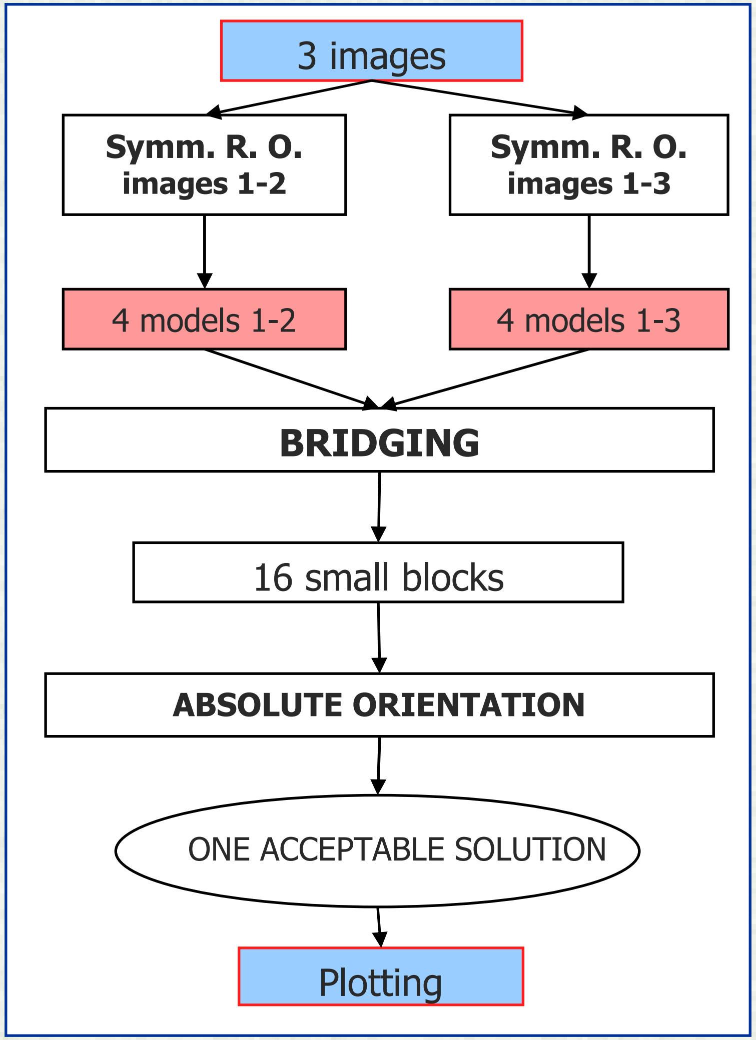
o $k_1 \equiv 0$ if $\varphi_1 \equiv \pm\Pi/2$ and/or $k_2 \equiv 0$ if $\varphi_2 \equiv \pm\Pi/2$



ORTRE – Three Image Orientation

Global Procedure

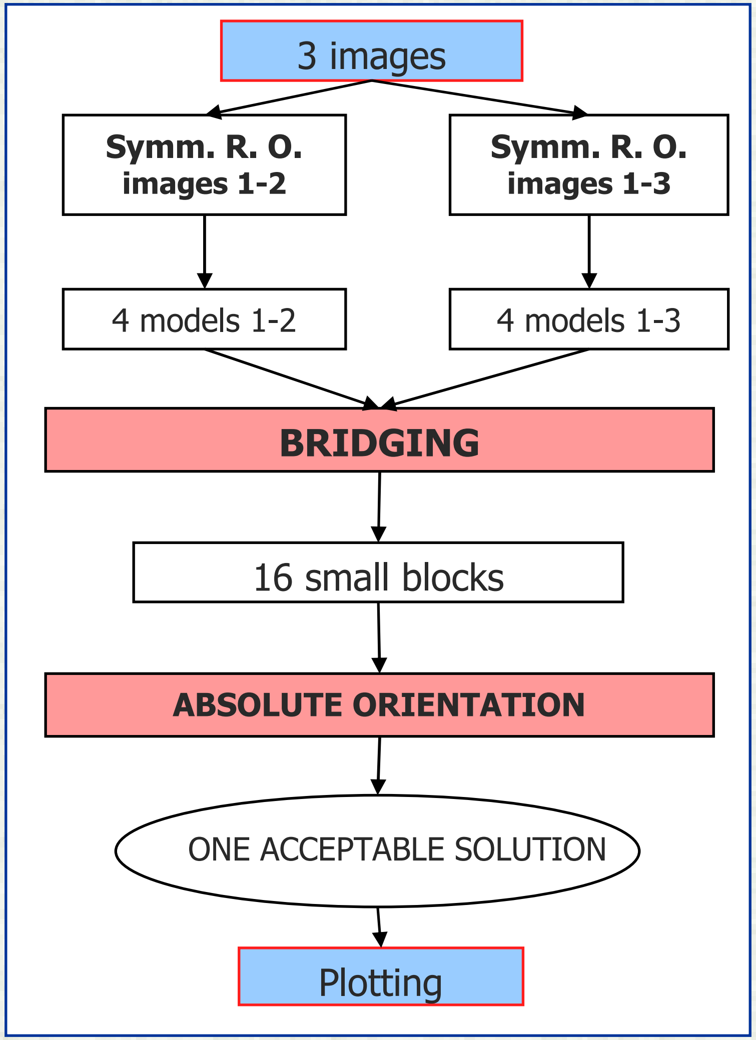
- 3 images
- Symmetric Relative Orientation
- 4 models
- Bridging
- 16 blocks
- Absolute Orientation
- One solution



ORTRE – Three Image Orientation

Global Procedure

- 3 images
- Symmetric Relative Orientation
- 4 models
- Bridging
- 16 blocks
- Absolute Orientation
- One solution



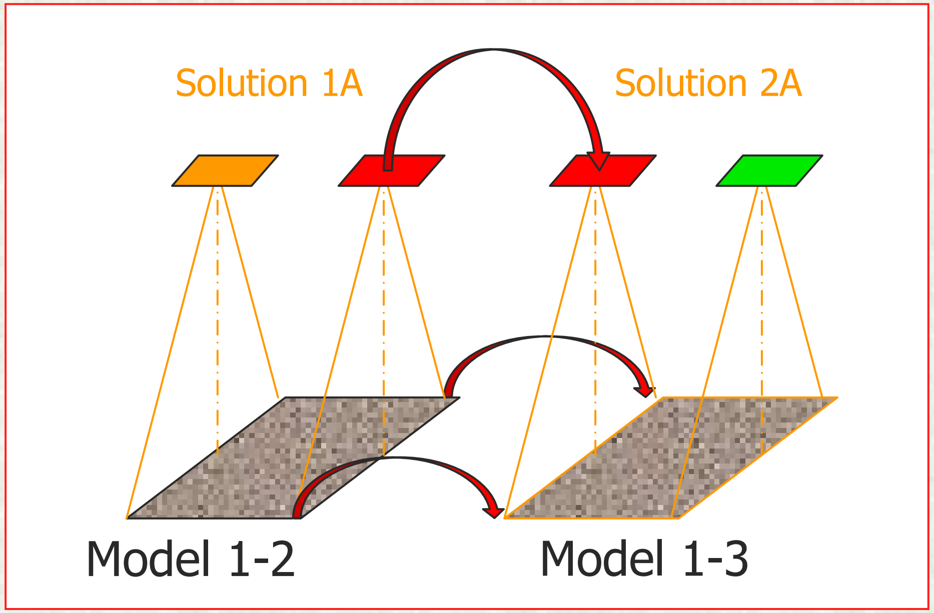
ORTRE – Bridging and Absolute Orientation

Model Construction furnishes 4 admissible solutions, and produce 4 distinct models.

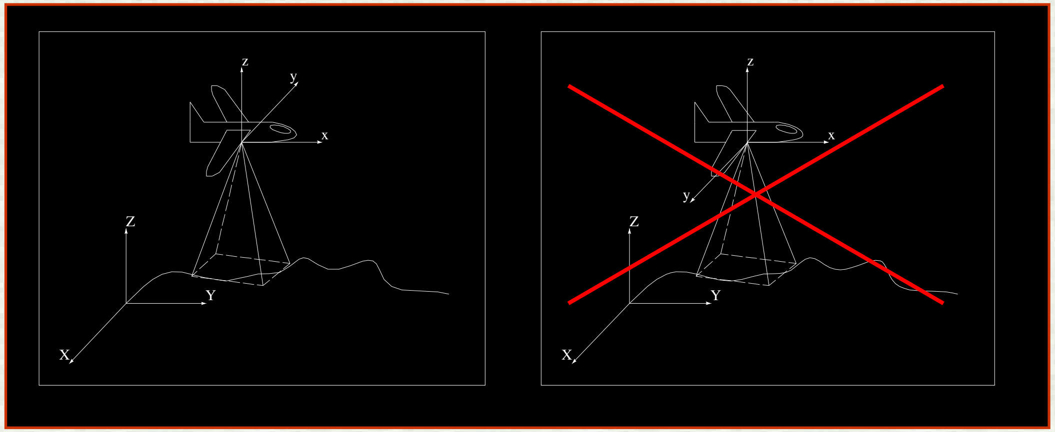
A 3D S-transformation allows to make the Bridging of these models.

The procedure leads to 16 different small blocks (only 2 of these small blocks are congruent).

Object reconstruction finds the unique congruent configuration.



Model Bridging

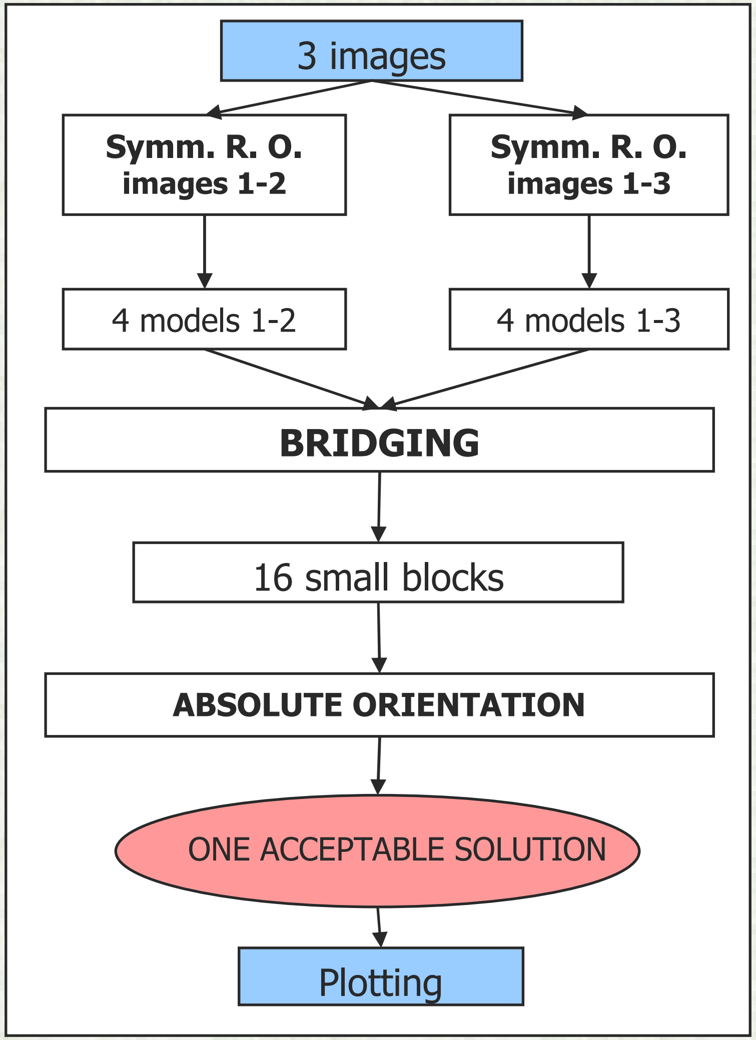


	2A	2B	2C	2D
1A	1A-2A	1A-2B	1A-2C	1A-2D
1B	1B-2A	1B-2B	1B-2C	1B-2D
1C	1C-2A	1C-2B	1C-2C	1C-2D
1D	1D-2A	1D-2B	1D-2C	1D-2D

ORTRE – Three Image Orientation

Global Procedure

- 3 images
- Symmetric Relative Orientation
- 4 models
- Bridging
- 16 blocks
- Absolute Orientation
- One solution

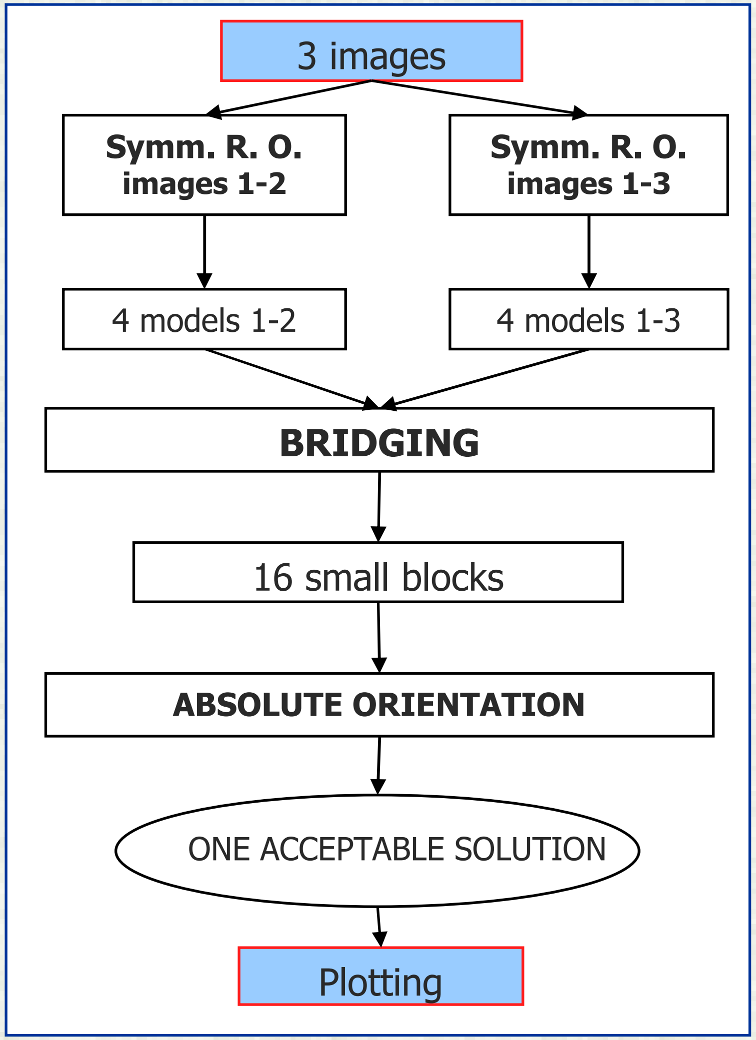


ORTRE – Advantages

Advantages of the procedure

- It doesn't need any preliminary values of the unknown parameters
- It runs automatically without interactive control

This procedure is usually completed by a rigorous adjustment by least squares.



Rigorous Adjustment - CALGE

Joint adjustment of geodetic networks and photogrammetric blocks.

Properties:

- Robust detection of outliers, down-weighting suspected observations
- A posteriori control on reliability and conditioning
- Refinement of stochastic model
- Camera self-calibration

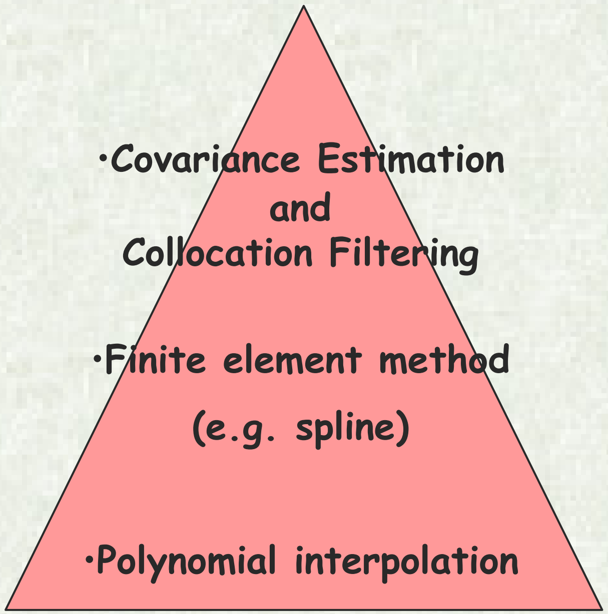
Input

- Images coordinates
- Object coordinates (GCP's)
- Preliminary values of the unknown parameters of external orientation (ORTRE)
- Accuracy of the observations

Output

- Object coordinates
- Adjusted parameters of external orientation
- Accuracy of the estimates
- Statistical and numerical additional information

3D MODELING + time – Integrated approach



THREE LEVEL PROCEDURE

1. Firstly low level polynomial interpolation removes a general trend
2. Finite element method (e.g. spline) to match local variations
3. Collocation, based on covariance estimation, filter signal from the noise, assuming the topography and/or dynamic to be a realization of a stochastic process

POST-ANALYSIS

for the study of the Solution Quality

After the rigorous network adjustment, as well as after a space-time modeling, residuals and/or noise remain in the data.

A post-analysis proceed to the study of the solution quality, trying to learn from residuals and/or noise a better knowledge of the phenomena.

A program of post-analysis is able to study errors charts (1 2 3D+t and 1 2 3 components).

Conclusion of *PART II*

- The whole photogrammetric method is very general and could be easily used by users not skilled in photogrammetry
- The integrated approach could spatio-temporally model scene sequences
- The post-analysis procedure is an important tool for the assessment solution quality and the model validation

Part III – Application

To test the procedure we compute a dynamic survey, as direct application of the work developed in this thesis.

The environmental monitoring is a really actual task and the integration, and development, with modern and non-conventional technologies is more and more frequent.

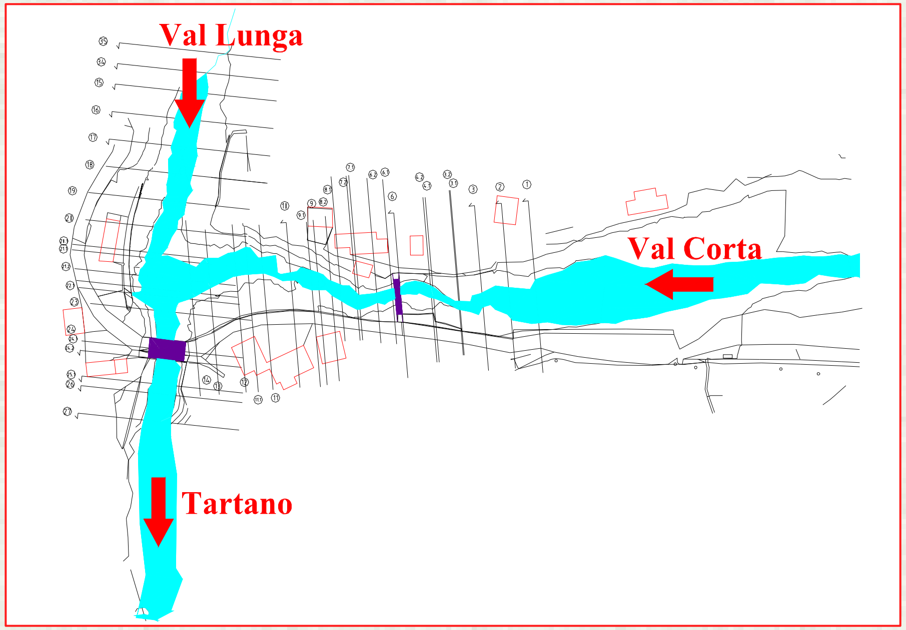
We integrated:

- Data processing
- Geo-data analysis
- Photogrammetry
- Hydrology

APPLICATIONS

Environment and Security Monitoring

Because of its size and nature, the confluence of two streams, named Vallunga and Valcorta, which after their confluence forms the stream, named Tartano, is quite important to study a typical phenomenon in the Alpine region of Valtellina in the north part of Italy. We want to give a powerful procedure to survey the dynamic behavior of the water surface in this critical zone.



Principal model parameters:

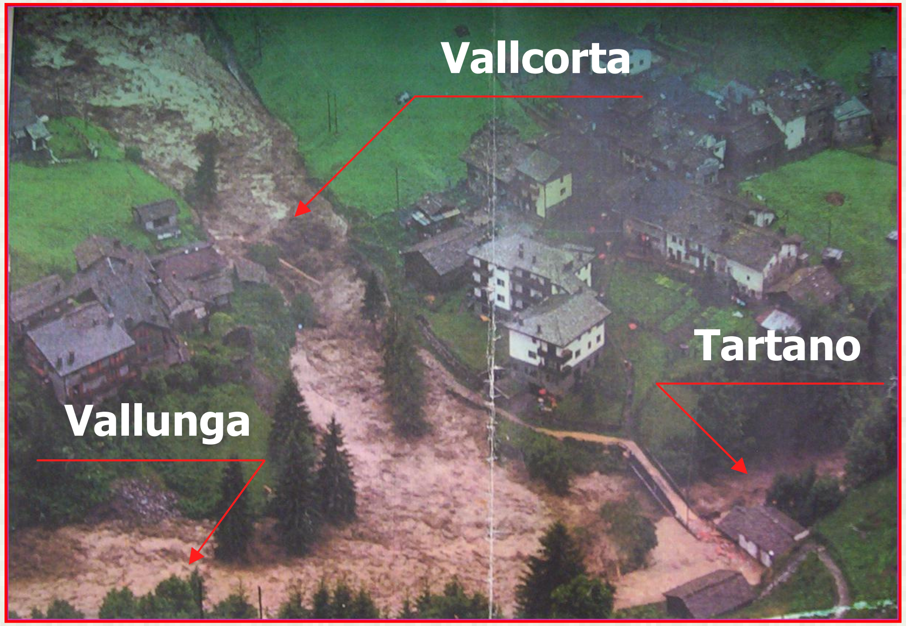
unbiased geometric scale	1:30
length	$\lambda_l = 1 : 30$
volume	$\lambda_W = 1 : 27000$
speed	$\lambda_V = 1 : 5.5$
time	$\lambda_t = 1 : 5.5$
flow rate	$\lambda_Q = 1 : 4930$

APPLICATIONS

Environment and Security Monitoring

Because of its size and nature, the confluence of two streams, named Vallunga and Valcorta, which after their confluence forms the stream, named Tartano, is quite important to study a typical phenomenon in the Alpine region of Valtellina in the north part of Italy. We want to give a powerful procedure to survey the dynamic behavior of the water surface in this critical zone.

Experiments on a physical model had the task to verify the existing situation and to detect the critical elements of the system. Taking into account the flooding in the 1987, the aim was to define eventual modifications in order to reduce the risk for the flooding itself. Notice that a bridge immediately after the stream confluence was overflowed during the above mentioned flooding.



