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A GIS METHOD FOR GEODETIC APPLICATIONS: THE CENTRAL APENNINE GEODETIC NETWORK (GeoNetGIS)

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Abstract

To geophysical research and monitor crustal deformation in seismic and volcanic areas, a Geodetic Geographical Information System has been developed (GeoNetGIS). We applied our geodetic oriented GIS to a new GPS network recently set up and surveyed in the Central Apennine region. The Central Apennine Geodetic Network (CA-GeoNet) consists in 130 stations with an average grid of 5 km, covering the main seismogenetic structures of the area.

Management and mapping GPS networks with large multi-scaled data set, geographically referenced and with continuous or discrete coverage, required a multidisciplinary approach. GeoNetGIS, allow us, to analyze in three and four dimensions GPS sources, improve crustal deformation analysis and tectonic structure interpretation. Thematic Layers can be set up by many different databases such as Geodesy, Topography, Seismicity, Geology, Geography and Raster Images. GPS site displacements, velocity vectors and strain rate maps, gained by numerical and spatial analysis, can be showed by GeoNetGIS.

Keywords

GIS - GPS geodetic networks — crustal deformation – Central Apennine

1. Introduction

For the last decade, the use of geodetic networks has greatly increased. Based on Global Positioning System, these networks are devoted to geophysical application, especially to monitor crustal deformation in seismic and volcanic areas.

Detecting and parameterize seismogenic sources has been made much easier by the extensive data from such networks as well as from independent observations. These include: epicentre distribution of recent and historical earthquakes, geological and structural data, photo interpretation of aerial and satellite images.

Integrating large data set of any different origin, in geophysics and geology, can be made by modern computers with large memory capacity. However we must still organize the data base and think how to manipulate the large amount of data. New advances arise continuously in the storage, retrieval and data interpretation, including spatial and temporal variations.

Between Umbria (Norcia area), Abruzzo and southern Lazio (Sora area) regions, was set up and surveyed a GPS network. This paper illustrates a GIS developed as a geodetic project, funded by the Italian Space Agency, to evaluate the present day crustal deformation of the Central Apennine region (Central Italy) by space geodesy techniques. The GIS uses space based integrated observations, such as GPS, DinSAR and remote sensing. Estimate geodetic deformation in high risk seismic area that experienced past destructive earthquakes and investigate active faults and seismogenic sources relationships, are our targets.

To improve geodetic data interpretation, different data layers can be easily managed and dynamically analyzed. Data layers can be periodically updated at each new geodetic campaign and the analysis repeated every time new data are added to the repository.

2. The Central Apennine Geodetic Network (CA-GeoNet)

The Central Apennine is characterized by several thrust sheets, mainly oriented NW - SE,

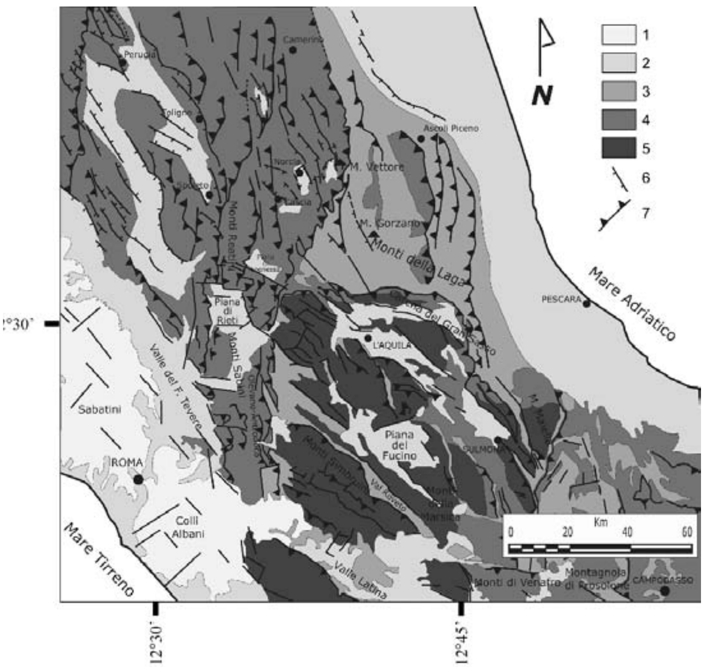


Figure 2 Geological – structural layer of the Central Apennine [edited by Mazzoli et al., 1997; Cello et al. 1997].