Principal model parameters:

unbiased geometric scale	1:30
length	$\lambda_l = 1 : 30$
volume	$\lambda_W = 1 : 27000$
speed	$\lambda_V = 1 : 5.5$
time	$\lambda_t = 1 : 5.5$
flow rate	$\lambda_Q = 1 : 4930$

APPLICATIONS

Survey of a Hydraulic 3D Model

1st step – Static survey

Survey of the floor without water

Close range photogrammetry

2nd step - Dynamic survey

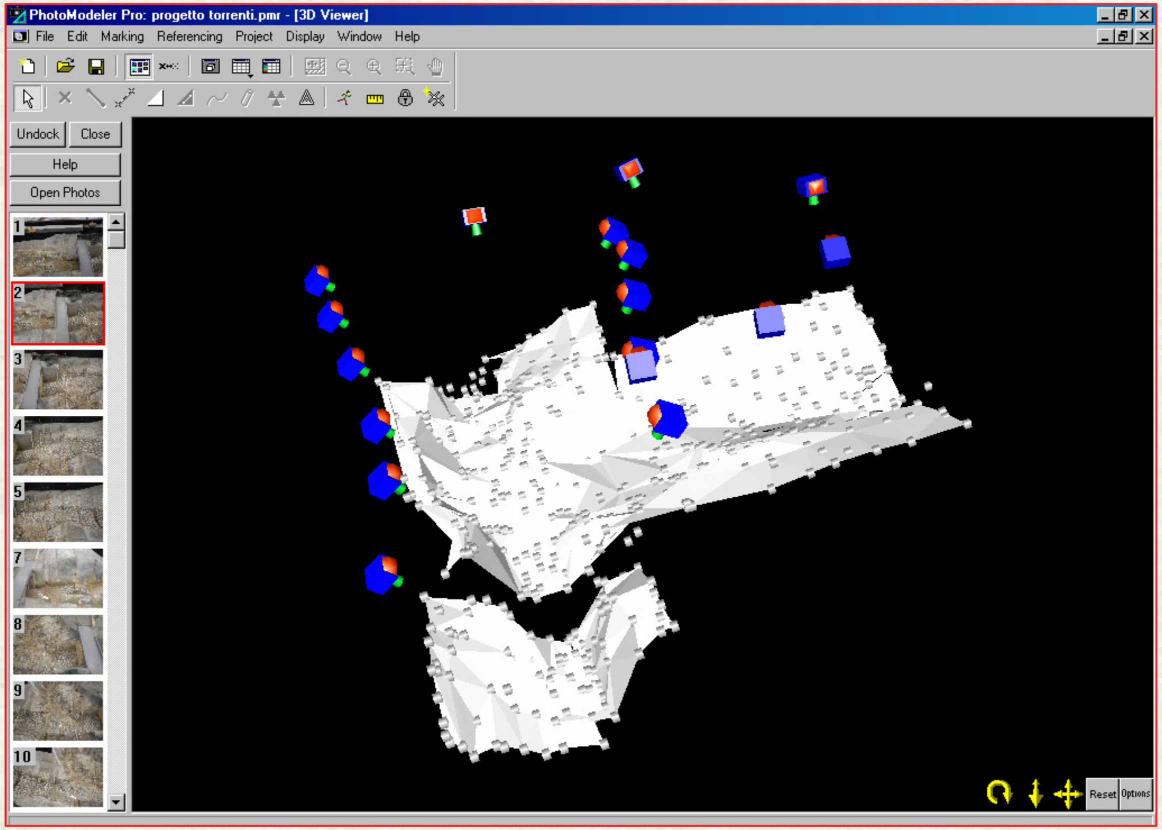
Survey of the water flooding surface

Three digital synchronized cameras

1^{st} step - Static Survey (without water)

- Orientation of pairs
- Millimetric accuracy in every direction:

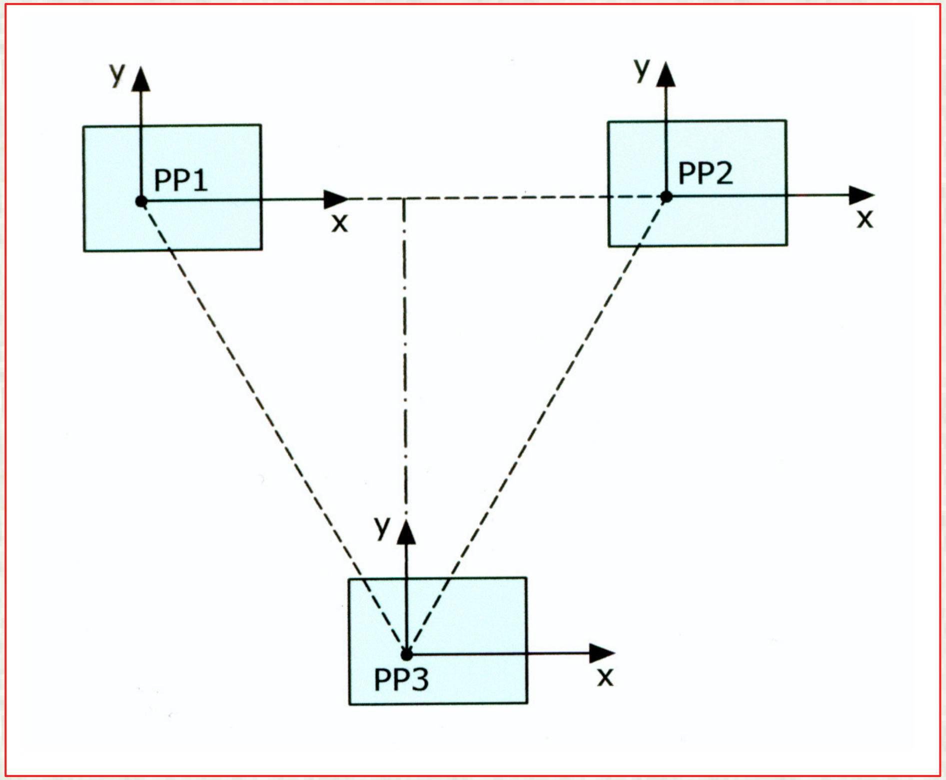
  Accuracy x=0,003 m
  y=0,002 m
  z=0,003 m
- DTM
- Survey of the control network



Digital Camera Nikon D100

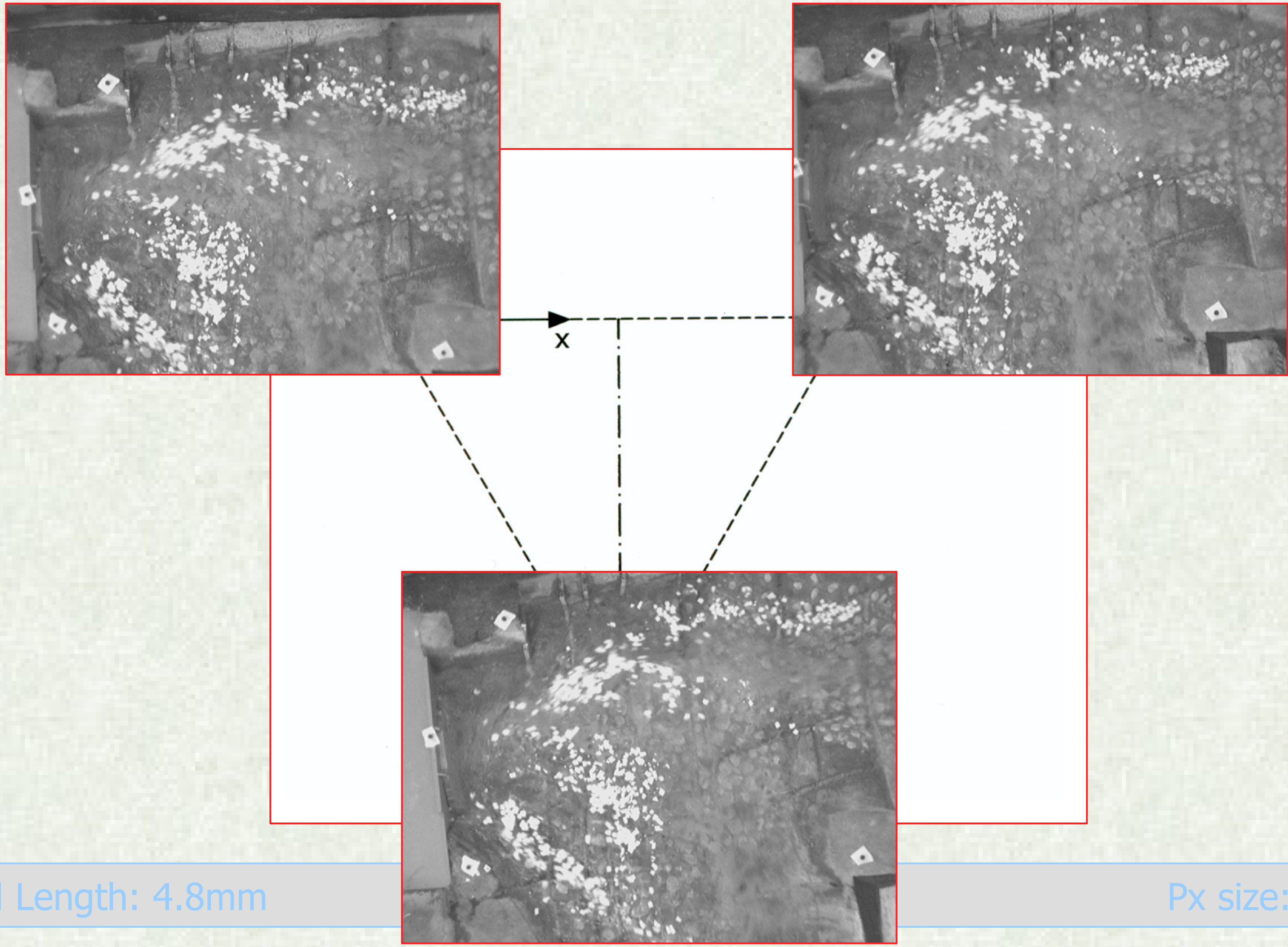
Focal Length: 20 mm | Resolution: 3008x2000 px | Px size: 7.9 micron

2nd step – Dynamic Survey (with water)



Focal Length: 4.8mm | Resolution: 640x480 px | Px size: 5.6 micron

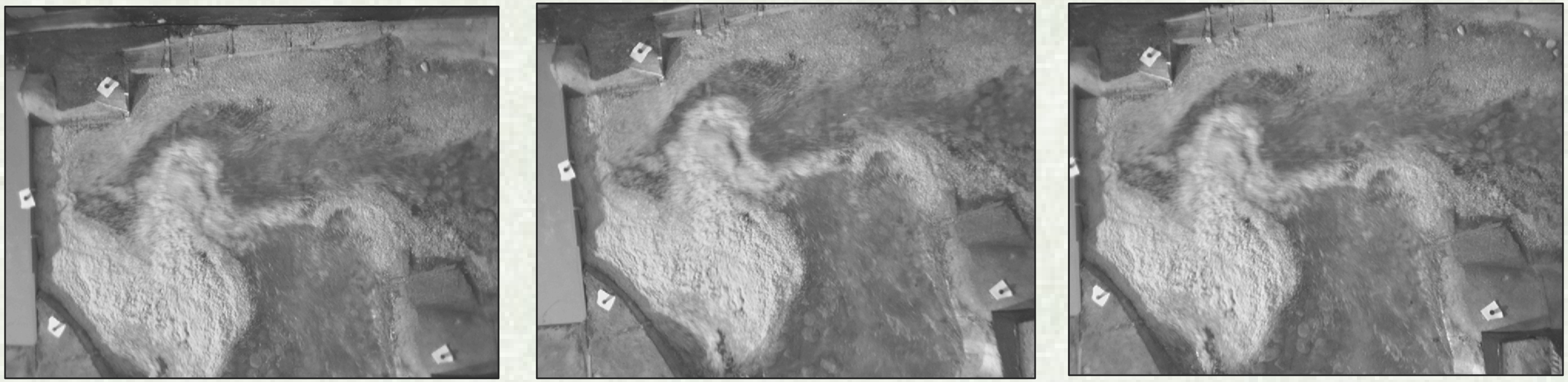
2nd step – Dynamic Survey (with water)



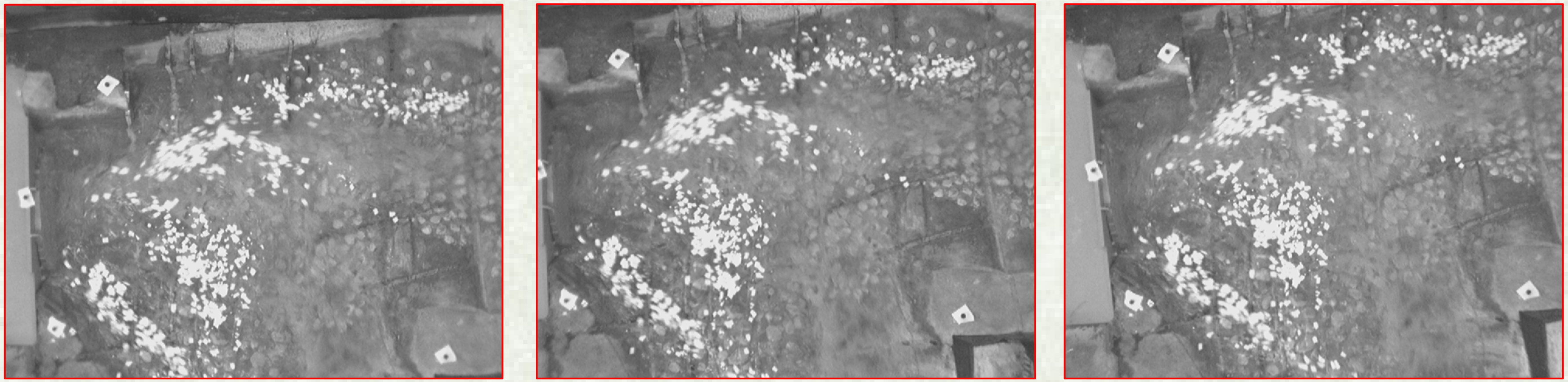
Focal Length: 4.8mm

Px size: 5.6 micron

2nd step – Dynamic Survey (with water)



With sawdust to improve the water reflectivity



With pieces of paper to improve the water reflectivity

2nd step – Dynamic Survey (with water)

- 3 pictures/sec
- 5 seconds of videoing
- almost 15 sequences (each one composed by three synchronized images).

2nd step – Matching and Adjustment

The matching of the homologous point was made manually:

- to avoid a long calibration of the automatic matching procedure
- to have a direct control of the measures

Camera calibration was computed with a standard method (proper of the same commercial software)

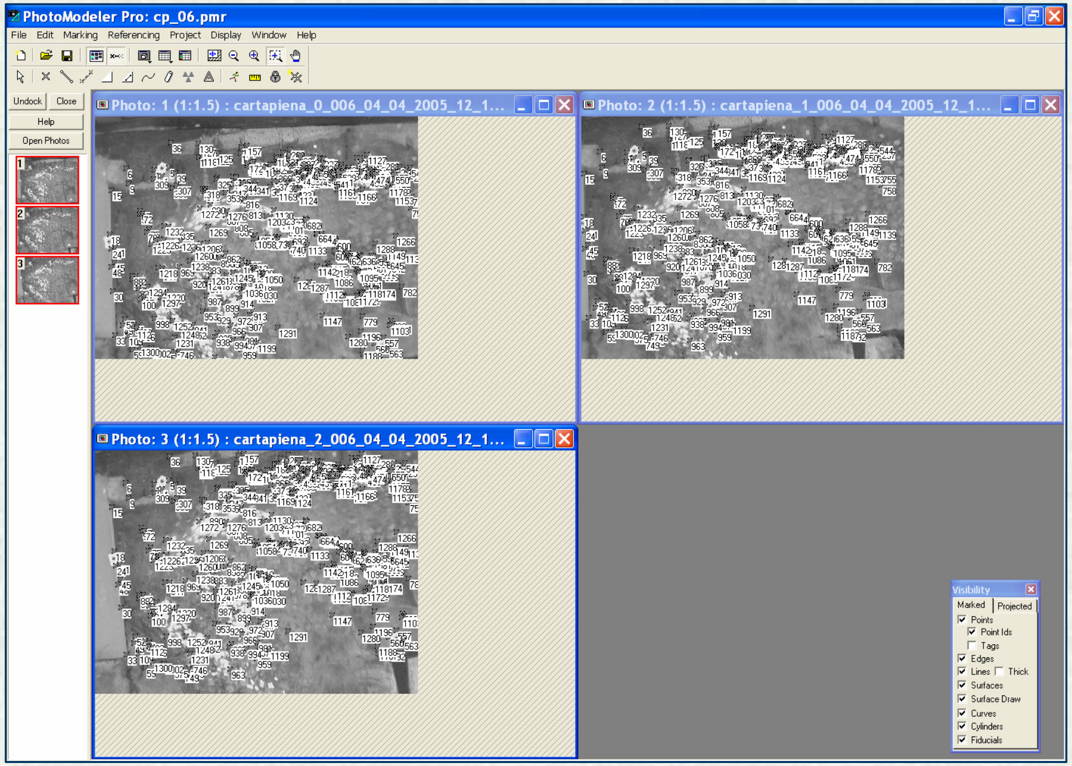


Photo #	Camera	Focal Length (mm)	Format Width (mm)	Format Height (mm)
1	web_00	4.637100	3.584000	2.688000
2	web_01	4.876914	3.584000	2.687650
3	web_02	5.004184	3.622600	2.688000

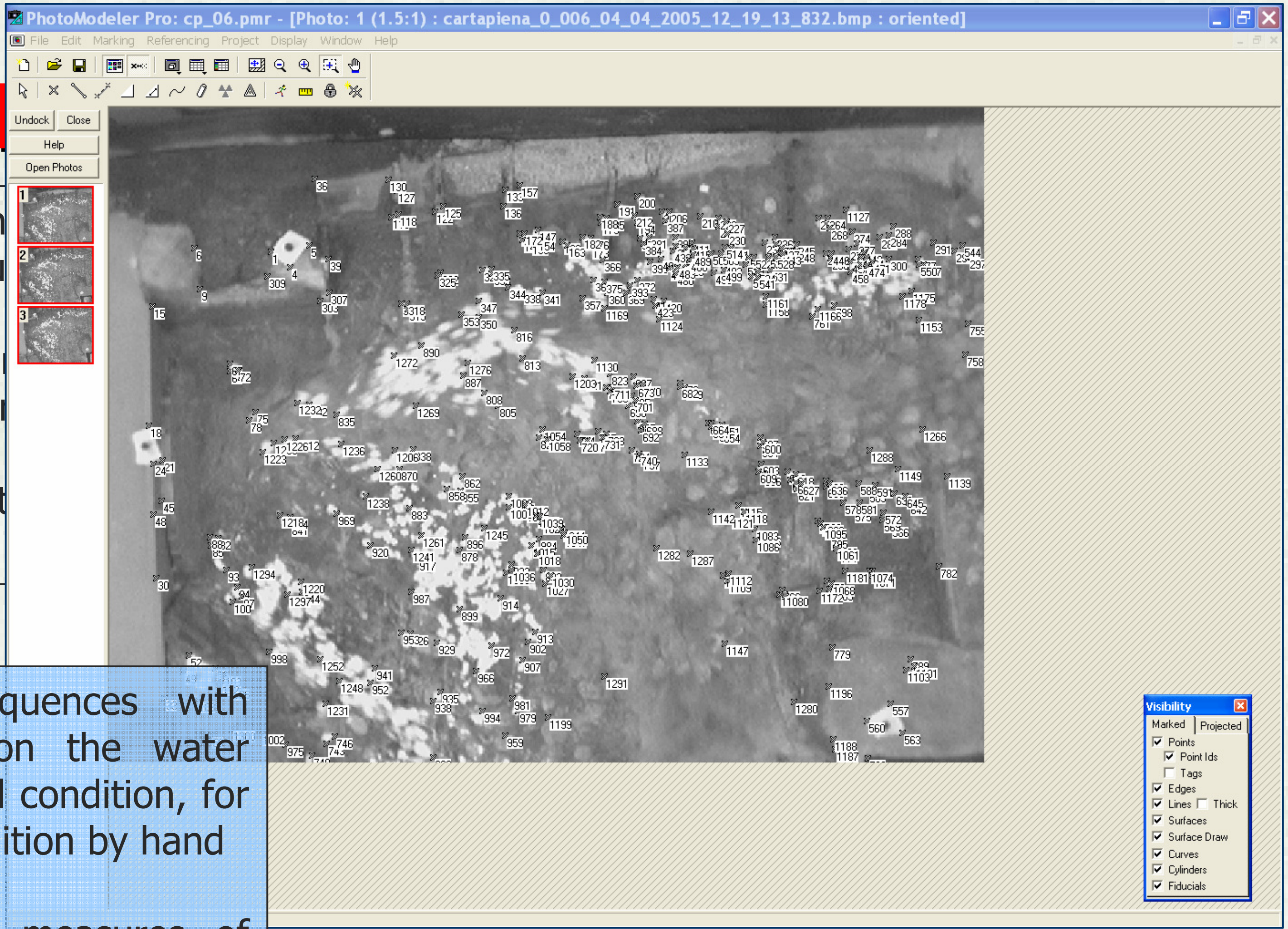
Camera	Principal Point X (mm)	Principal Point Y (mm)	K1	K2	P1	P2
web_00	1.779700	1.335500	0.002052	0.000455	0.002488	-0.002195
web_01	1.781745	1.336895	0.002086	0.000433	-0.000163	0.000799
web_02	1.777600	1.210300	-0.000364	0.000386	-0.000277	0.000204

2nd ste

The matching of the h
point was made manu

• to avoid a long calib
automatic matching pr

• to have a direct cont
measures



• 8 consecutive sequences with pieces of paper on the water surface and in flood condition, for easy pattern recognition by hand

• image coordinates measures of 400 points, for each image, using a commercial software for photogrammetry orientation

2nd ste

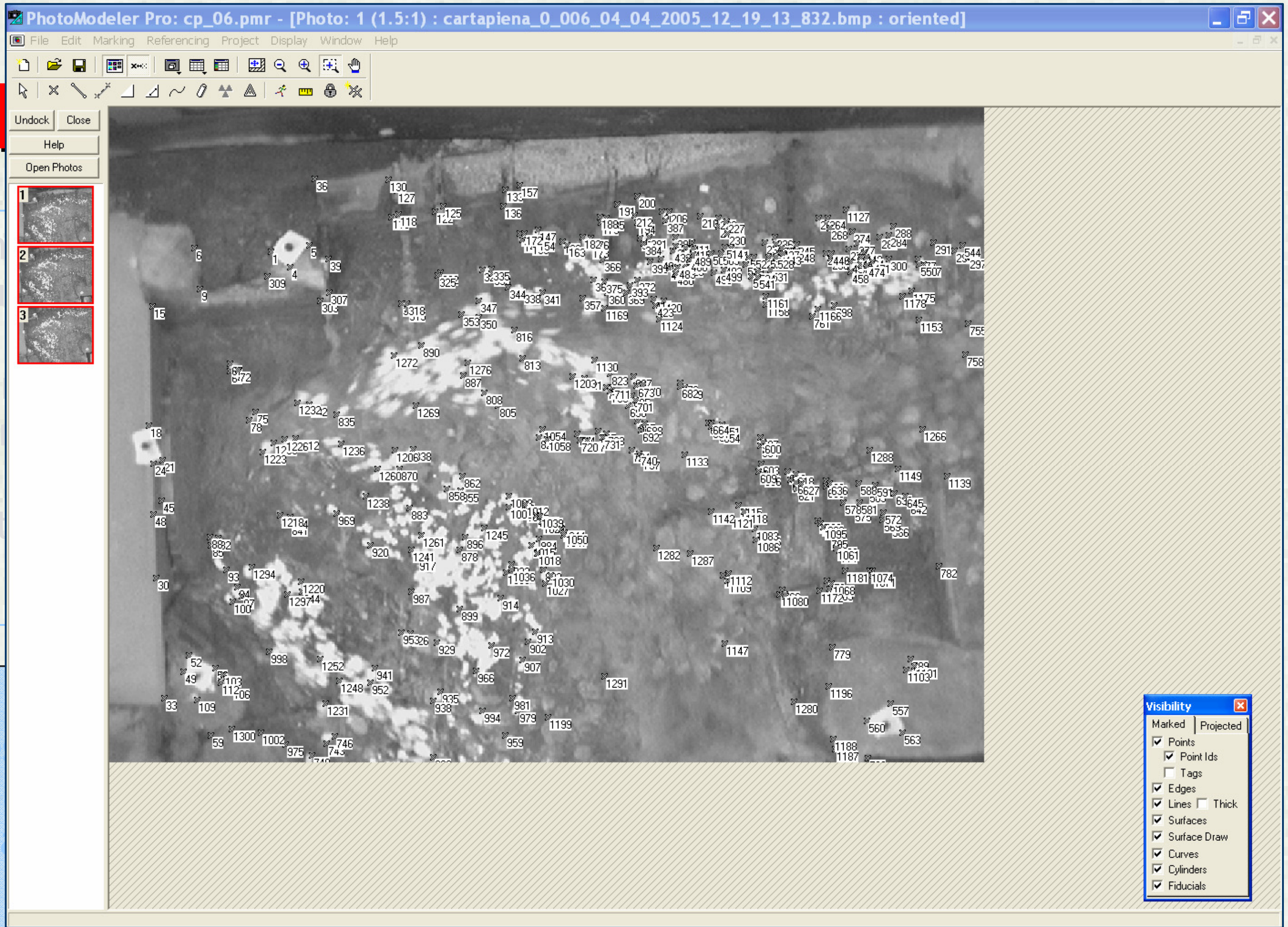
The matching of the h
point was made manu

• to avoid a long calib
automatic matching p

• to have a direct cont
measures

• We selected 8
sequences with piece
the water surface
condition, for e
recognition by hand

• We measured the image coordinates of 400 points, for each image, using a commercial software for photogrammetry orientation



Frequency of acquisition too slow

Non-homogeneous distribution of points

Low cost system

Synchronized cameras

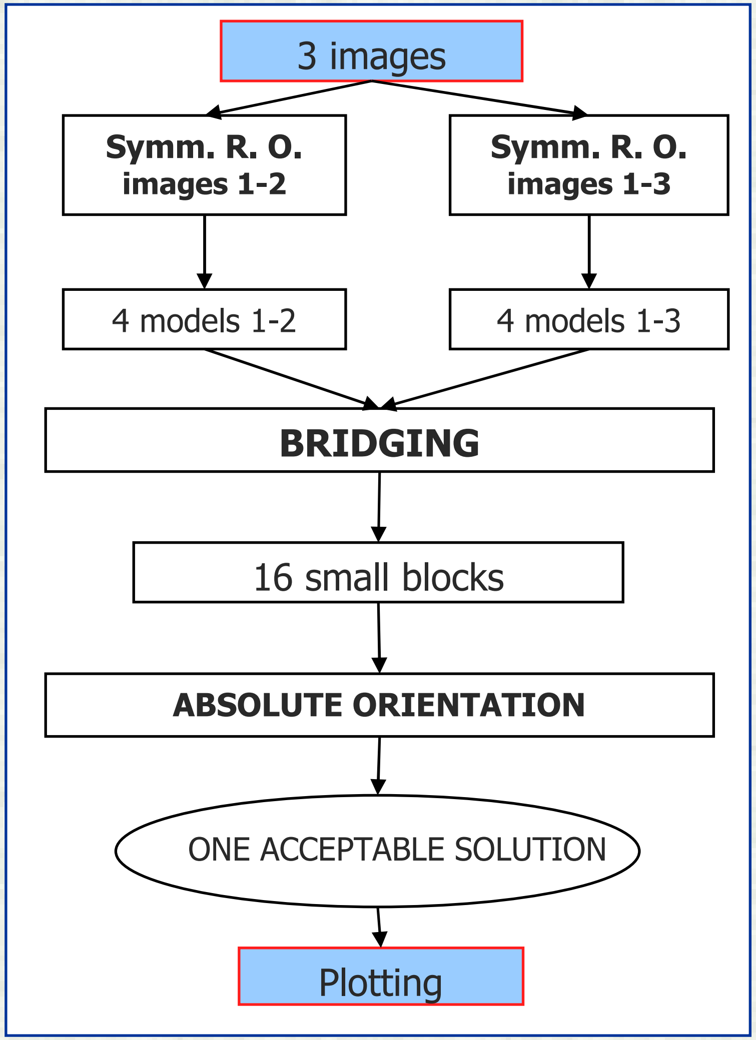
Orientation and Adjustment

ORTRE and CALGE

Sensor orientation was performed by using the generalized procedure presented (ORTRE) for three image orientation.

In a second time we executed the rigorous adjustment (CALGE), and a detection of outliers.

Serie	Nr. points	x [mm]		y [mm]		z [mm]	
		RMS	MAX	RMS	MAX	RMS	MAX
6	388	6.0	11.2	4.1	7.6	12.0	16.0
7	388	6.7	10.5	5.6	14.1	10.1	16.6
8	305	8.9	13.2	9.5	20.2	13.5	18.8
9	395	6.8	12.3	4.3	9.7	12.2	16.5
10	399	6.7	10.6	5.5	10.8	9.5	16.8
11	307	7.9	12.2	6.0	10.6	13.2	19.3
12	352	4.7	8.1	3.2	5.6	10.0	13.4
13	169	9.0	12.8	8.2	12.7	14.6	20.1



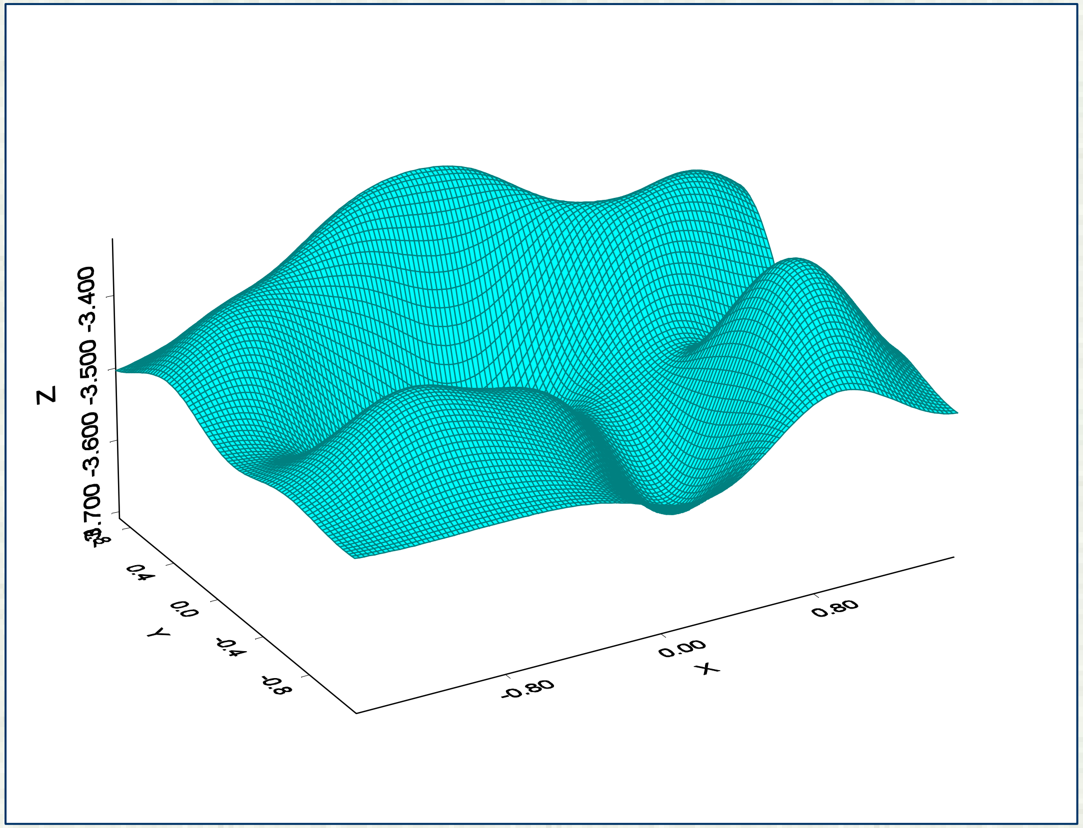
Spatio-temporal Interpolation

Covariance estimation and Collocation filter

From a rigorous adjustment we obtain an irregular field of points.

An optimal filter permits us to predict elevations in a regular grid.

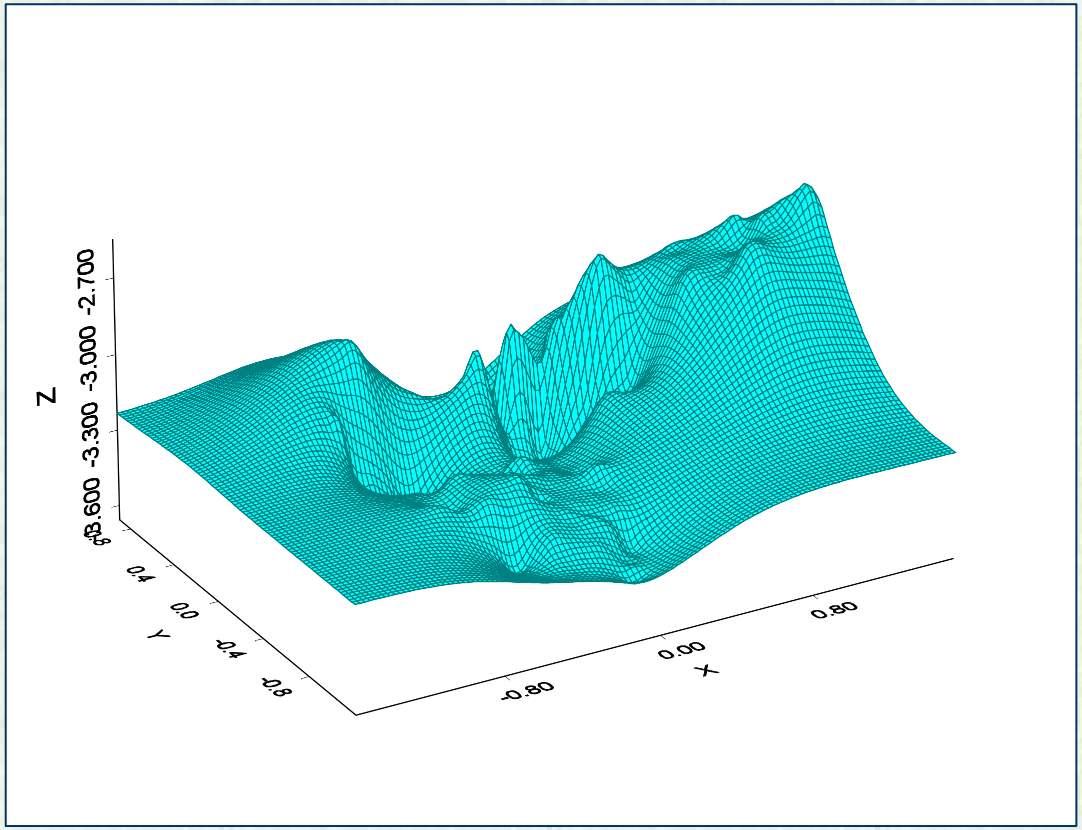
This step is fundamental for temporal comparison and the related statistical analysis.



Scene 6

Spatio-temporal Interpolation

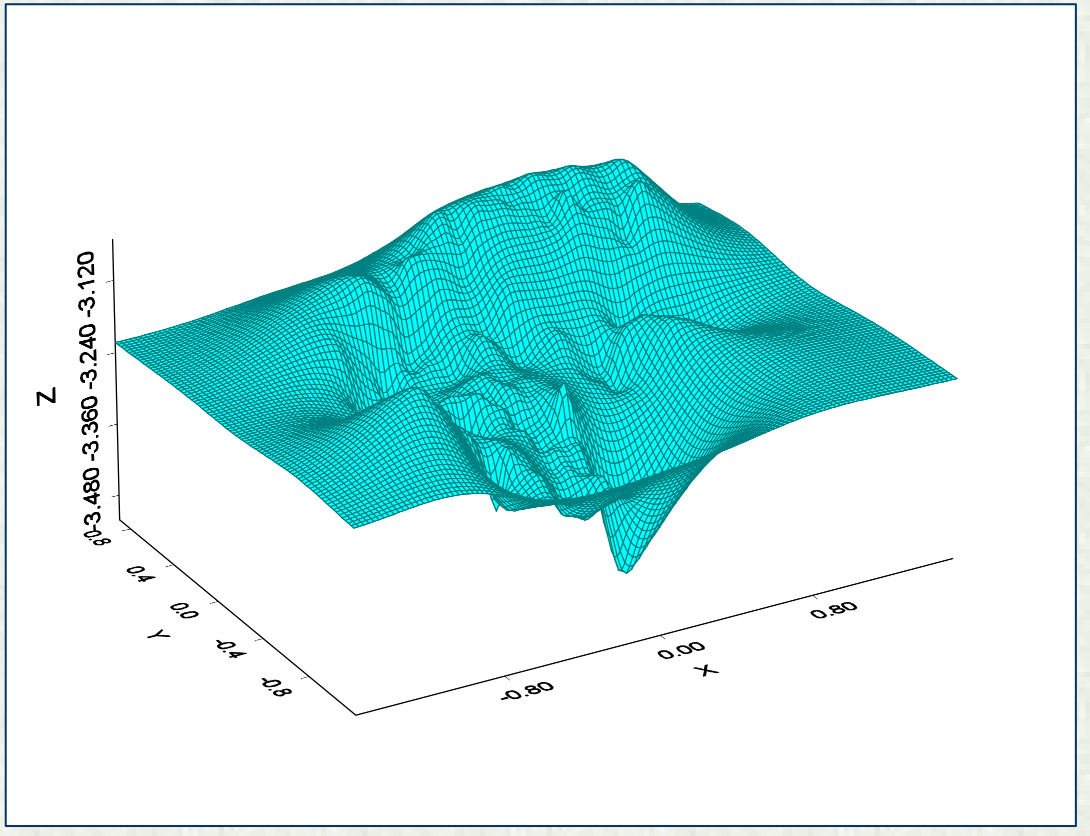
Covariance estimation and Collocation filter



Scene 7

Spatio-temporal Interpolation

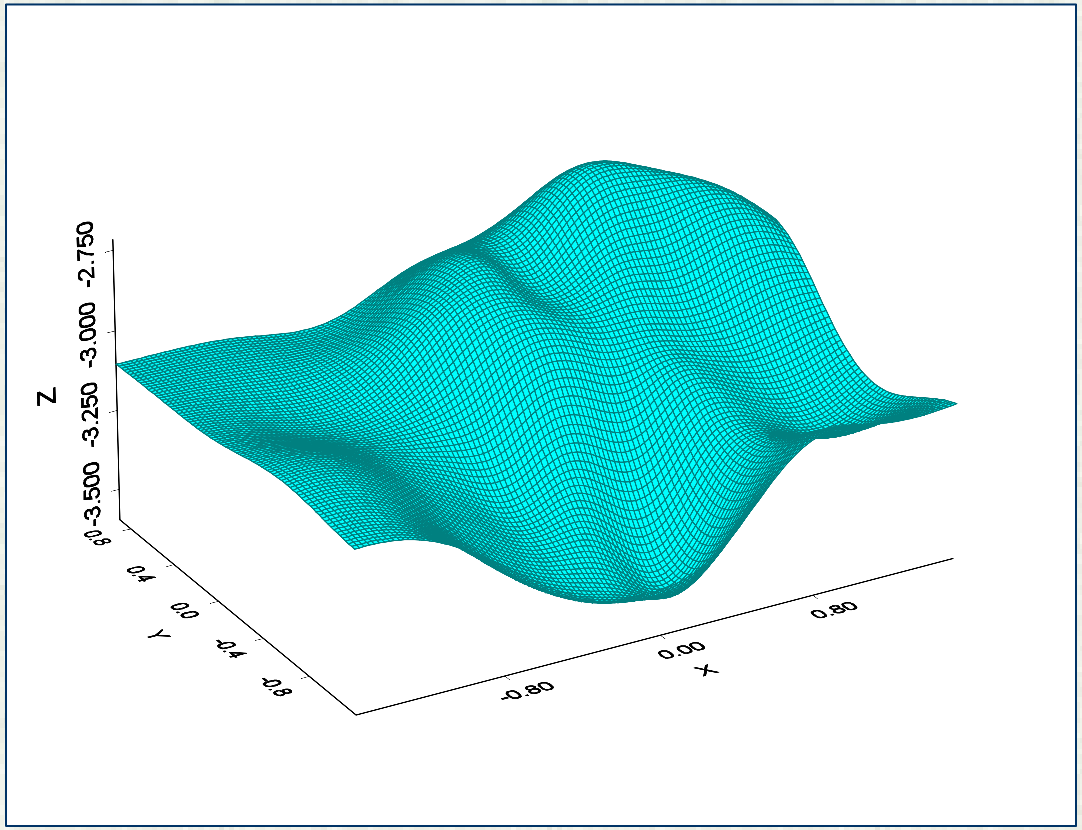
Covariance estimation and Collocation filter



Scene 8

Spatio-temporal Interpolation

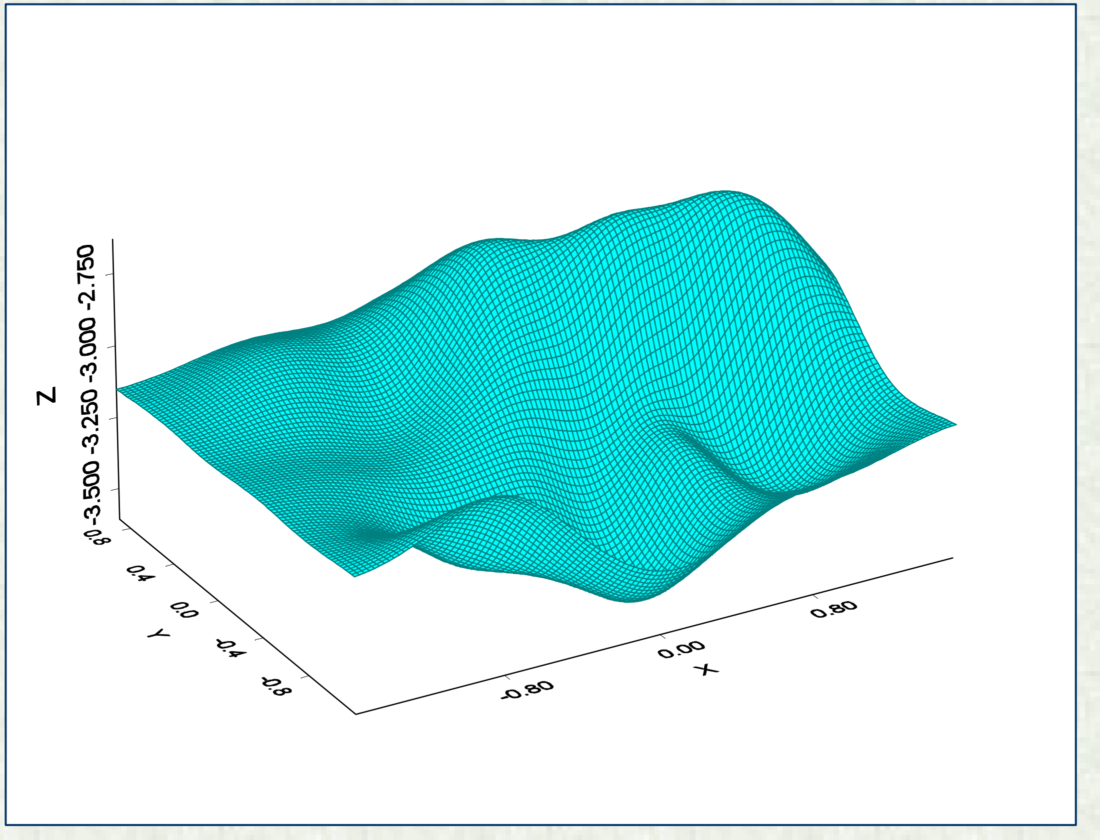
Covariance estimation and Collocation filter



Scene 9

Spatio-temporal Interpolation

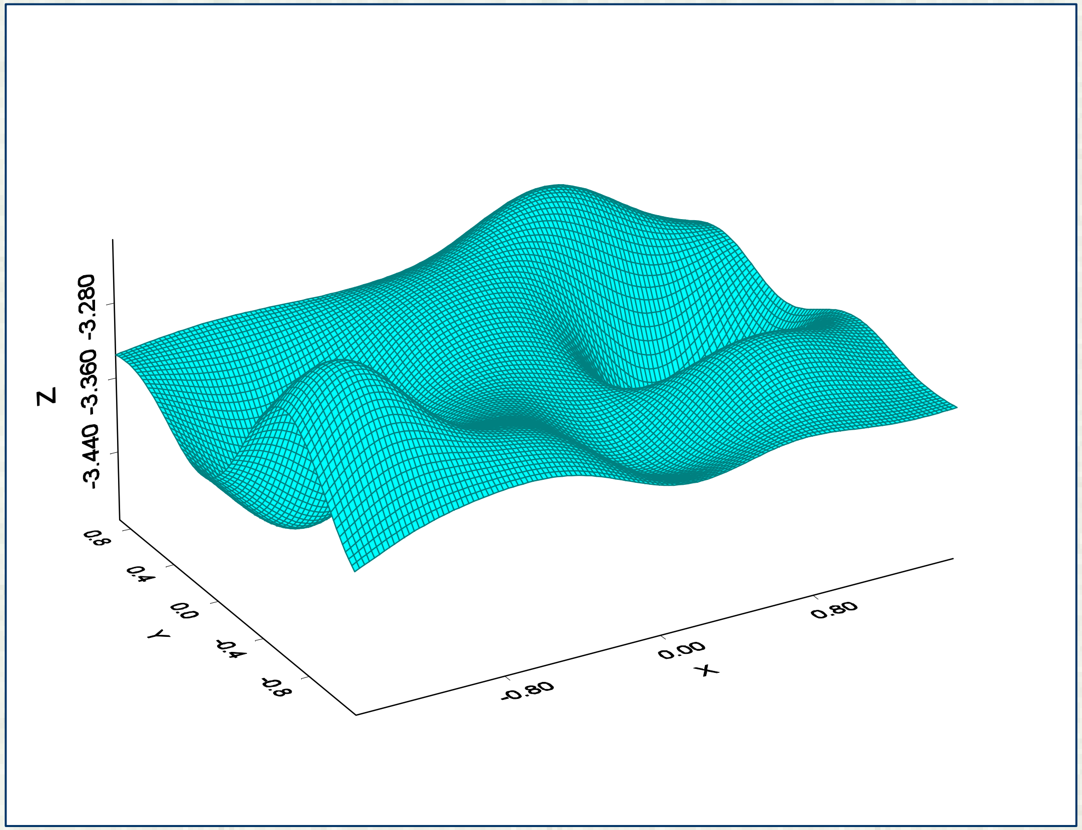
Covariance estimation and Collocation filter



Scene 10

Spatio-temporal Interpolation

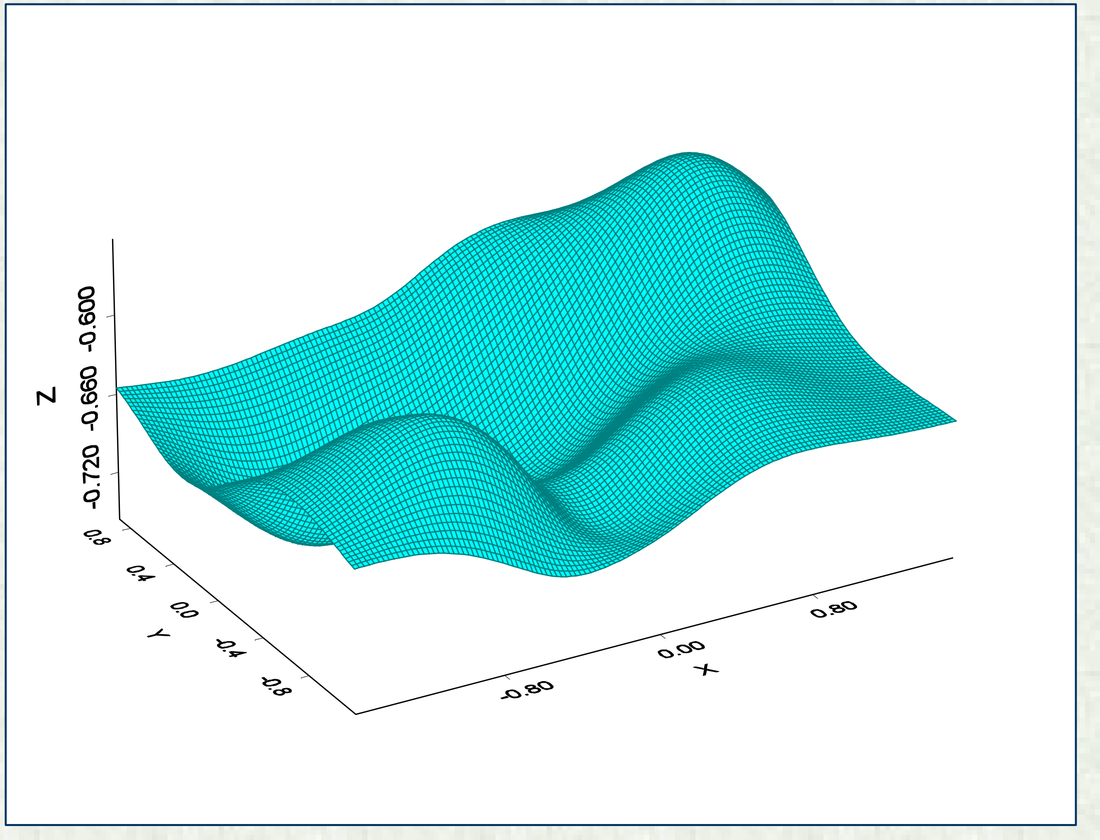
Covariance estimation and Collocation filter



Scene 11

Spatio-temporal Interpolation

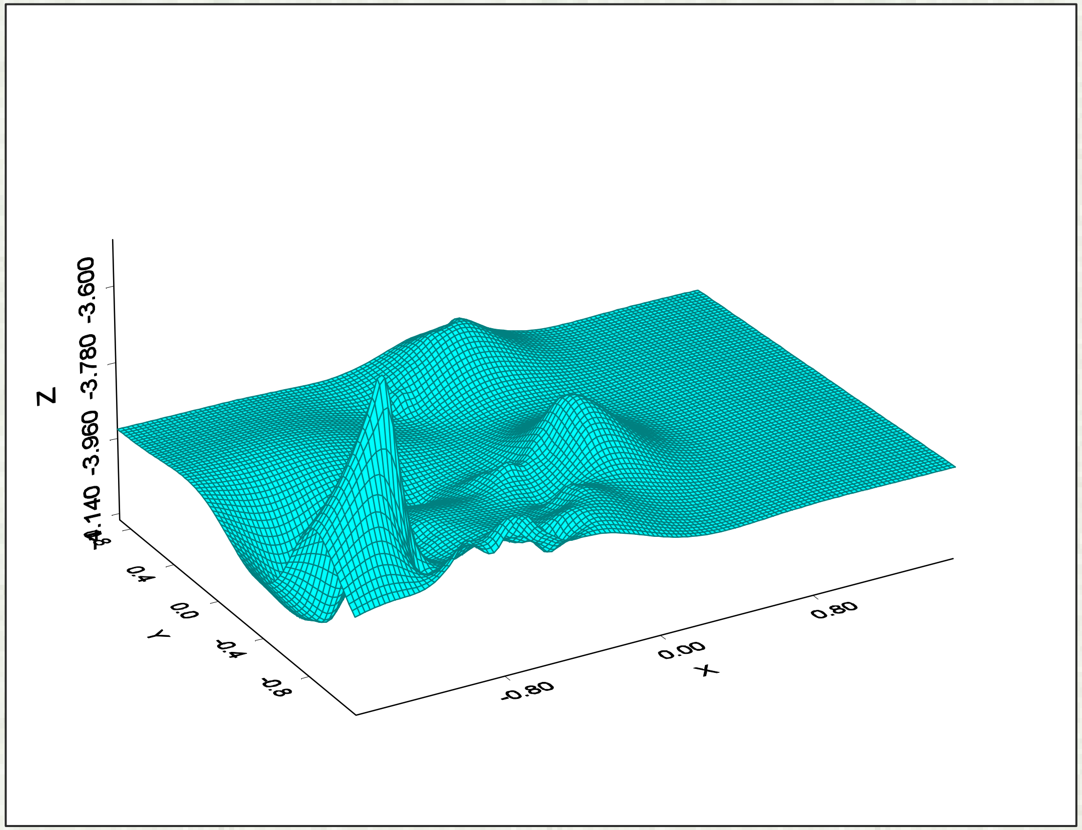
Covariance estimation and Collocation filter



Scene 12

Spatio-temporal Interpolation

Covariance estimation and Collocation filter



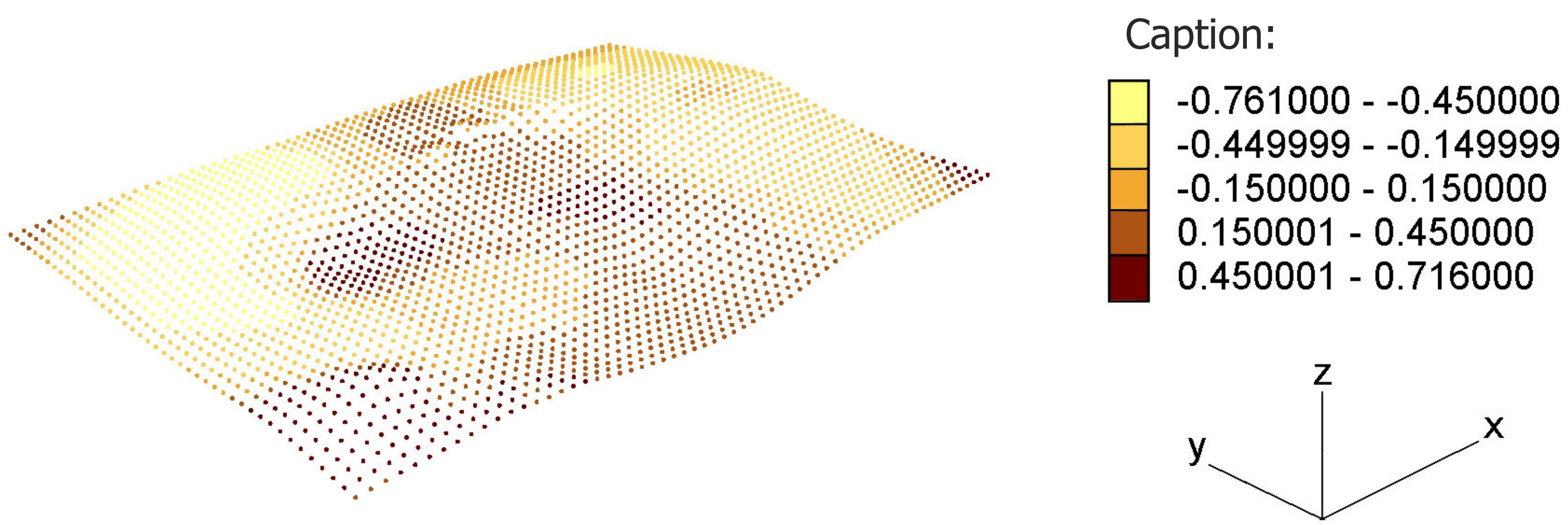
Scene 13

Temporal Interpolation

A linear regression studies temporal dependency due to the small number of sequences.

- Where the linear correlation coefficient is quite high, the water behavior is quasi-laminar (brown and yellow).
- Where the linear correlation coefficient is near to zero, a turbulence zone is found (orange).

Correlation Index Clusters

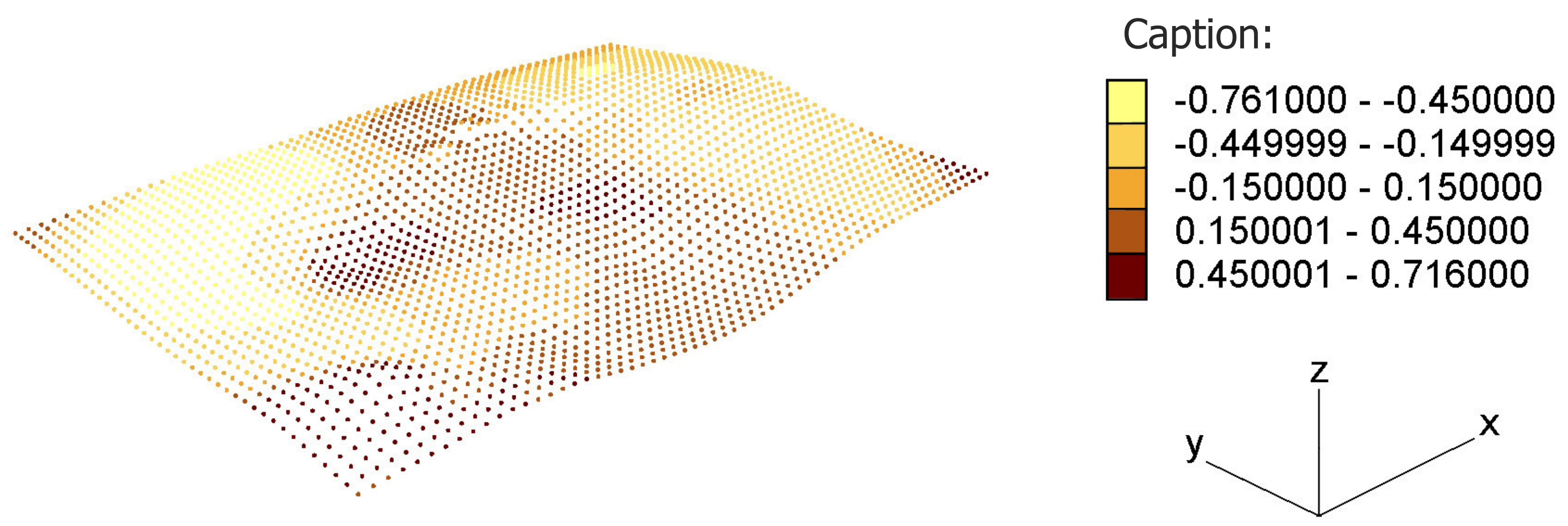


Temporal Interpolation

Concordance between the hydraulic quasi-laminar areas (in the zone near the borders) and the zones characterized by a relatively high correlation coefficient

Concordance between the hydraulic turbulent areas (in the zone of the confluence) and the zones characterized by a low correlation coefficient

Correlation Index Clusters



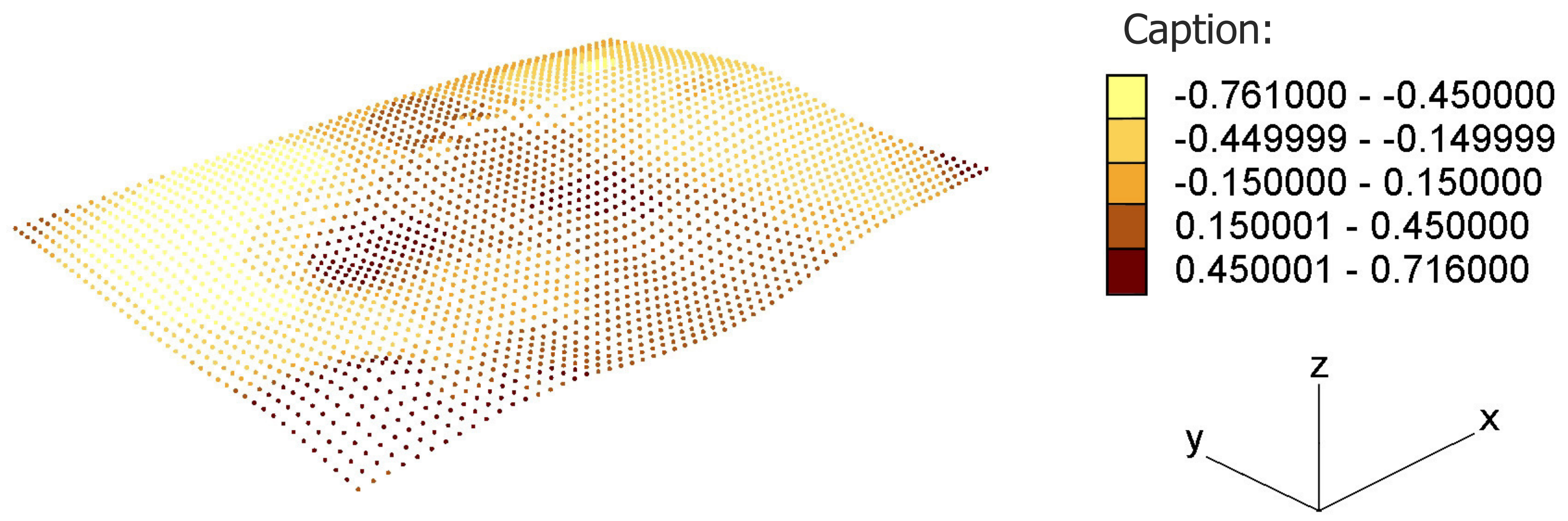
back

Temporal Interpolation

A hydraulic judgment responds the question how the photogrammetric model and the digital surfaces constitute a true representation of the physical hydraulic model, built in the laboratory.

Independent direct measurements determined a maximum in the height differences ranged from 1 meter to 1,2 meter. The same measure in the digital surface (i.e. the largest height variation, analyzing all girded points in the sequence of 8 scenes) is 1.06 meter.

Correlation Index Clusters



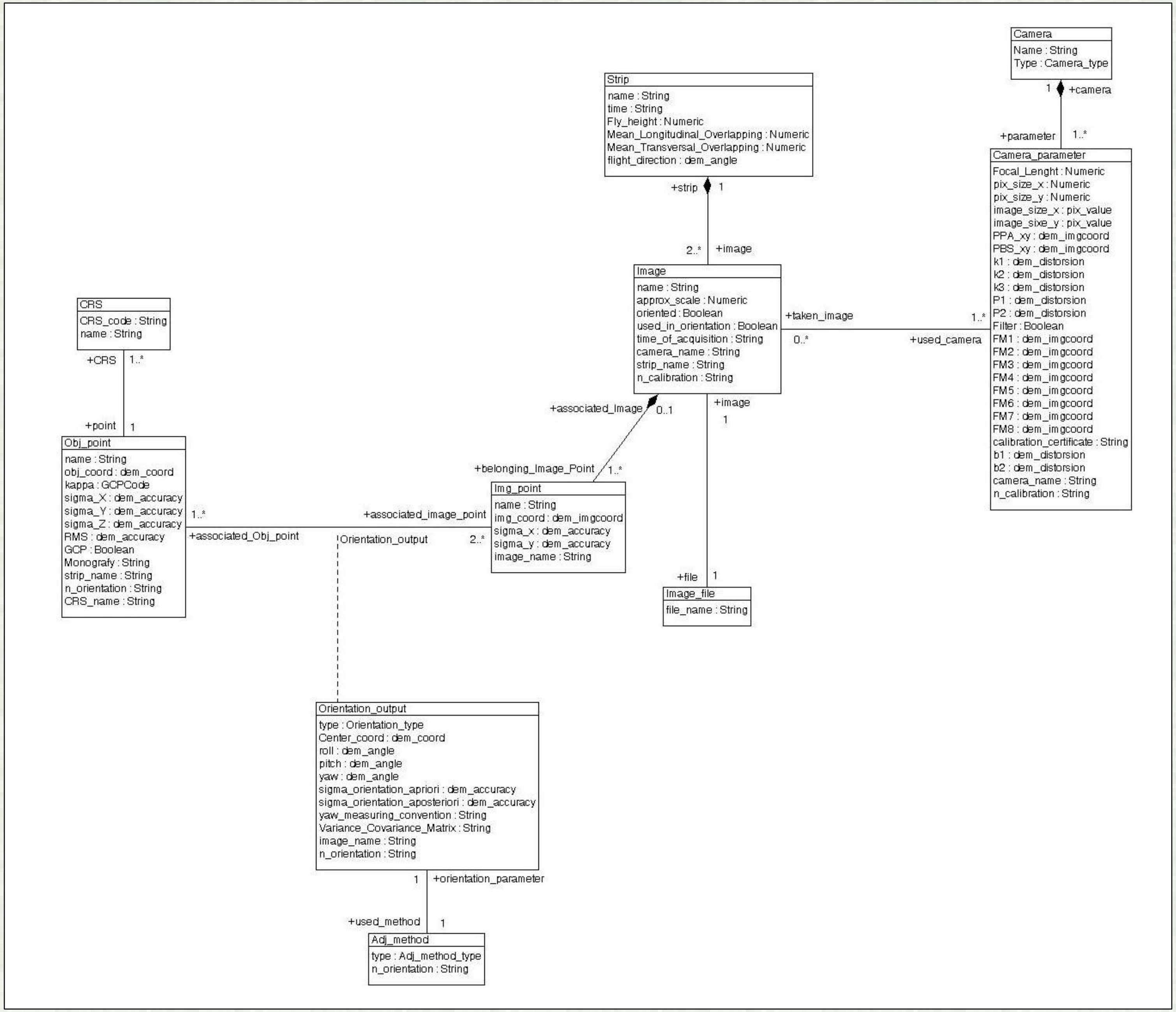
back

Data Modeling
UML

- Model Driven Approach
- INTERLIS/UML Editor

Class diagram shows the structure of data to de transferred (independent from format and system exact description):

- Entities
- Attributes
- Relationships


Camera
Name : String
Type : Camera_type
1 +camera
+parameter 1..*
Camera_parameter
Focal_Lenght : Numeric
pix_size_x : Numeric
pix_size_y : Numeric
image_size_x : pix_value
image_sixe_y : pix_value
PPA_xy : dem_imgcoord
PBS_xy : dem_imgcoord
k1 : dem_distorsion
k2 : dem_distorsion
k3 : dem_distorsion
P1 : dem_distorsion
P2 : dem_distorsion
Filter : Boolean
FM1 : dem_imgcoord
FM2 : dem_imgcoord
FM3 : dem_imgcoord
FM4 : dem_imgcoord
FM5 : dem_imgcoord
FM6 : dem_imgcoord
FM7 : dem_imgcoord
FM8 : dem_imgcoord
calibration_certificate : String
b1 : dem_distorsion
b2 : dem_distorsion
camera_name : String
n_calibration : String
Strip
name : String
time : String
Fly_height : Numeric
Mean_Longitudinal_Overlapping : Numeric
Mean_Transversal_Overlapping : Numeric
flight_direction : dem_angle
+strip 1
2..* +image
Image
name : String
approx_scale : Numeric
oriented : Boolean
used_in_orientation : Boolean
time_of_acquisition : String
camera_name : String
strip_name : String
n_calibration : String
+taken_image 1..*
0..* +used_camera
+associated_Image 0..1
+image 1
+belonging_Image_Point 1..*
Img_point
name : String
img_coord : dem_imgcoord
sigma_x : dem_accuracy
sigma_y : dem_accuracy
image_name : String
+file 1
Image_file
file_name : String
CRS
CRS_code : String
name : String
+CRS 1..*
+point 1
Obj_point
name : String
obj_coord : dem_coord
kappa : GCPCode
sigma_X : dem_accuracy
sigma_Y : dem_accuracy
sigma_Z : dem_accuracy
RMS : dem_accuracy
GCP : Boolean
Monografy : String
strip_name : String
n_orientation : String
CRS_name : String
1..* +associated_Obj_point
+associated_image_point 2..*
Orientation_output
Orientation_output
type : Orientation_type
Center_coord : dem_coord
roll : dem_angle
pitch : dem_angle
yaw : dem_angle
sigma_orientation_apriori : dem_accuracy
sigma_orientation_aposteriori : dem_accuracy
yaw_measuring_convention : String
Variance_Covariance_Matrix : String
image_name : String
n_orientation : String
1 +orientation_parameter
+used_method 1
Adj_method
type : Adj_method_type
n_orientation : String

GML Schema

A GML Schema is automatically generated from the UML file (INTERLIS .ili file) and contains:

- UML Class defined as complex data structure (and associated behavior), mapped by default to a complexType in xsd (Schema file)

Class: *DEM_model.Orientation_Info.Img_point*

GML Schema

```
<xsd:element name="DEM_model.Orientation_Info.Img_point"
type="DEM_model.Orientation_Info.Img_point"
substitutionGroup="gml:_Feature"/>
<xsd:complexType  name="DEM_model.Orientation_Info.Img_point">
  <xsd:complexContent>
    <xsd:extension base="gml:AbstractFeatureType">
      <xsd:sequence>
        <xsd:element name="name">
          <xsd:simpleType>
            <xsd:restriction base="xsd:normalizedString">
              <xsd:maxLength value="20"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="img_coord" type="DEM_model.dem_imgcoord"/>
        <xsd:element name="sigma_x" type="DEM_model.dem_accuracy"
minOccurs="0"/>
        <xsd:element name="sigma_y" type="DEM_model.dem_accuracy"
minOccurs="0"/>
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
```

GML Schema

A GML Schema is automatically generated from the UML file (INTERLIS .ili file) and contains:

- UML Class defined as complex data structure (and associated behavior), mapped by default to a complexType in xsd (Schema file)

  Class: *DEM_model.Orientation_Info.Img_point*

- Description of objects relations

  Relation: *DEM_model.Orientation_Info.Camera_Camera_parameter*

GML Schema

```
<xsd:element name="DEM_model.Orientation_Info.Camera_Camera_parameter"
type="DEM_model.Orientation_Info.Camera_Camera_parameter"
substitutionGroup="gml:_Feature"/>
         <xsd:complexType
name="DEM_model.Orientation_Info.Camera_Camera_parameter">
          <xsd:complexContent>
                 <xsd:extension base="gml:AbstractFeatureType">
                         <xsd:sequence>
                                 <xsd:element name="parameter"
type="gml:ReferenceType">
                                 </xsd:element>
                                 <xsd:element name="camera"
type="gml:ReferenceType">
                                 </xsd:element>
                         </xsd:sequence>
                 </xsd:extension>
          </xsd:complexContent>
         </xsd:complexType>
```

GML Schema

- The same conceptual model may be used to generate different XML Schemas (such as GML2.0, ISO 19118 XML Encoding and XMI) for the data level as well as other representations
- The automatic generation of the GML Schema from the UML model avoid errors or no univoque codification of the data structure
- It is also possible the reconstruction of the conceptual model starting from the GML Schema, thanks to the univoque and strict rules of codification

XML file

A GML Schema needs a corresponding GML file which contains the data.

The GML file (.xml) is a transfer format, it is written in XML grammar and the interpretation is not immediate.

A short Java program was written; it helped to write the GML file, starting from the GML Schema, and it is able to fill it with geo-data.

Difficult codification of object relations

The *annex E* of GML specifics is not so clear and detailed, any clarifying example.

We found that a possible codification of the object relations should contain the identifier of the related object.

CONCLUSION of *PART III*

- An environmental monitoring application was done for testing the whole procedure (from data acquisition to data archiving)
- It was possible to study the dynamic behavior of scene sequences (water surface flood), both spatially and temporally
- A correspondence between our results and the hydraulic expectation was found
- MDA promotes the independence of the application model from the implementation technologies and platform
- The automatic generation of the GML Schema from the UML model avoid errors or no univoque codification of the data structure

FINAL CONCLUSIONS

Summary of the Achievements

The achieved goals are:

- the creation of a new procedure for the automatic orientation of three simultaneous images for non–conventional photogrammetry (without the need of preliminary values)
- an integrated approach for the statistical data processing from robust adjustment to interpolation techniques for continuous data (this step uses already existing tools previously developed and implemented in Milan)
- the description of geo-data coming from photogrammetric survey with GML/XML language for interoperability data exchange
- the survey of a hydraulic model to test the whole procedure and to validate some expected hydraulic phenomena (innovative application)

FINAL CONCLUSIONS

Further Developments

- Total automation of the matching procedure (automatic matching software and elimination of the points not belonging to the water surface)
- High-resolution cameras
- Implementation of graphic data modeling, representation and mosaiking
- Creation of a tool for data download in XML format
- Integration with a GIS
- Integration with an ontology plug in
- Real time analysis to set a risk level factor

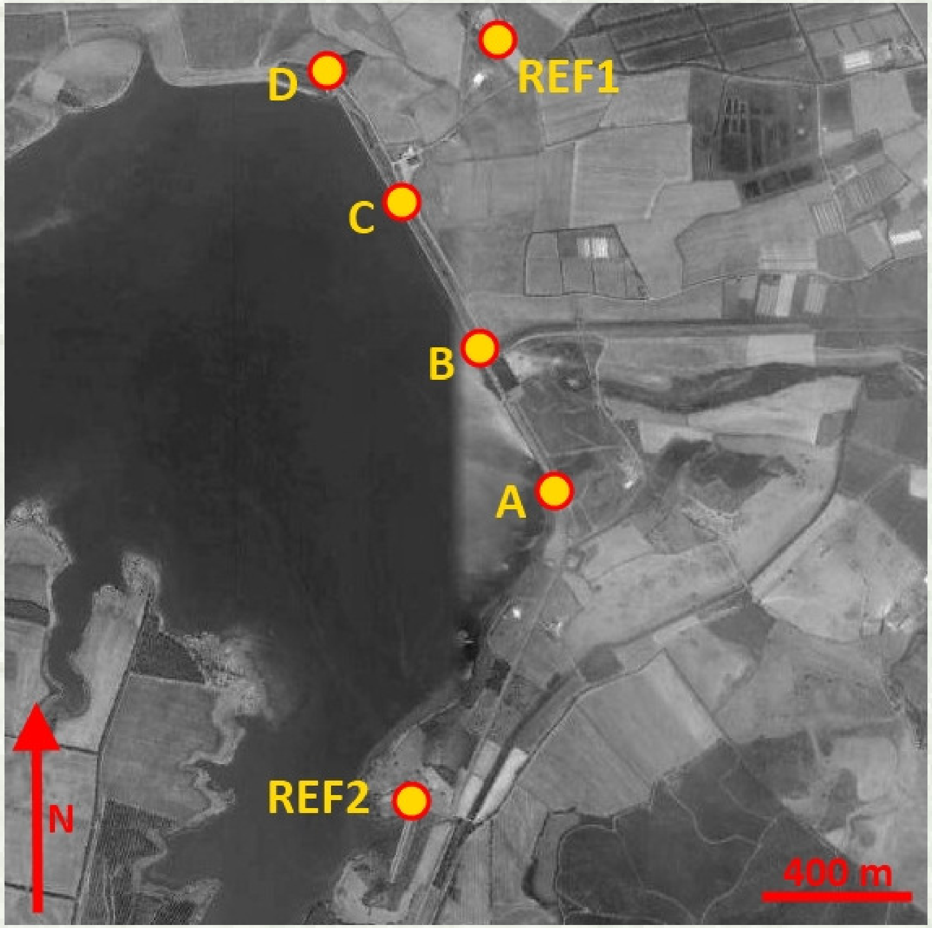
Grazie per l'attenzione

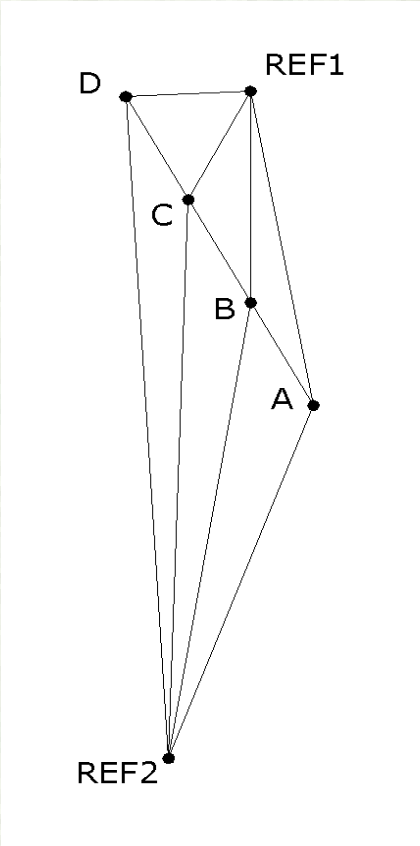
Il Monitoraggio della Diga Cixerri

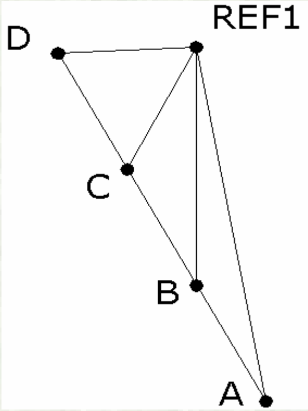
Diga fiume Cixerri in Sardegna [Genna Is Abis - Uta (CA)]

Si è voluto verificare se il GPS poteva essere uno strumento di misura valido per il monitoraggio dei movimenti stagionali di una diga e la previsione del rischio. Attualmente le dighe vengono monitorate dei pendoli e con un collimatore ottico. Le misure del collimatore ottico però per dighe molto ampie sono affette da fenomeni di rifrazione atmosferica e non possono essere utilizzate.

Sistema di Monitoraggio GNSS installato







Caratteristiche della rete GPS:

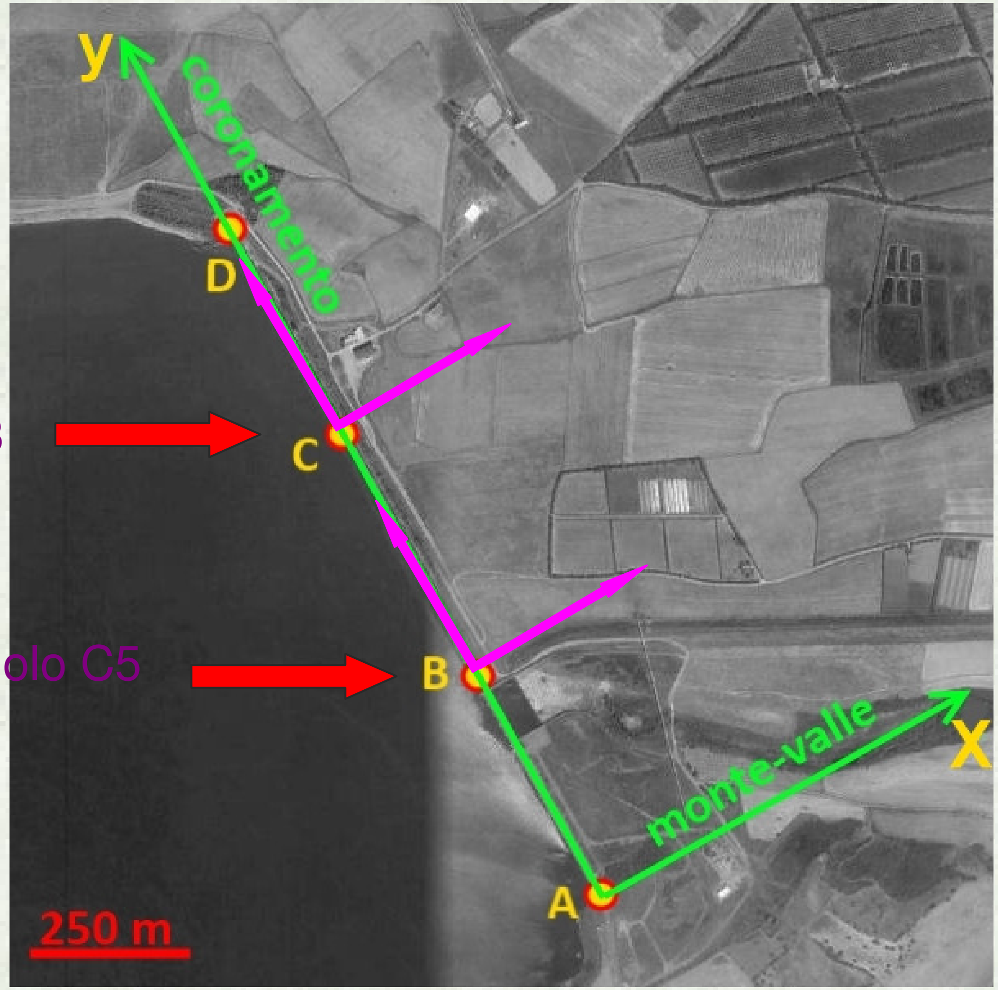
Soluzioni giornaliere
Distanza tra i GPS sulla diga: ≅ 430 m
Distanza tra stazioni sulla diga e reference: 500÷1000 m
Software di elaborazione: LGO di Leica Geosystems

Dati GNSS elaborati:
fine giugno 2007 primi ottobre 2008

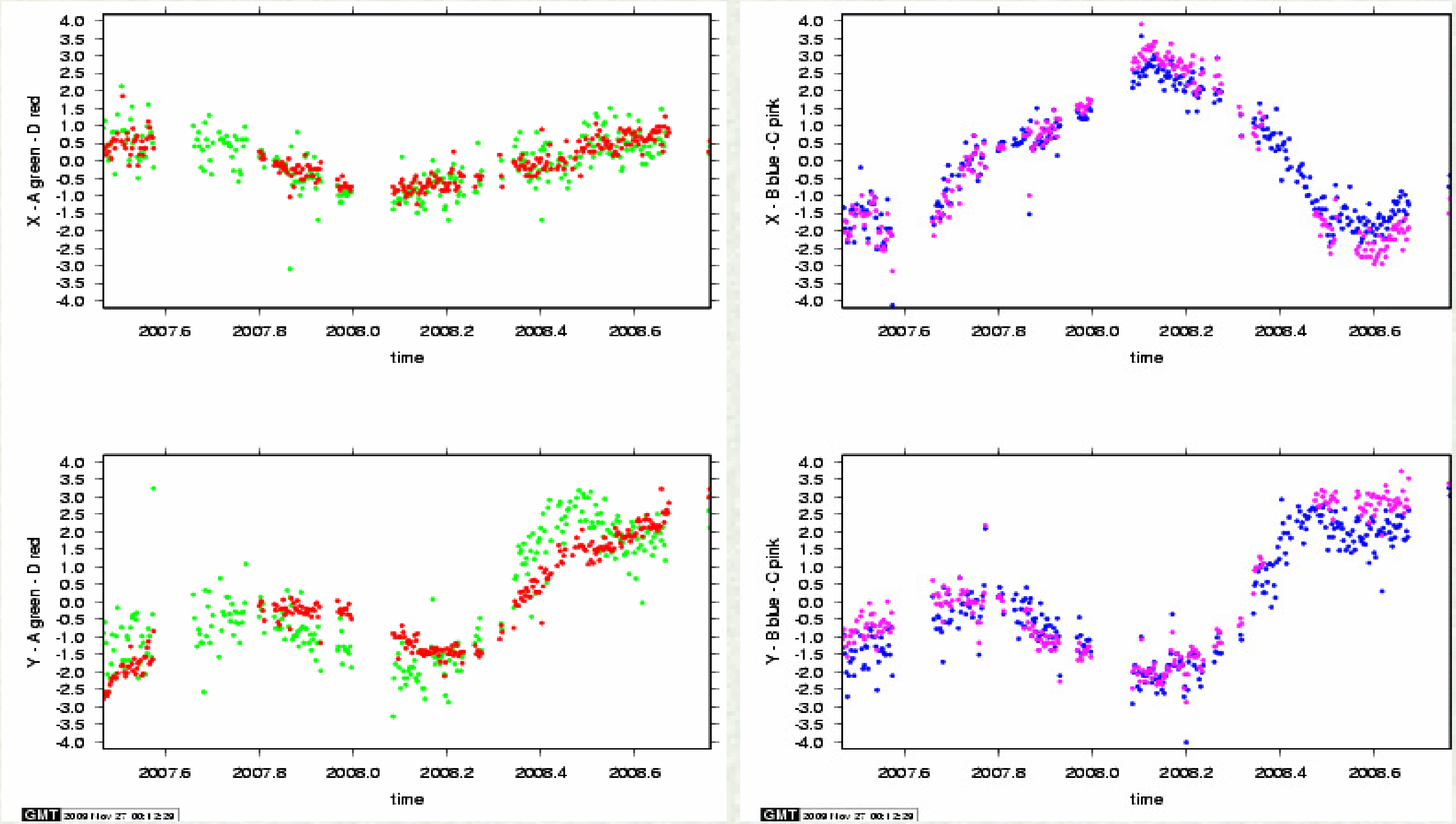
Sistema di Riferimento Geodetico scelto

Pendolo C43

Pendolo C5

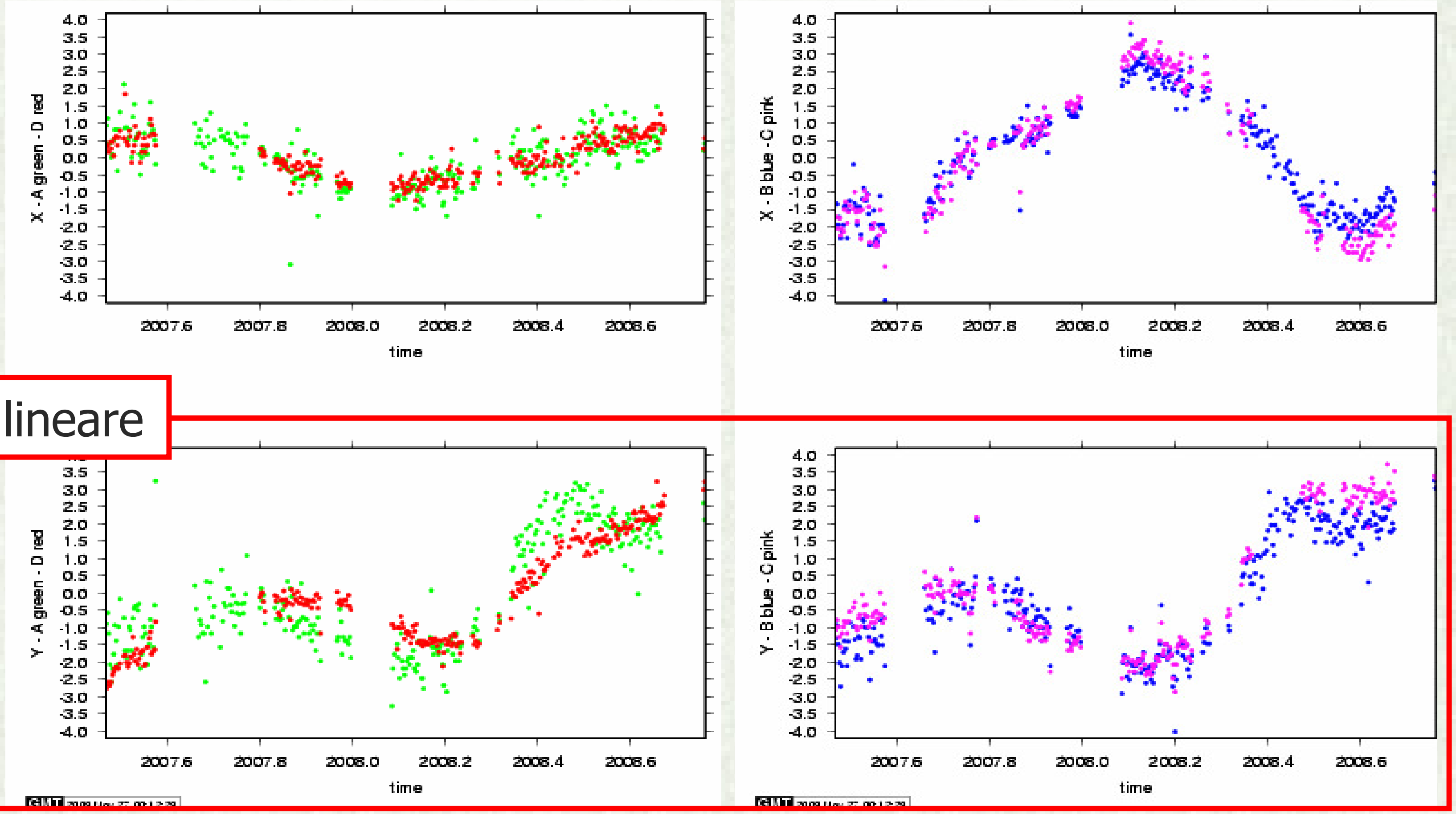


Serie Temporali GNSS



Statistiche spostamenti	GPS sulle spalle della diga				GPS sul coronamento della diga			
Millimetri	A		D		B		C	
	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento
Minimo	-3.1	-4.8	-1.2	-2.8	-4.1	-4.0	-3.1	-2.9
Massimo	2.1	4.4	1.9	4.6	3.6	3.3	3.9	3.7
Max-Min	5.2	9.2	3.1	7.4	7.7	7.3	7.0	6.6

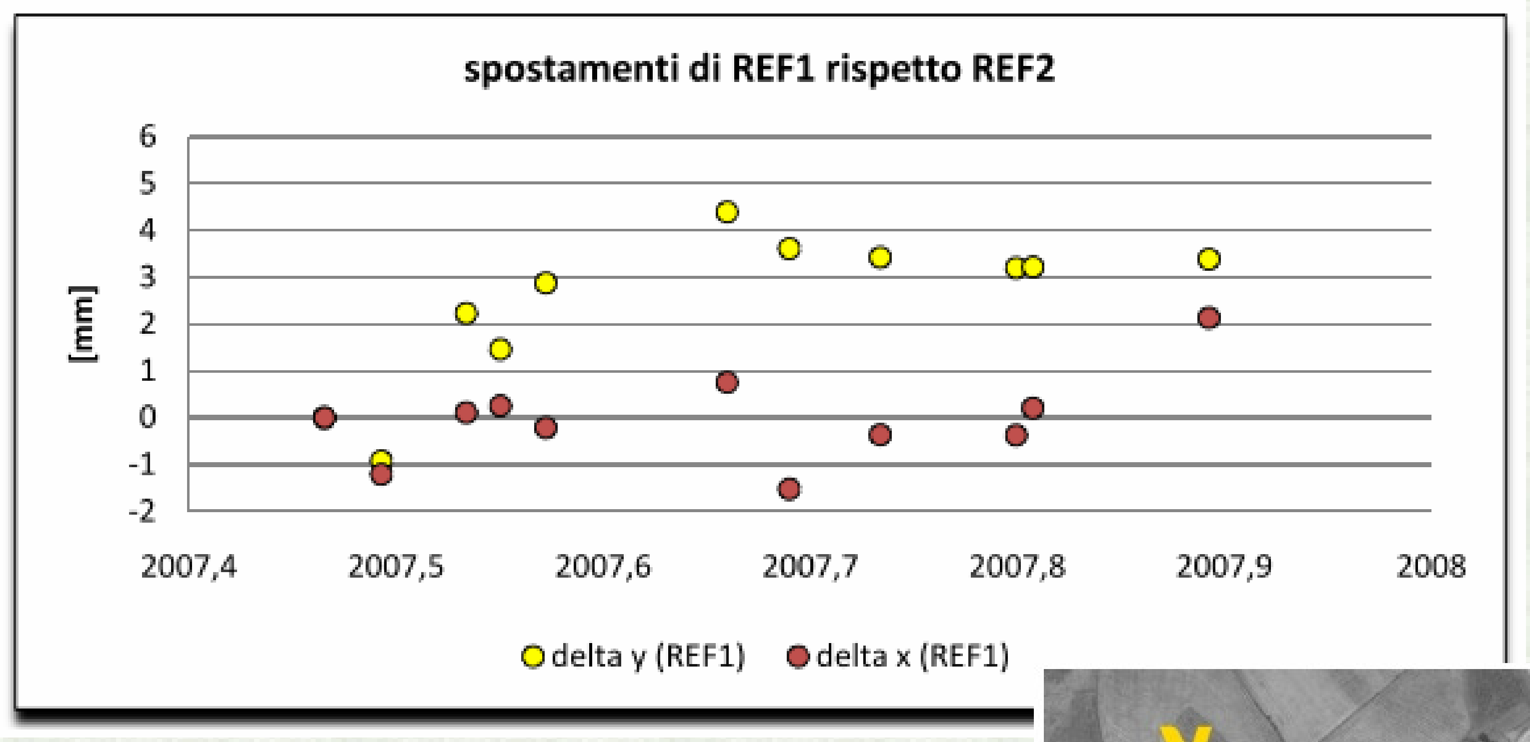
Serie Temporali GNSS

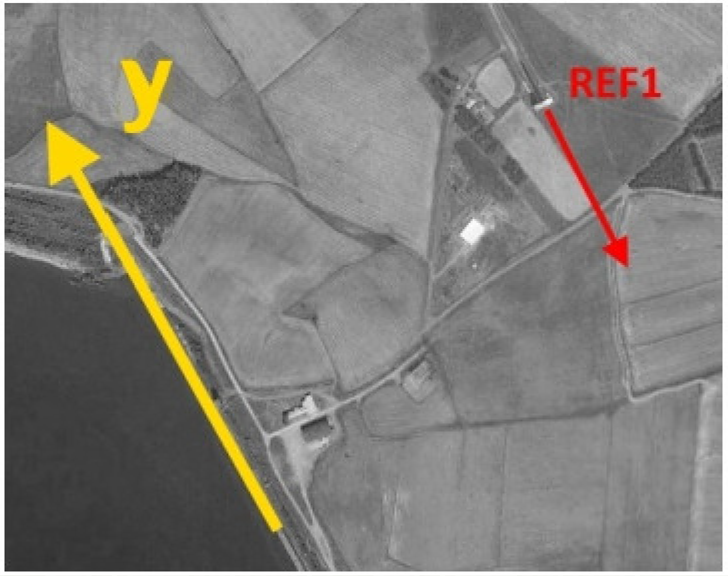


Trend lineare

Statistiche spostamenti	GPS sulle spalle della diga				GPS sul coronamento della diga			
Millimetri	A		D		B		C	
	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento
Minimo	-3.1	-4.8	-1.2	-2.8	-4.1	-4.0	-3.1	-2.9
Massimo	2.1	4.4	1.9	4.6	3.6	3.3	3.9	3.7
Max-Min	5.2	9.2	3.1	7.4	7.7	7.3	7.0	6.6

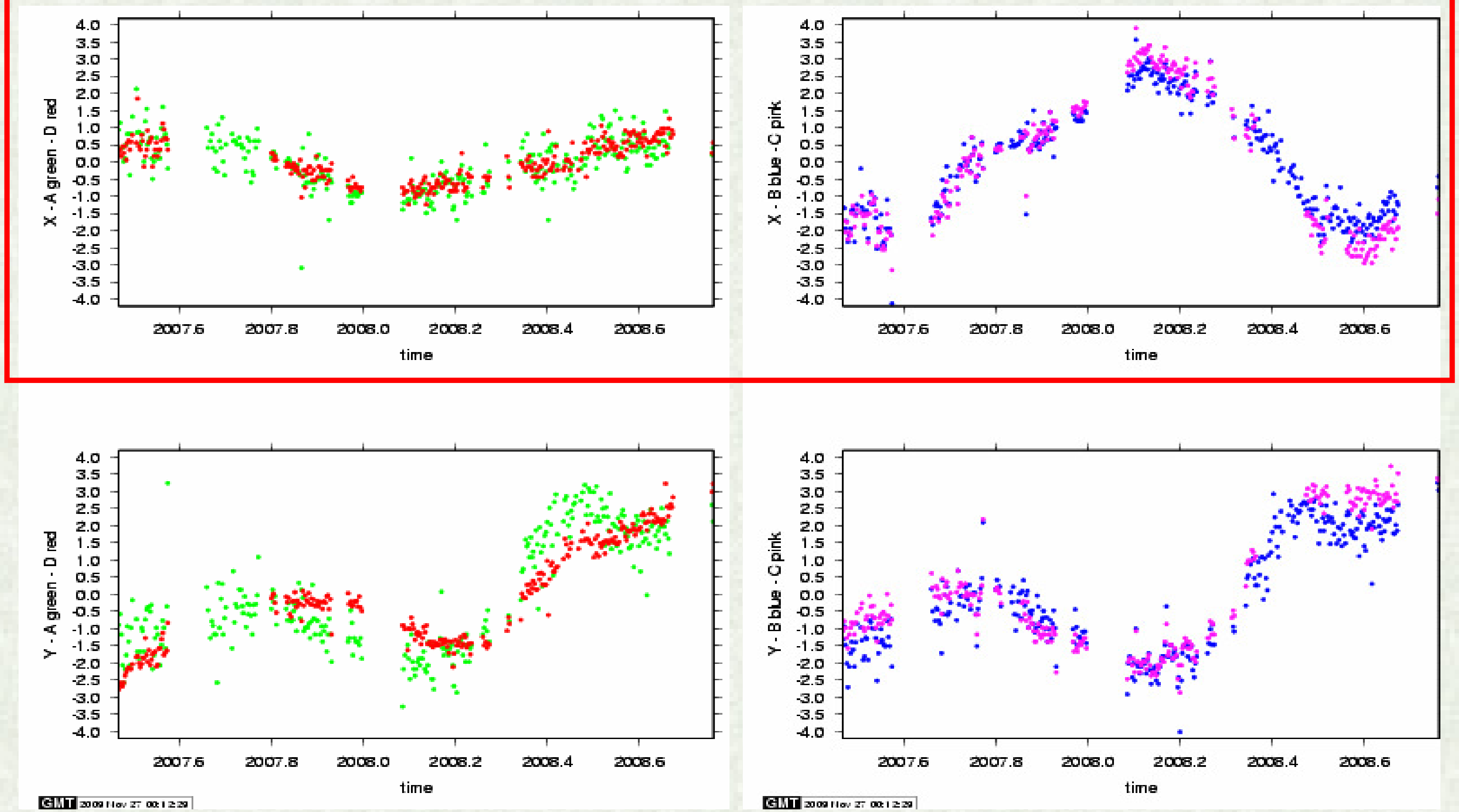
Analisi di Stabilità di REF1





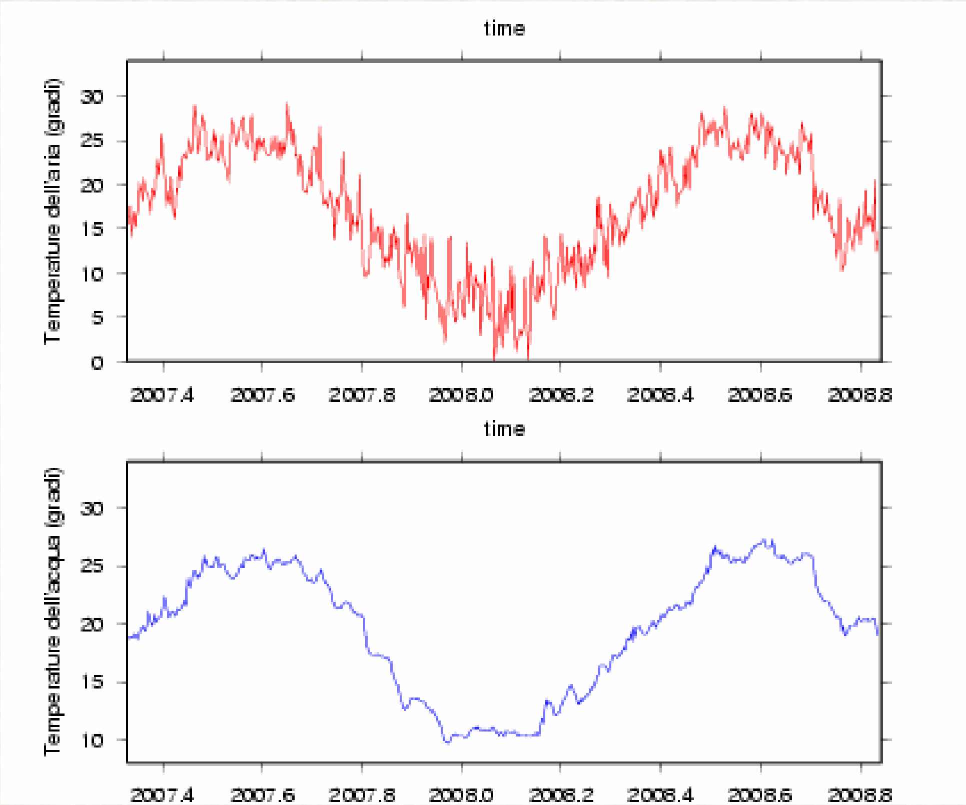
REF1 poggia su una struttura in posizione sopraelevata rispetto al piano campagna e collegata ad un canale posto in direzione parallela all'asse Y (direzione di massima pendenza del pendio)

Serie Temporali GNSS

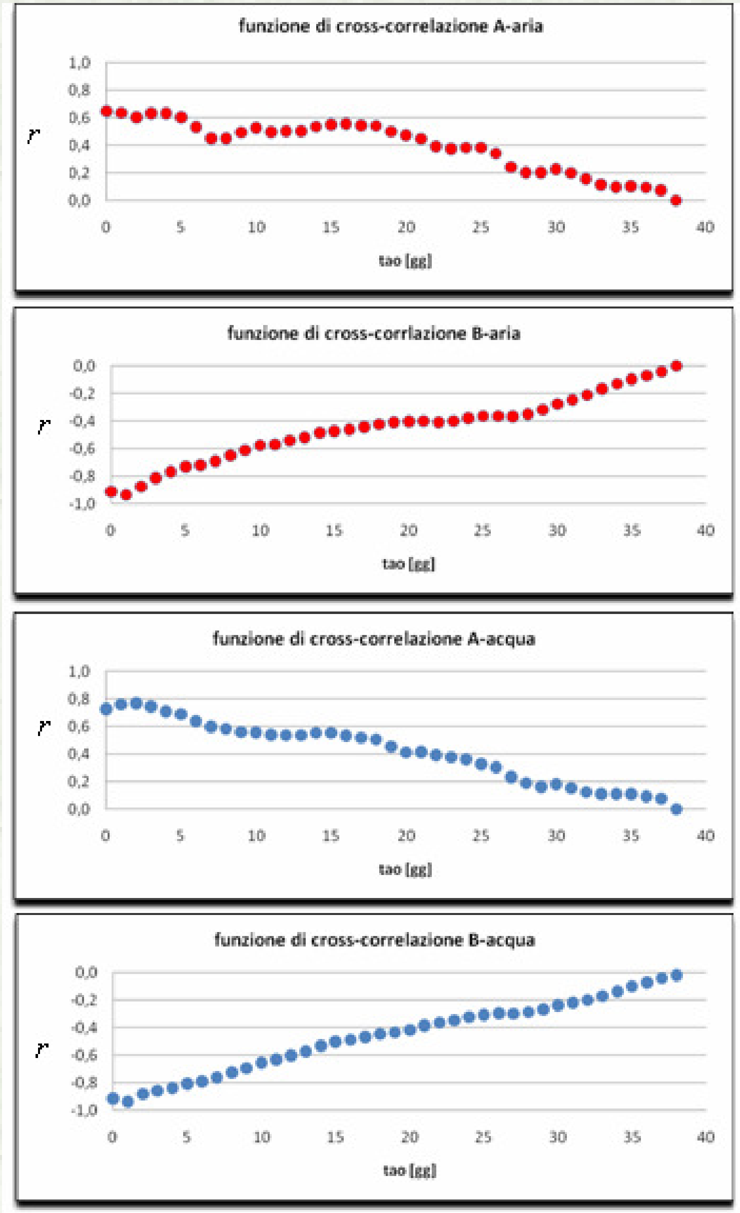


Statistiche spostamenti	GPS sulle spalle della diga				GPS sul coronamento della diga			
Millimetri	A		D		B		C	
	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento	Monte-valle	Corona-mento
Minimo	-3.1	-4.8	-1.2	-2.8	-4.1	-4.0	-3.1	-2.9
Massimo	2.1	4.4	1.9	4.6	3.6	3.3	3.9	3.7
Max-Min	5.2	9.2	3.1	7.4	7.7	7.3	7.0	6.6

Analisi Grandezze "Causa-Effetto"



	Δx *vs* ΔT_{aria}	Δx *vs* ΔT_{acqua}
Stazioni	ρ_{max}	ρ_{max}
A	**66%**	**77%**
B	**94%**	**94%**

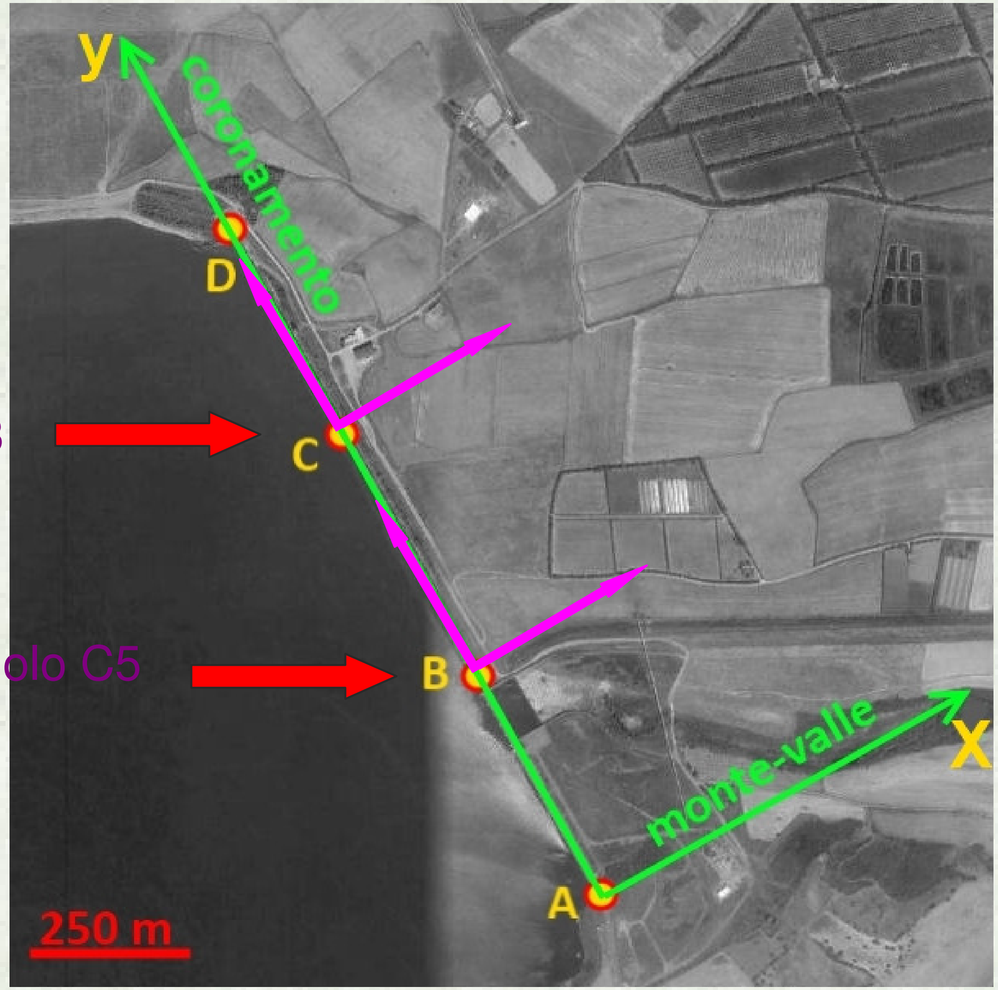


Cross-correlazione in funzione del ritardo tra i due segnali

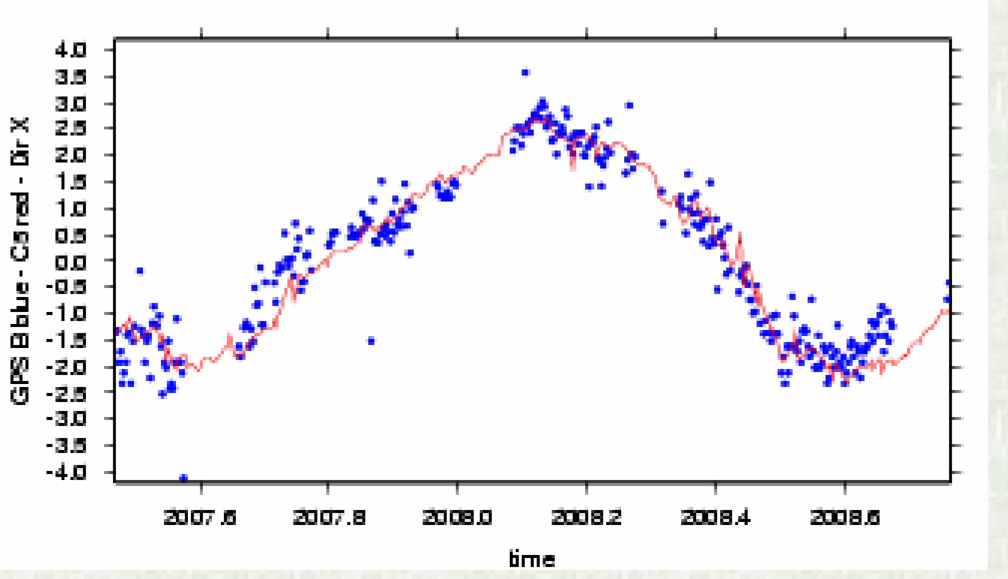
Confronto spostamenti misurati dai pendoli

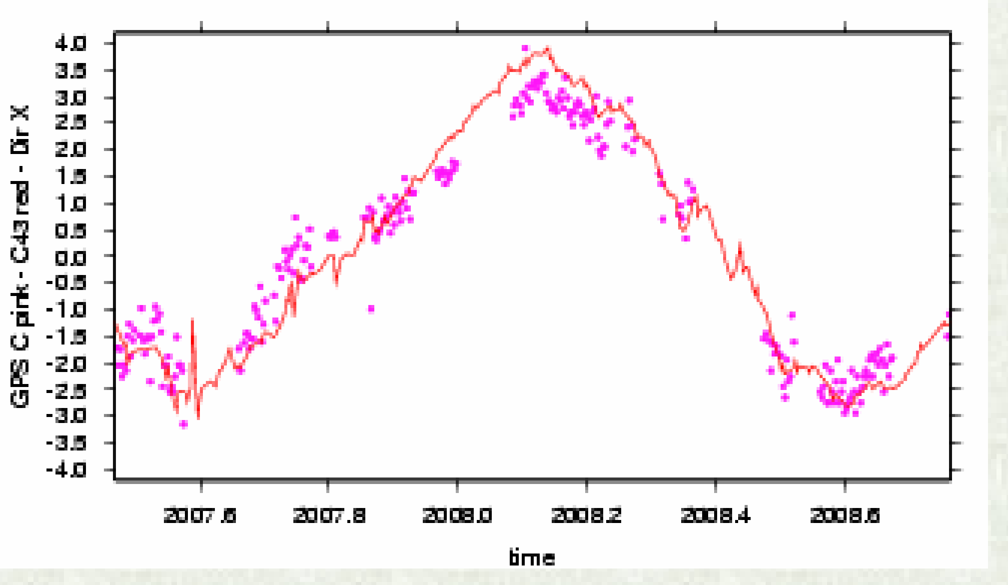
Pendolo C43

Pendolo C5



Confronto con i Pendoli

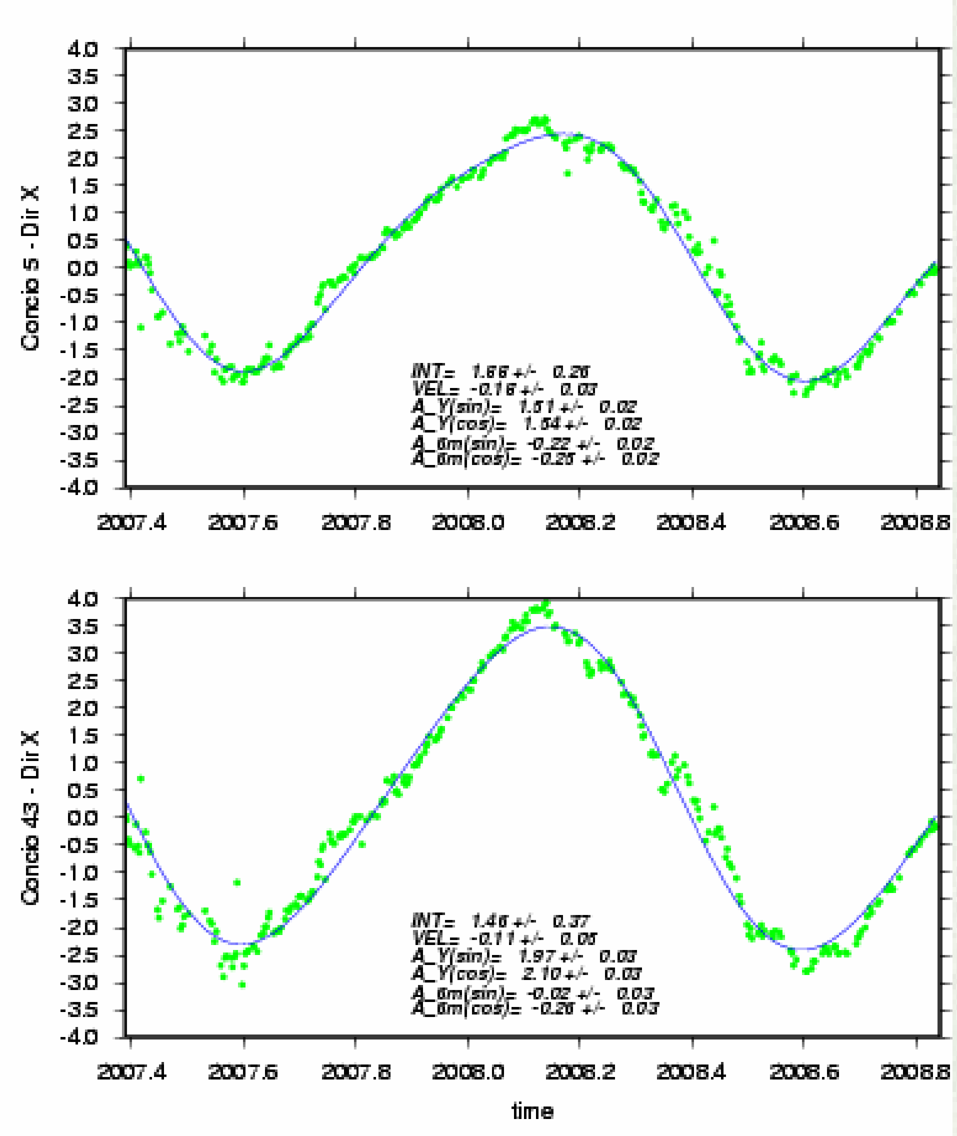




Spostamenti qualitativamente comparabili

Modello del comportamento strutturale

$$y_i = \quad a t_i + b + A\cos(\omega_{year} t_i) + B\sin(\omega_{year} t_i) + C\cos(\omega_{6month} t_i) + D\sin(\omega_{6month} t_i)$$



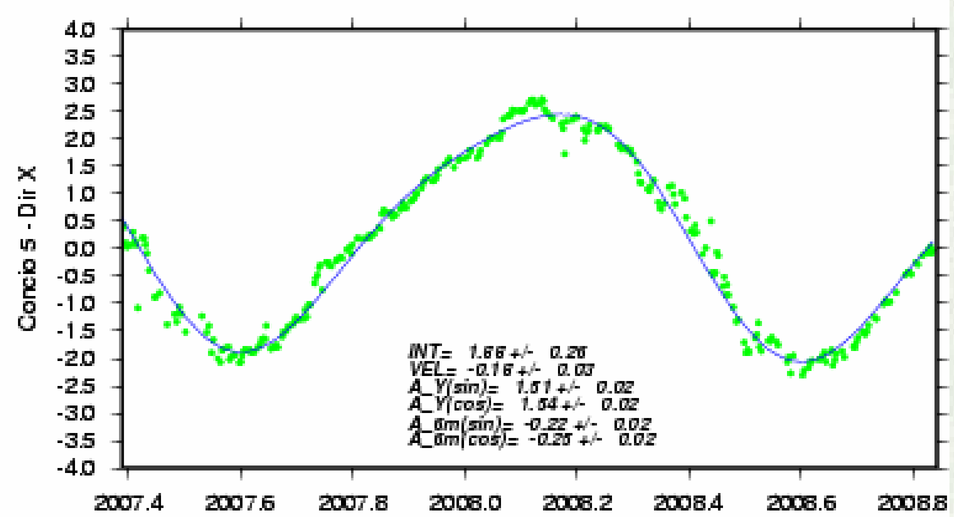
Il comportamento "standard" della diga è correttamente descritto dalle osservazioni dei pendoli (causate dalla temperatura atmosferica)

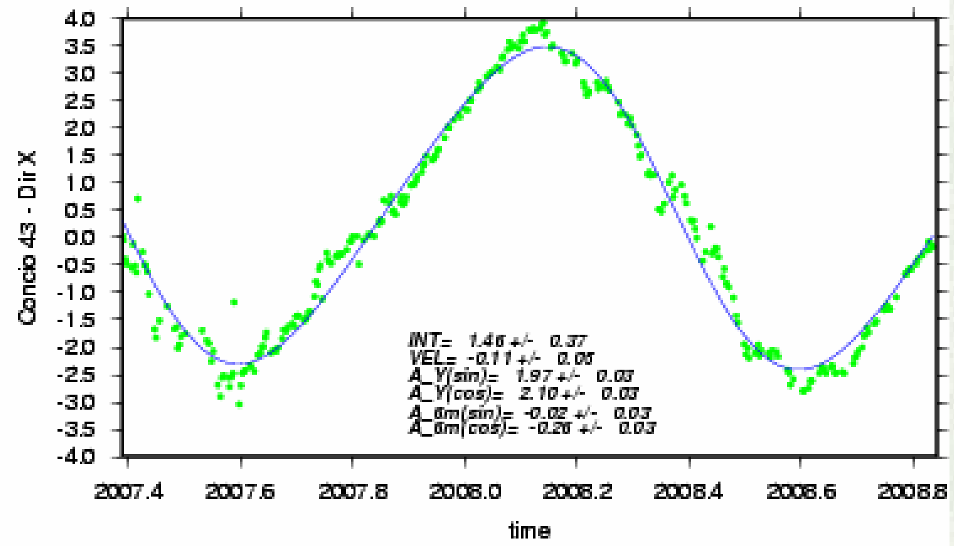
- **y_i** : lo spostamento i-esimo nella direzione monte-valle registrato al tempo t_i
- **ω_{year}** e **ω_{6month}**: le pulsazioni delle armoniche di frequenza annuale e semestrale caratteristiche dell'andamento stagionale della temperatura
- **A, B, C, D**: le ampiezze delle componenti armoniche
- **a** e **b**: i parametri di un eventuale spostamento di tipo lineare

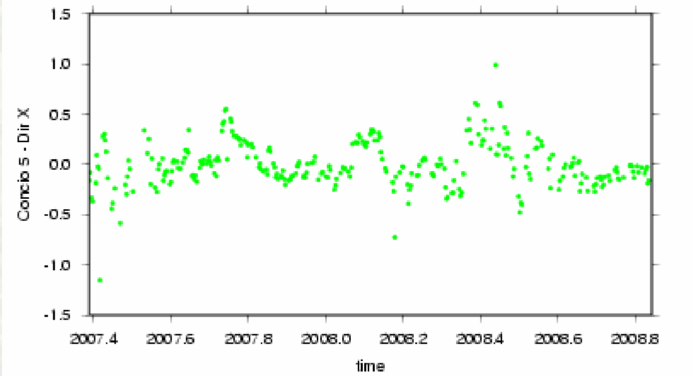
Interpolazione ai MQ

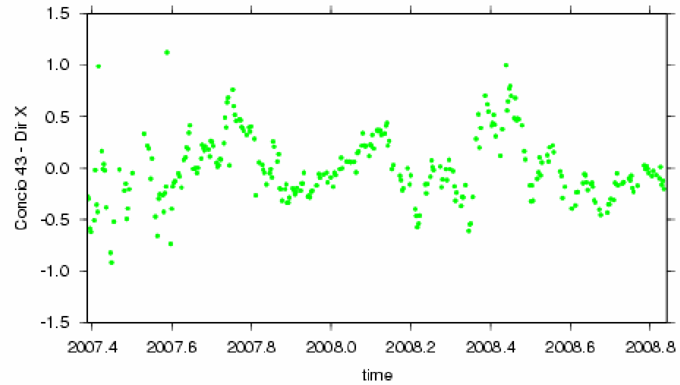
Modello del comportamento strutturale

$$y_i = at_i + b + A\cos(\omega_{year} t_i) + B\sin(\omega_{year} t_i) + C\cos(\omega_{6month} t_i) + D\sin(\omega_{6month} t_i)$$







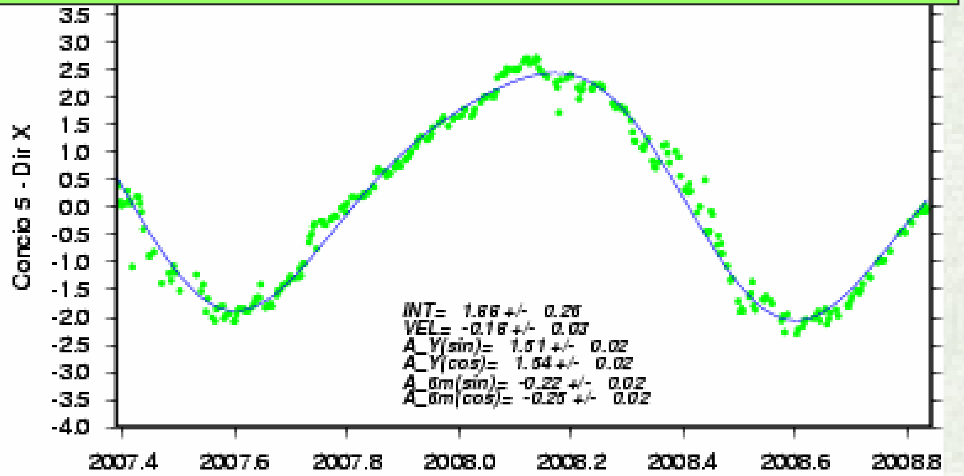


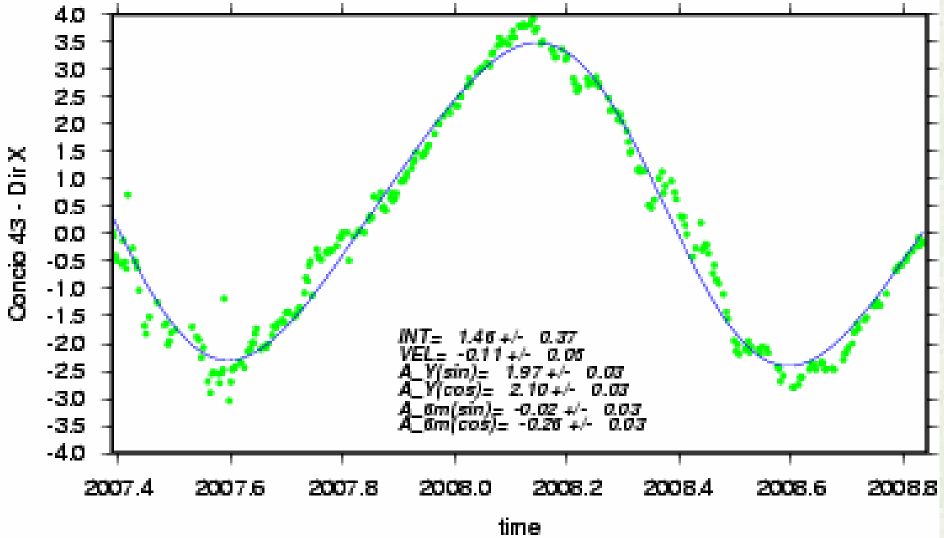
Statistiche (mm)	Pendolo C5	Pendolo C43
Minimo	-1.1	-0.9
Massimo	1.0	1.1
Intervallo di variazione	2.1	2.0
Dev. St.	0.2	0.3

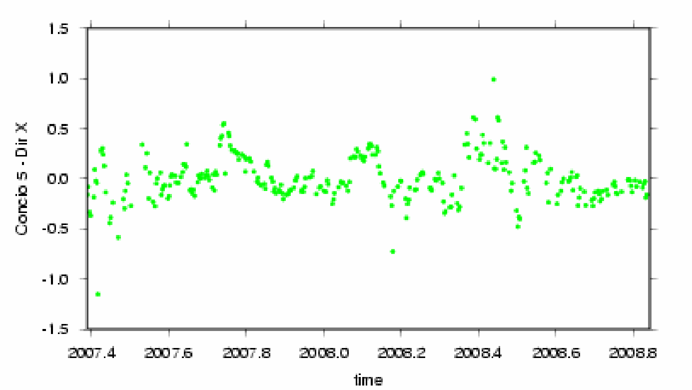
Modello del comportamento strutturale

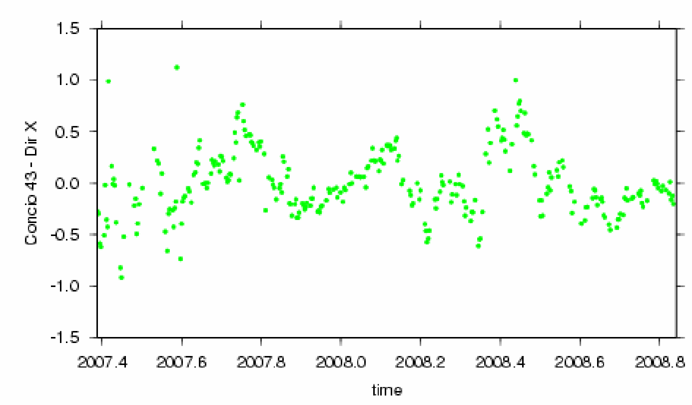
$$y_i = \quad at_i + b + A\cos\left(\omega_{year} t_i\right) + B\sin\left(\omega_{year} t_i\right) + C\cos\left(\omega_{6month} t_i\right) + D\sin\left(\omega_{6month} t_i\right)$$

Buona taratura del modello funzionale affidabile se fatta con un set di dati sufficientemente lungo (16 mesi dati)



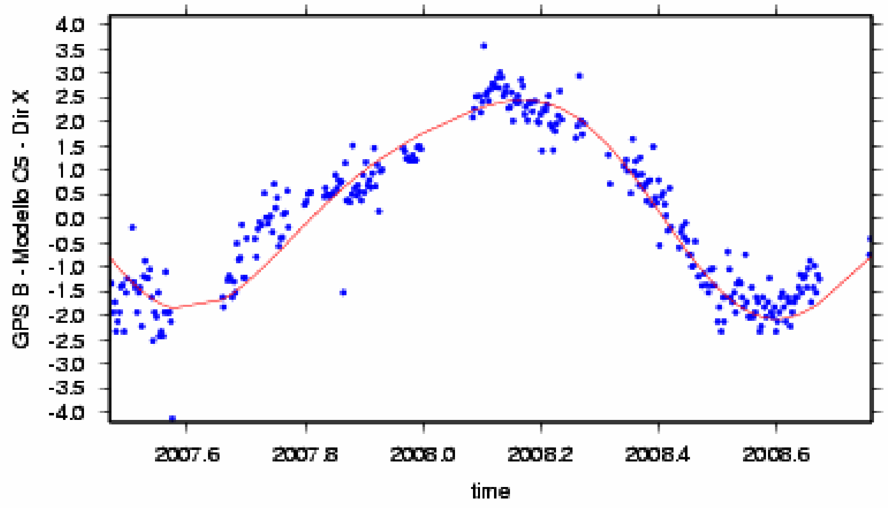


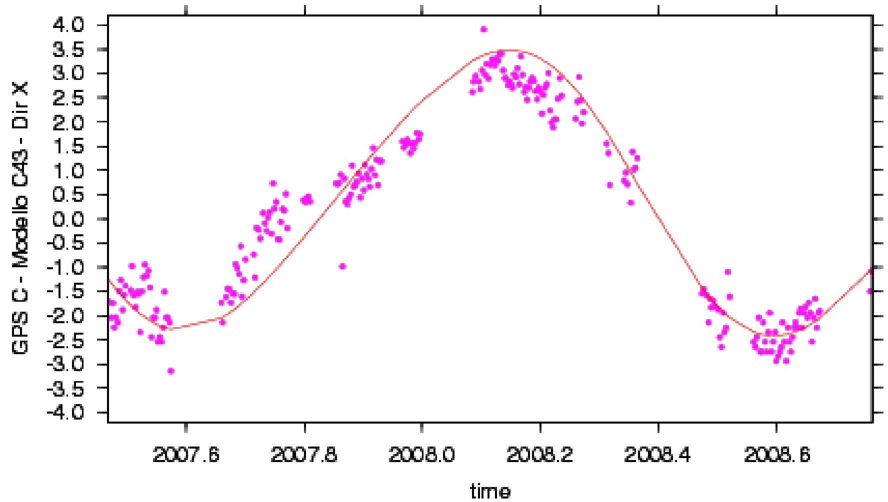


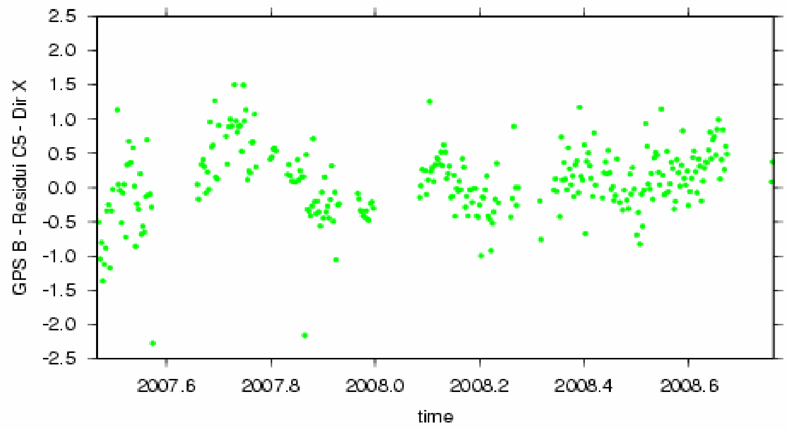


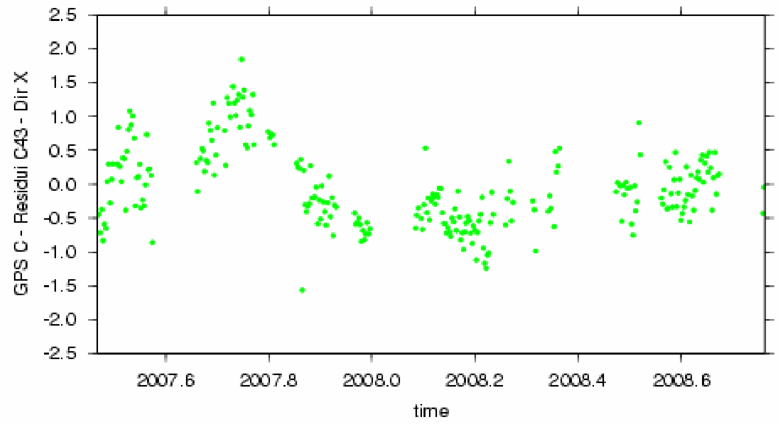
Statistiche (mm)	Pendolo C5	Pendolo C43
Minimo	-1.1	-0.9
Massimo	1.0	1.1
Intervallo di variazione	2.1	2.0
Dev. St.	0.2	0.3

Modello Pendoli vs. GNSS





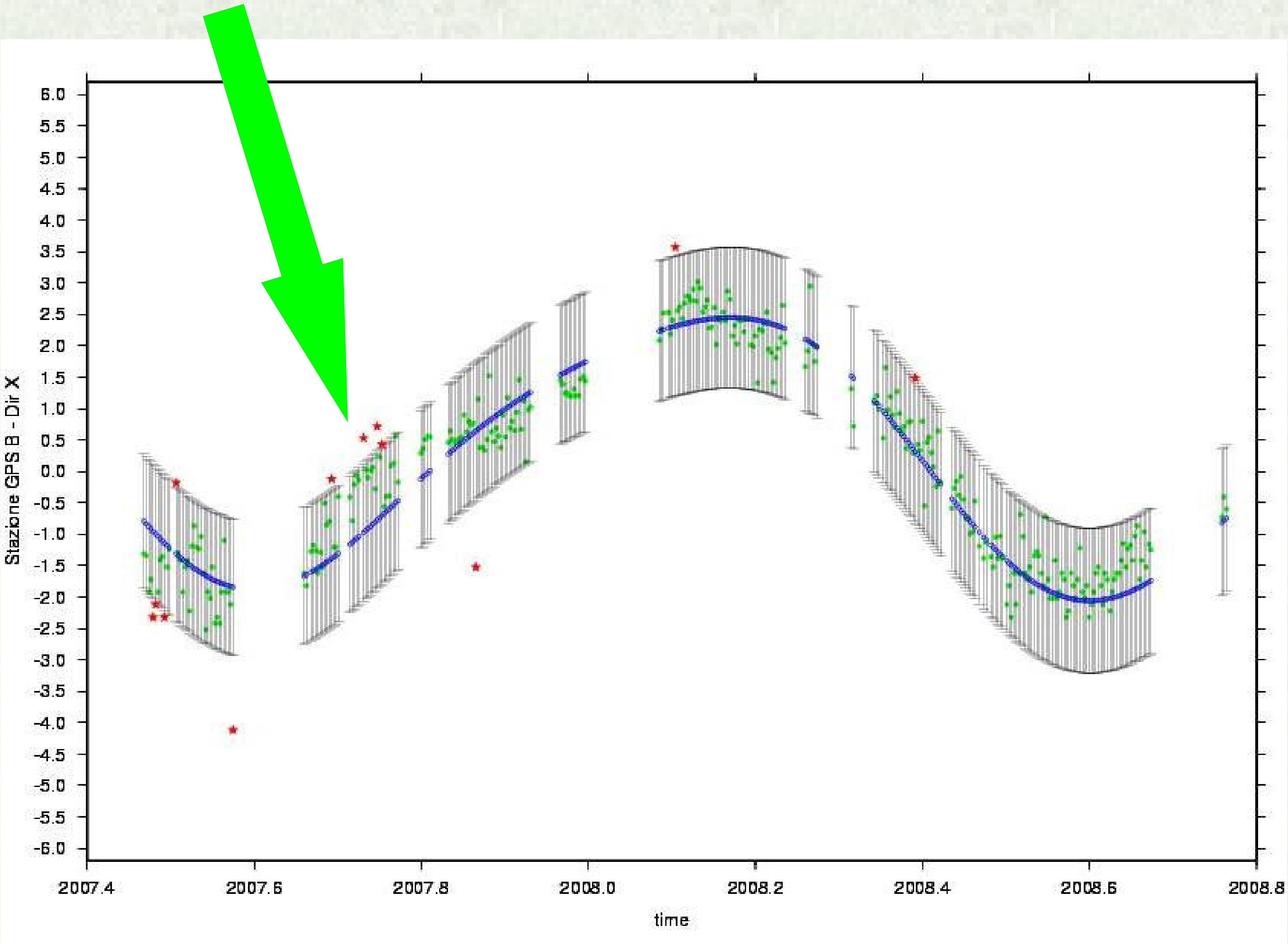




Statistiche (mm)	GPS B	GPS C
Minimo	-2.3	-1.6
Massimo	1.5	1.8
Intervallo di variazione	3.8	3.4
Media	0.1	-0.1
Dev. St.	0.5	0.6

Verifica qualità adattamento tra spostamenti GPS e modello deterministico tarato sui dati dei pendoli

Supporto alle decisioni



Conclusioni

- I sistemi GNSS sono validi nell'ambito del monitoraggio strutturale nel caso di una diga
- PREVISIONE, BUONI RISULTATI
- La possibilità di automatizzare la misura, la validazione del dato e la sua analisi permettono un controllo "in continuo" affidabile
- E' pensabile estendere l'esperimento anche a strutture diverse da una diga
- La scelta dei punti di riferimento va valutata con accortezza
- Le stazioni *reference* devono essere almeno 2 per un controllo reciproco
- La serie temporale dei fenomeni "causa-effetto" non può essere troppo limitata

Grazie per l'attenzione

Frana di Vallcebre - Catalunya

Frana monitorata in continuo dal 1996.

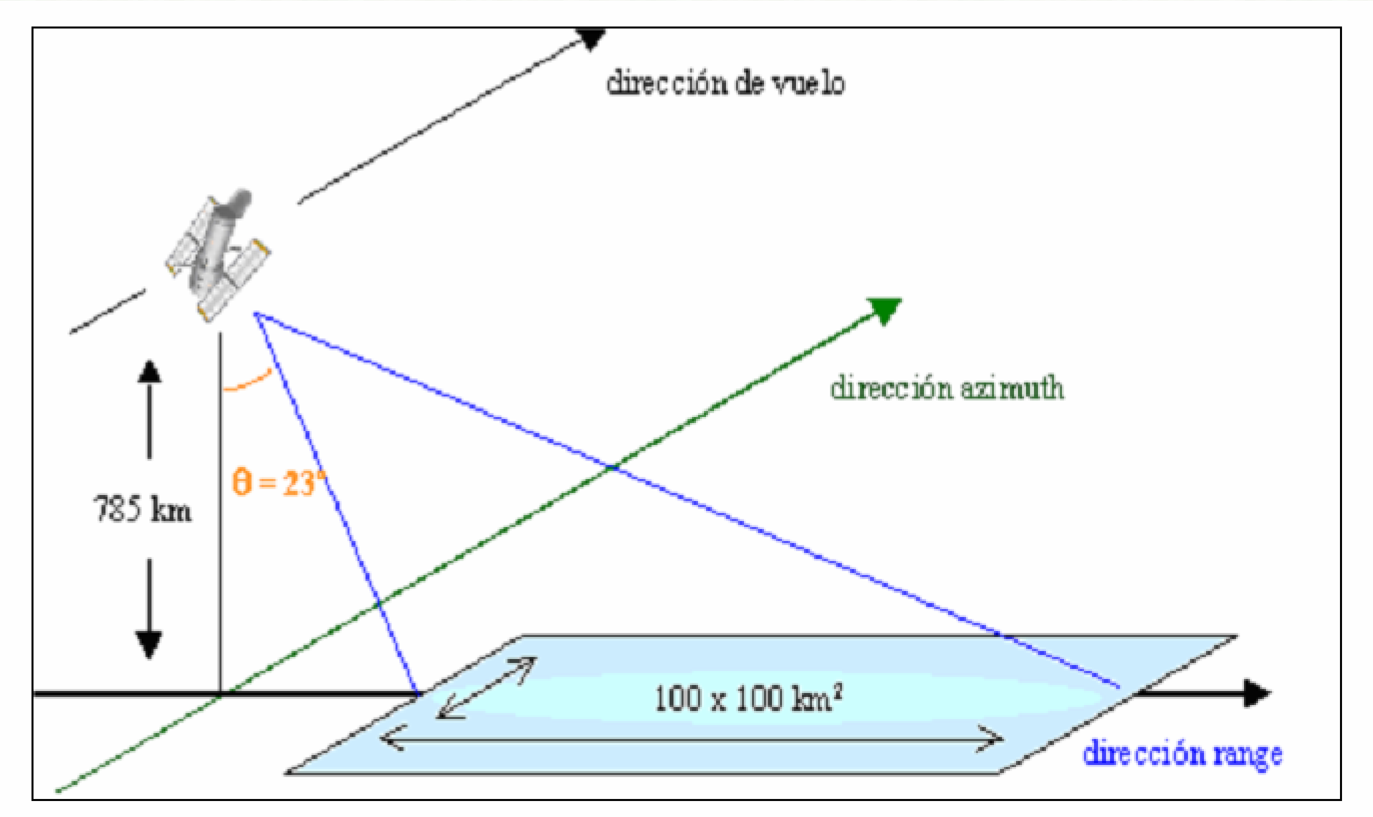
Frana lenta. Attivata da piogge.

Ubicazione: Berguedà, Nord-Est Catalunya, Pirenei.

Synthetic Aperture Radar

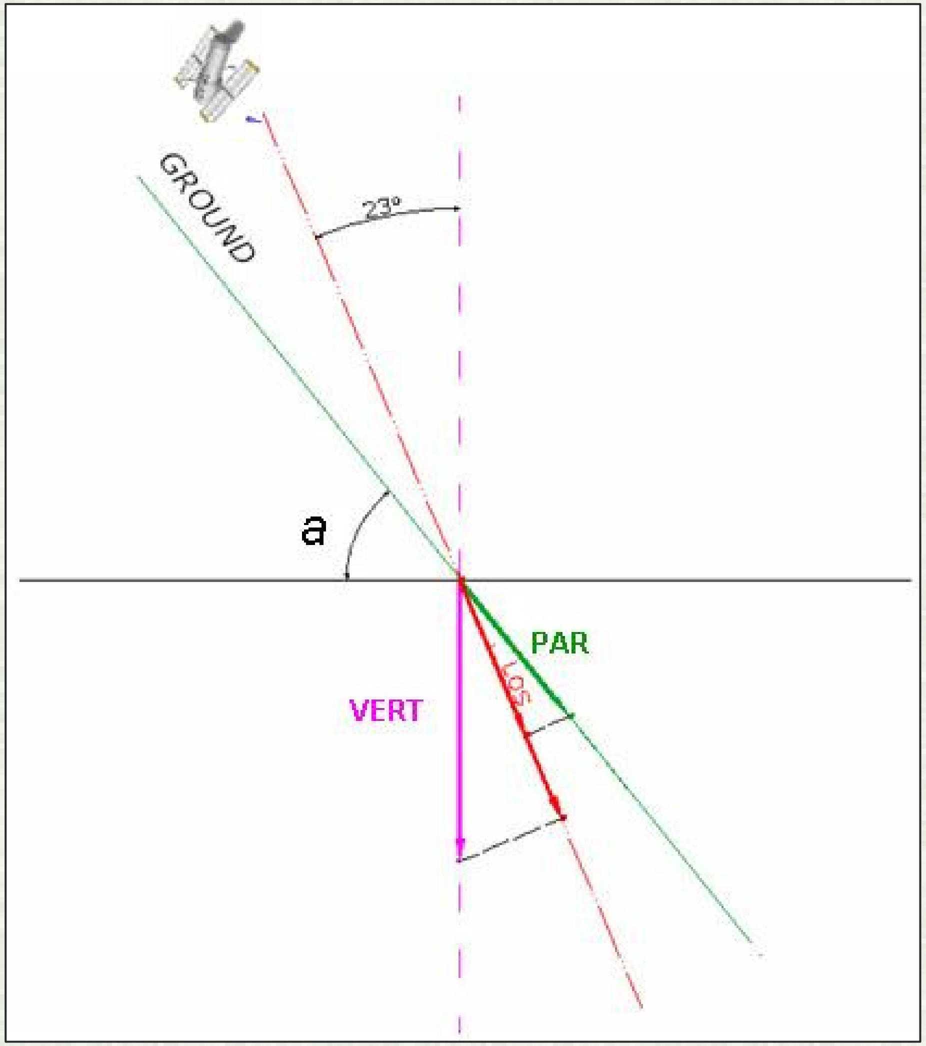
Il SAR (Synthetic Aperture Radar) è un sensore ad alta risoluzione in grado di restituire immagino 2D della terra.

E' un sistema coerente che restituisce misure di ampiezza e di fase del segnale radar retro-diffuso.



Synthetic Aperture Radar

Il SAR misura distanze e fasi in direzione LOS (Line of sight – linea che unisce satellite e punto osservato) e restituisce una matrice 2D complessa.



Synthetic Aperture Radar

Ogni pixel contiene due componenti corrispondenti:

- Parte immaginaria → *immagine di fase* → attraverso tecniche di interferometria radar permette di misurare distanze

- Parte reale → *immagine di ampiezza* → potenza del segnale riflesso dal terreno, utile per identificare le aree e i manufatti d'interesse

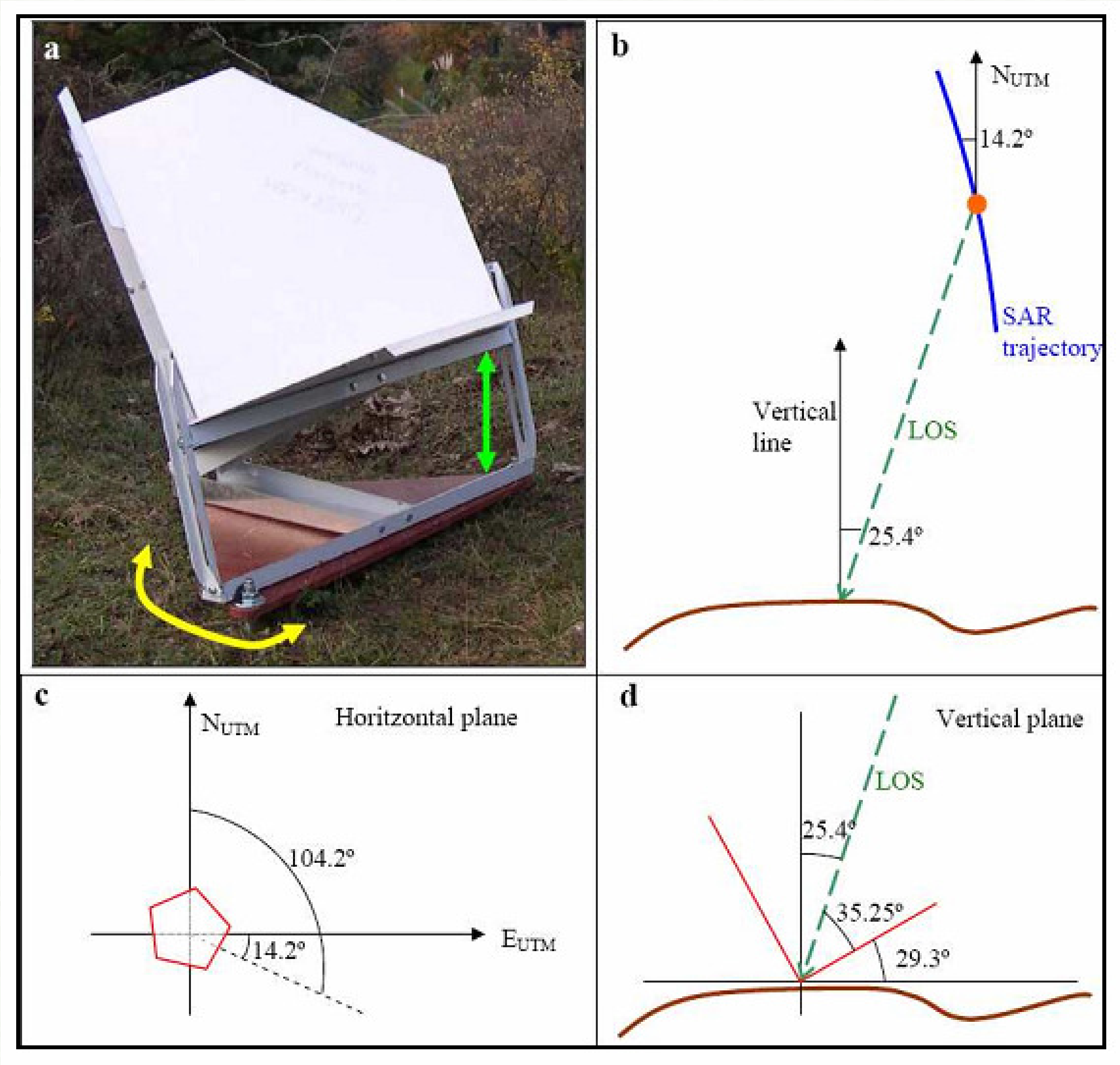
Interferometria Differenziale (DInSAR): sfrutta la differenza di fase acquisita in due passaggi differenti del satellite sulla stessa zona (qualità della misura di fase buona in entrambe le misure, alta coerenza) per misurare le deformazioni del terreno.

In zone densamente vegetate la qualità della fase è bassa

↓

Riflettori artificiali (corner-reflector)

Corner Reflector (Riflettori aritificiali)



Nella frana di Vallcebre, altamente vegetata la tecnica di interferometria differenziale (DInSAR) è molto limitata, poiché l'informazione contenuta nella fase è molto rumorosa.

Installazione di 7 **corner reflector** (fase importante - 2006)

- Devono ricevere e riflettere efficacemente il segnale radar

Planimetria: <u>CR perpendicolare alla traiettoria del satellite</u>

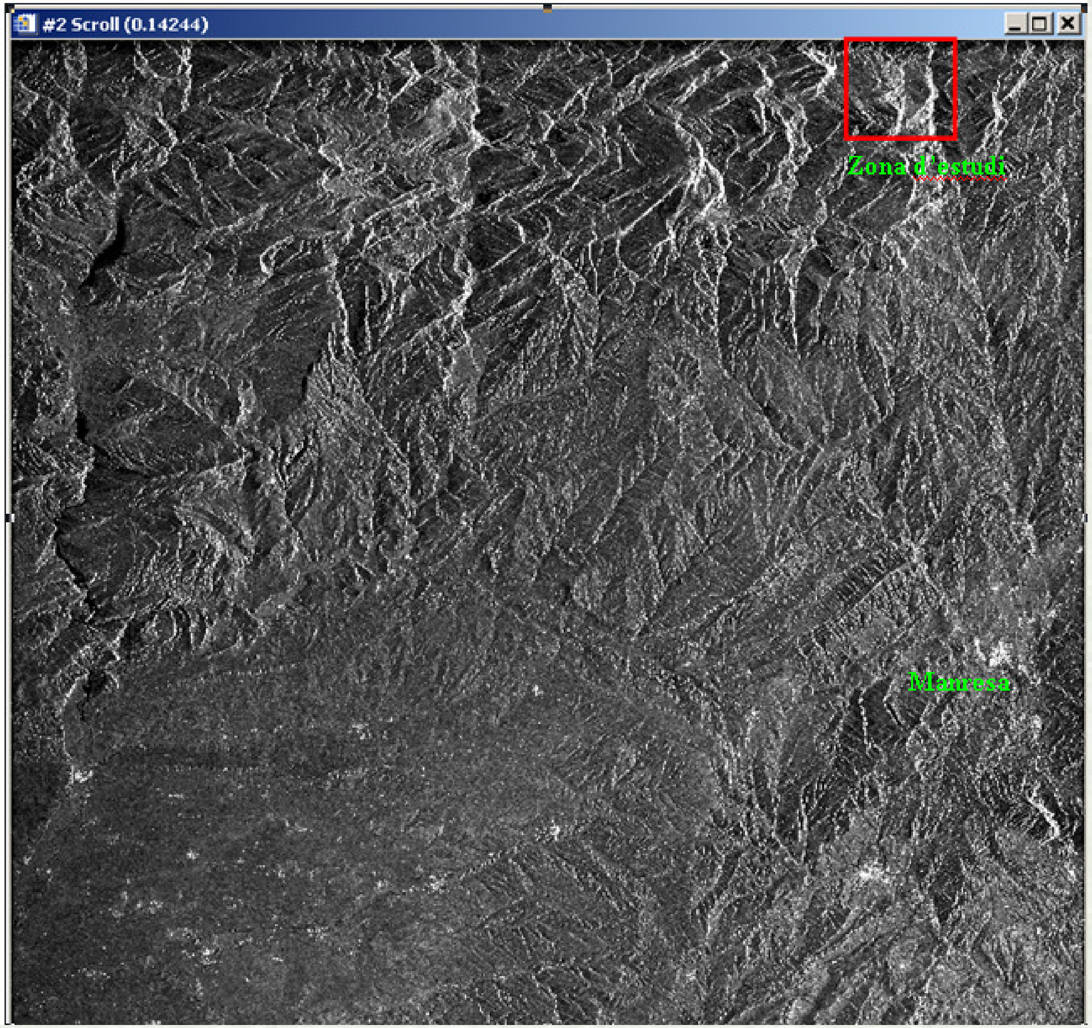
Verticalmente: CR deve essere relazionato con l'angolo d'incidenza dell'acquisizione del SAR

- Fissati adeguatamente

Acquisizione immagini e Localizzazione (Area Frana)

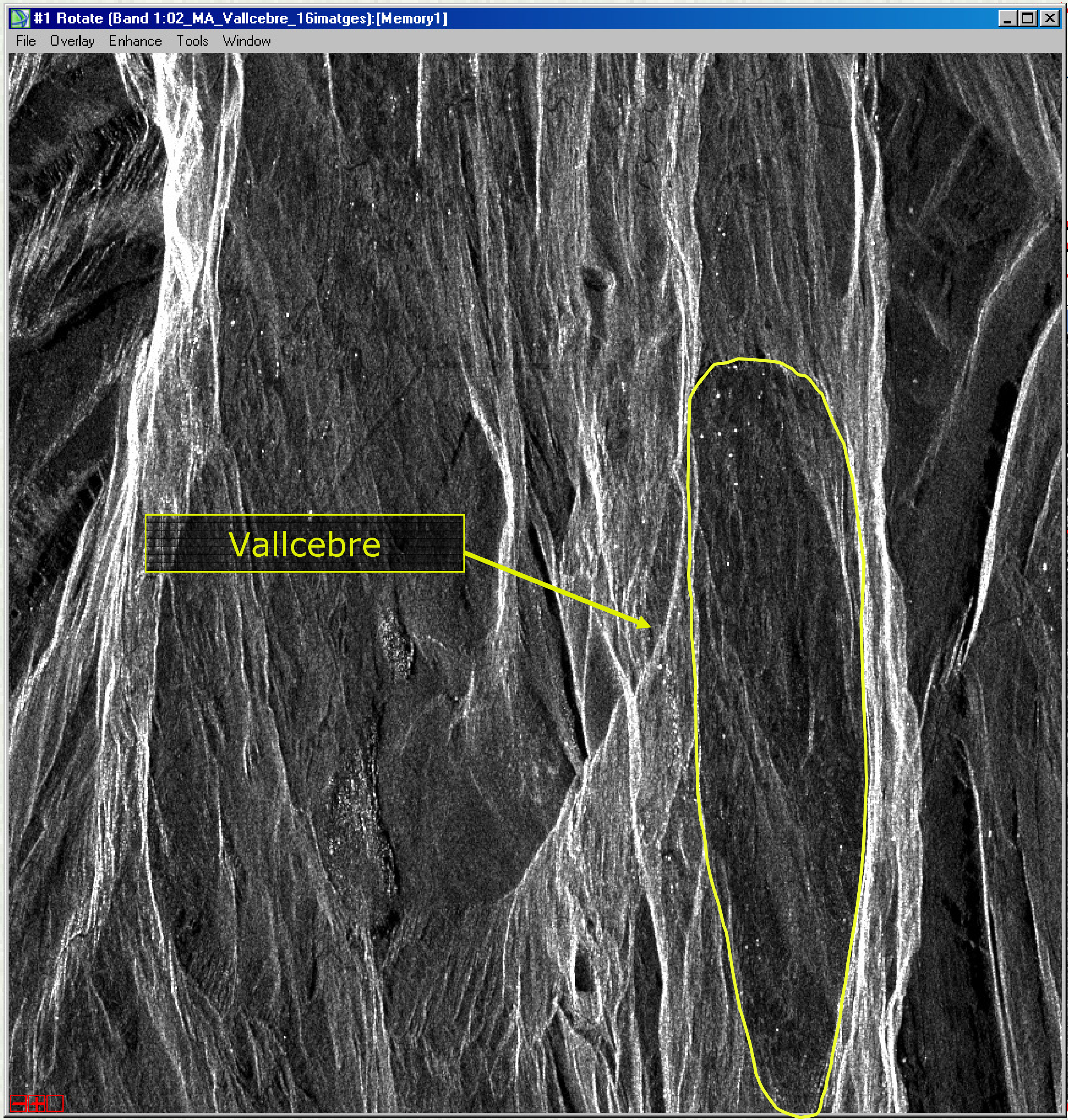
Acquisizione immagini ASAR (Advanced Synthetic Aperture Radar) del satellite ENVISAT posteriori a novembre 2006

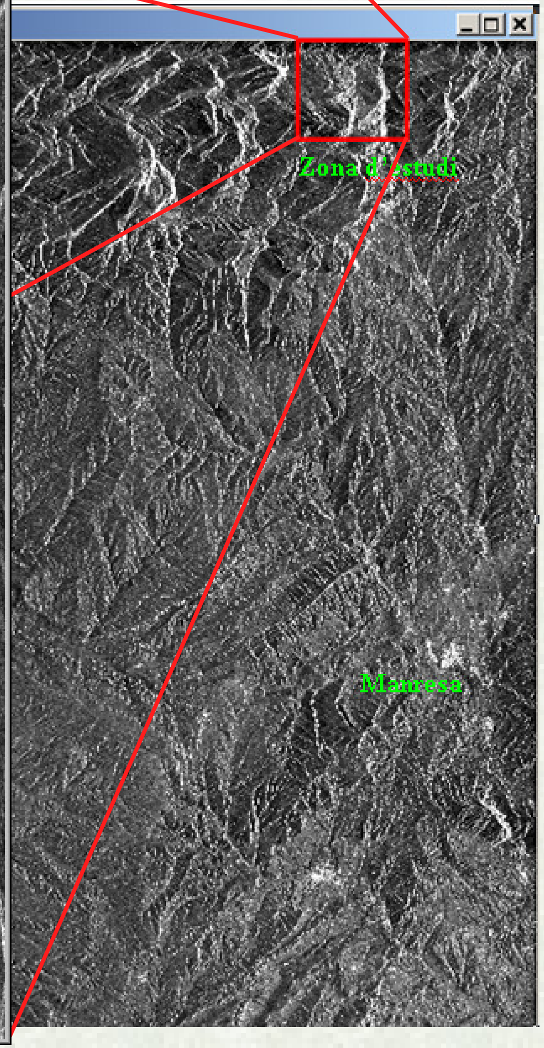
(16 immagini)



ini e

Frana)


#1 Rotate (Band 1:02_MA_Vallcebre_16imatges):[Memory1]
File Overlay Enhance Tools Window
Vallcebre


Zona d'estudi
Manresa

Localizzazione (Corner Reflector)

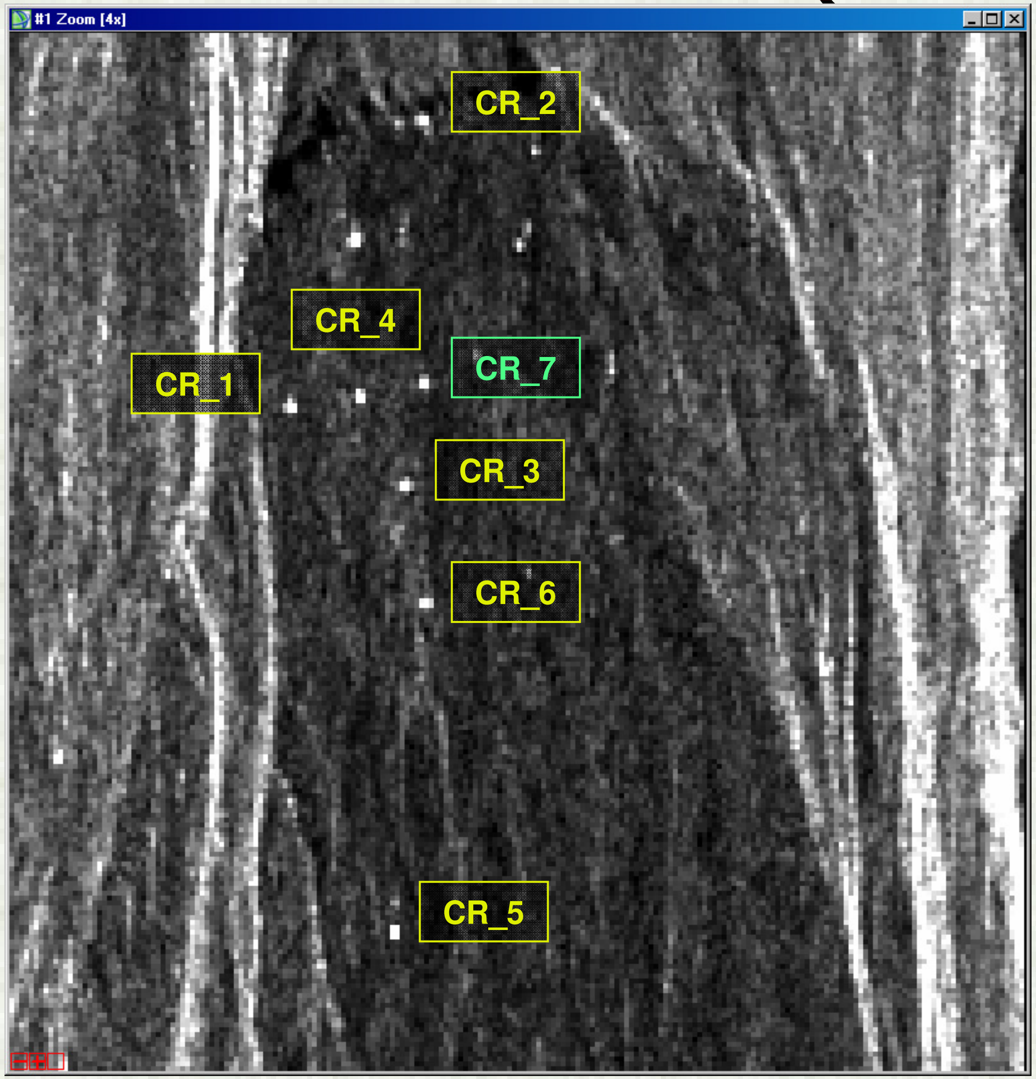


Immagine d'ampiezza SAR (Mean Amplitude Map)

Elaborazioni interferometriche

Misure ed elaborazioni eseguite in due tempi:

- **2008**: 4 immagini ENVISAT (29/12/2006 – 22/06/2007) – 6 interferogrammi
- **2009** : 16 immagini ENVISAT (29/12/2006 - 02/01/2009) - 93 interferogrammi

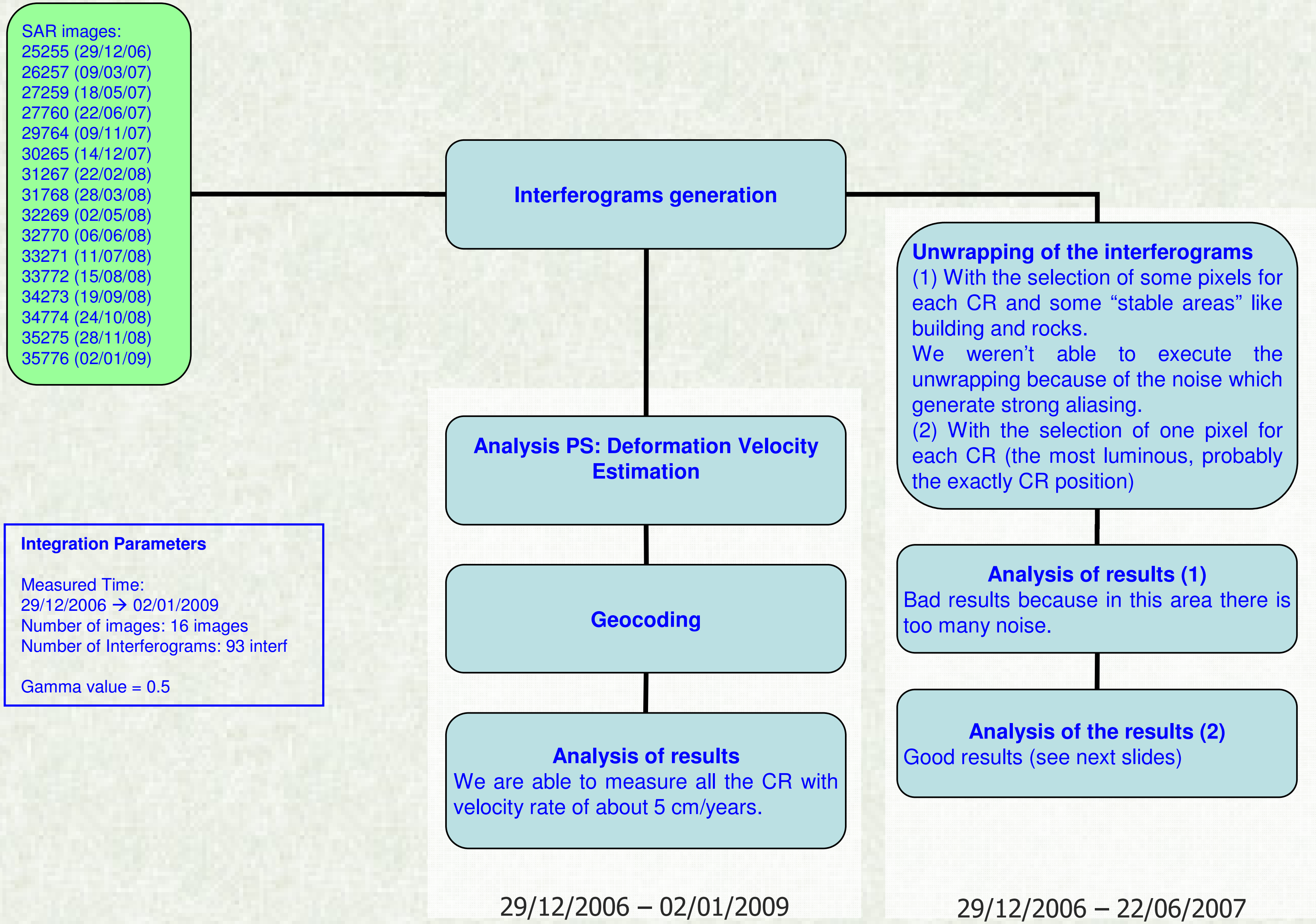
La tecnica si basa sulle informazioni contenute nelle immagini acquisite dallo stesso satellite in momenti differenti.

Se c'è uno spostamento questo si riflette nella fase interferometrica differenziale.

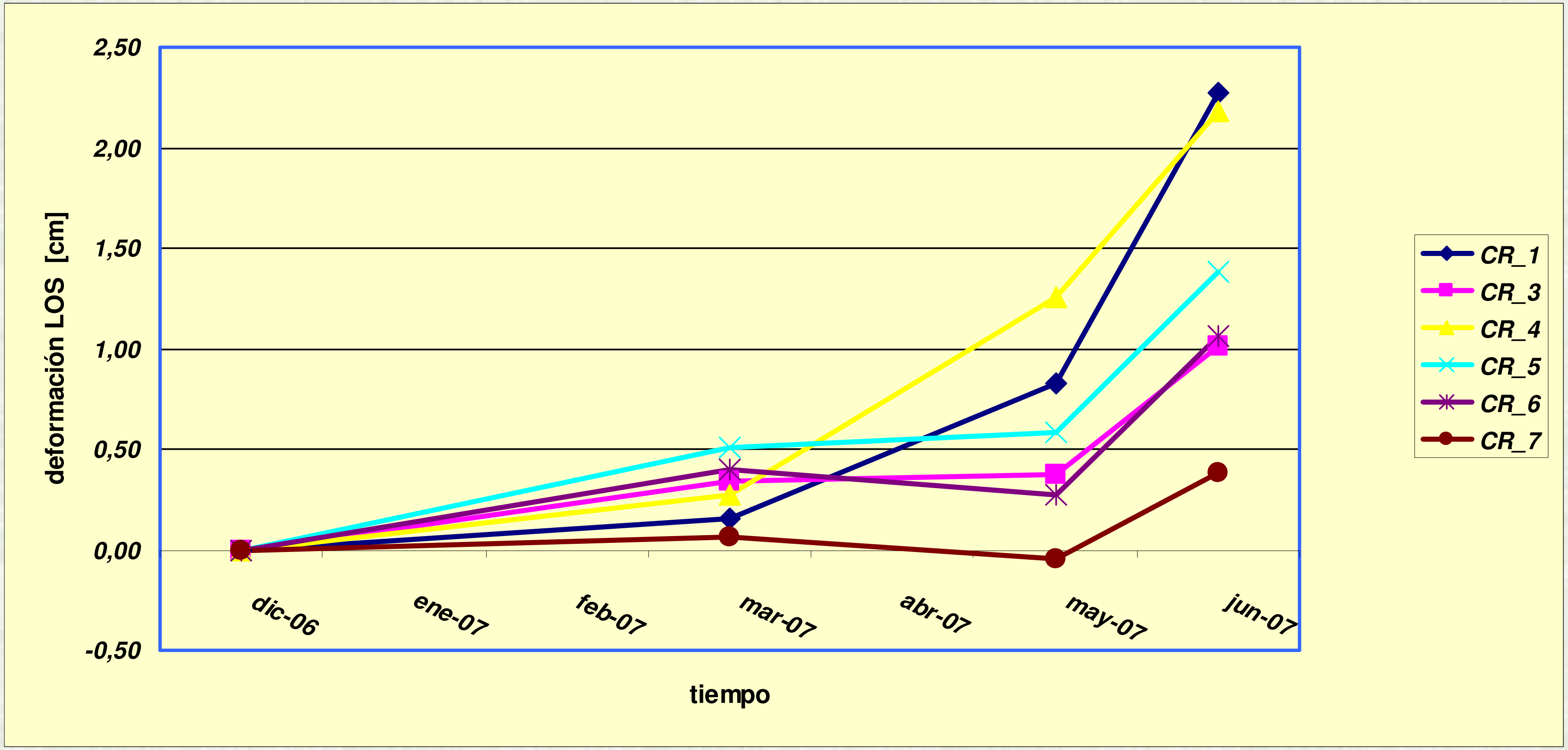
Phase unwrapping (srotolamento della fase) è necessario in quanto la fase è nota a meno di un numero intero di cicli di modulo 2Π. (Possibili errori di *aliasing* sono molto frequenti).

Siamo in grado di stimare la velocità di deformazione (distanza).

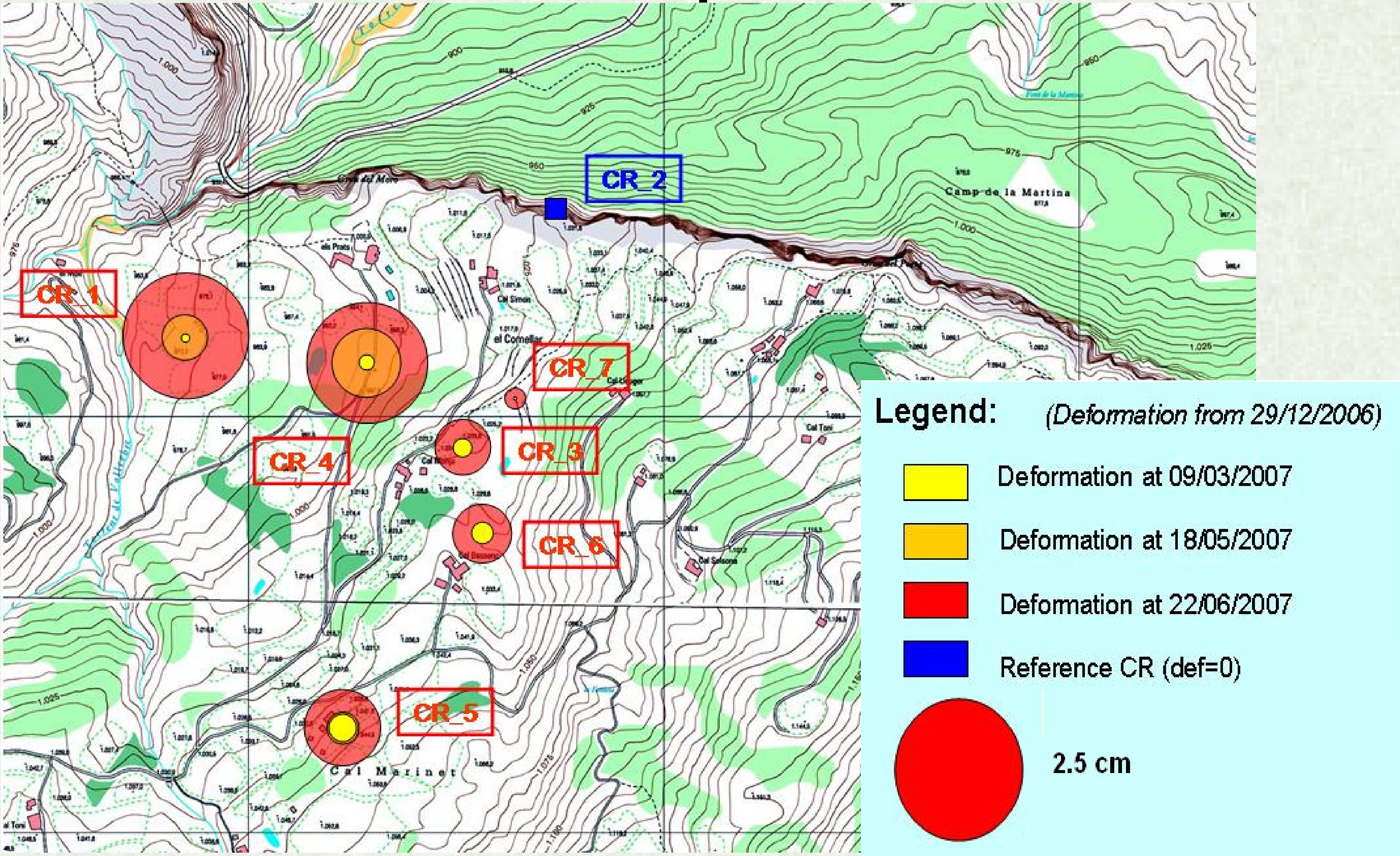
Risultati elaborazioni (1)



Deformations profiles in LOS direction



Deformations Map: 12/2006-06/2007



Risultati elaborazioni (2)

SAR images:
25255 (29/12/06)
26257 (09/03/07)
27259 (18/05/07)
27760 (22/06/07)
29764 (09/11/07)
30265 (14/12/07)
31267 (22/02/08)
31768 (28/03/08)
32269 (02/05/08)
32770 (06/06/08)
33271 (11/07/08)
33772 (15/08/08)
34273 (19/09/08)
34774 (24/10/08)
35275 (28/11/08)
35776 (02/01/09)

Interferograms generation

Analysis PS: Deformation Velocity Estimation

Geocoding

Analysis of results
We are able to measure all the CR with velocity rate of about 5 cm/years.

29/12/2006 – 02/01/2009

Unwrapping of the interferograms
(1) With the selection of some pixels for each CR and some "stable areas" like building and rocks.
We weren't able to execute the unwrapping because of the noise which generate strong aliasing.
(2) With the selection of one pixel for each CR (the most luminous, probably the exactly CR position)

Analysis of results (1)
Bad results because in this area there is too many noise.

Analysis of the results (2)
Good results (see next slides)

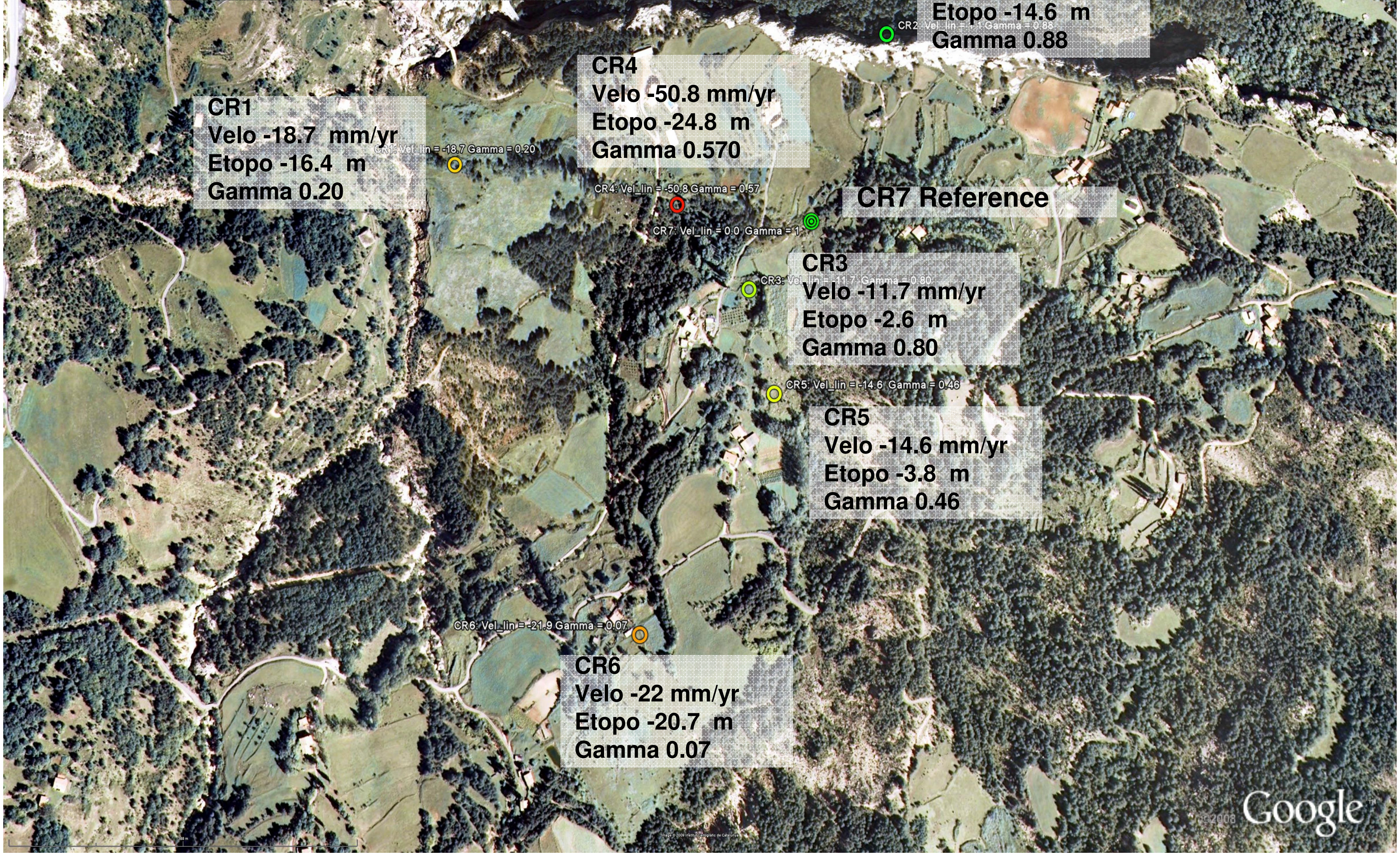
29/12/2006 – 22/06/2007

Integration Parameters

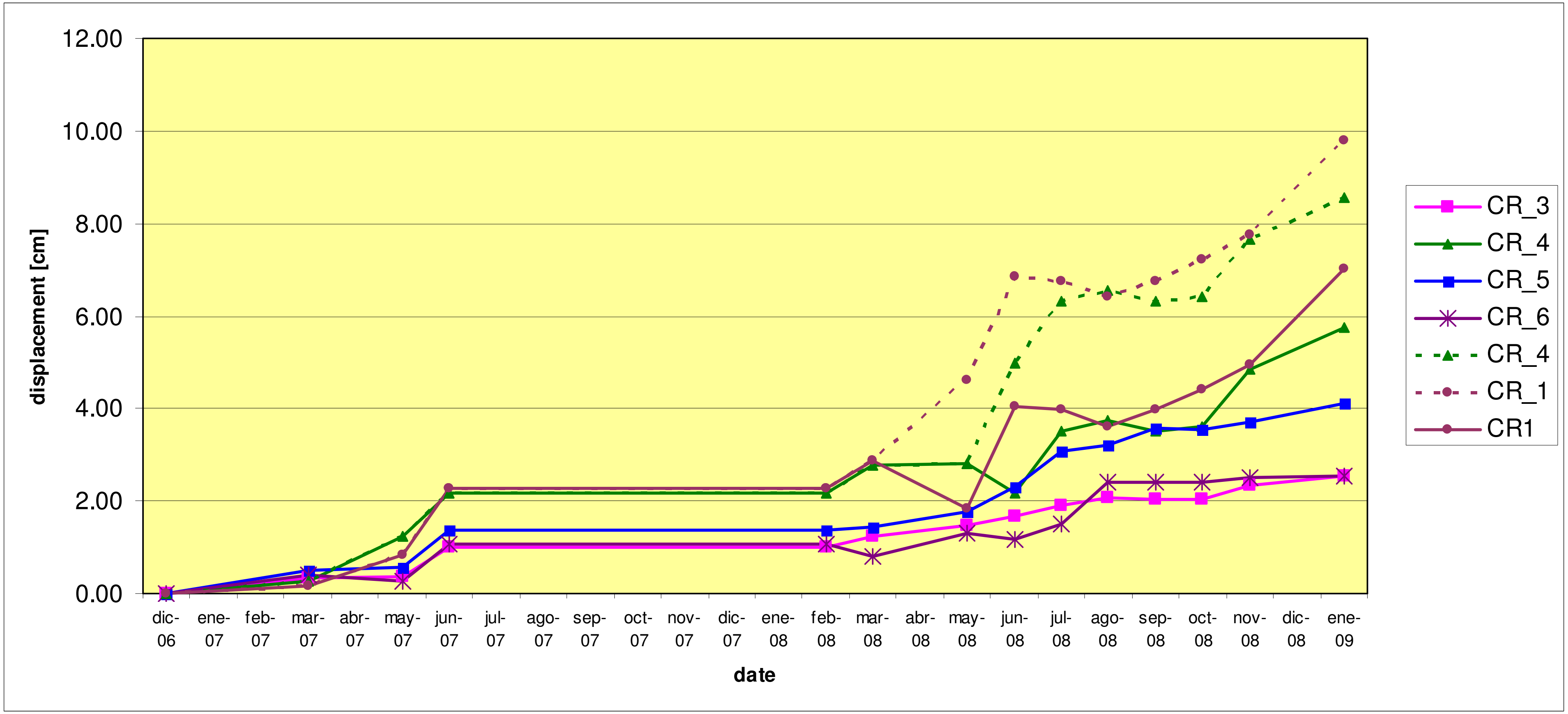
Measured Time:
29/12/2006 → 02/01/2009
Number of images: 16 images
Number of Interferograms: 93 interf

Gamma value = 0.5

Analysis PS: Velo & etopo



Serie temporali della deformazione dei CR



Conclusioni

- Esempio di analisi con riflettori artificiali in zone coperte da vegetazione ha dato buoni ed interessanti risultati
- Importanza dell'installazione dei riflettori artificiali (geometria frana, direzione degli spostamenti, geometria acquisizione dati SAR)
- Spostamenti rapidi e aliasing non sempre possono essere discriminati
- Misure in direzione LOS (da tenere in conto nell'analisi dei dati)

Grazie per l'attenzione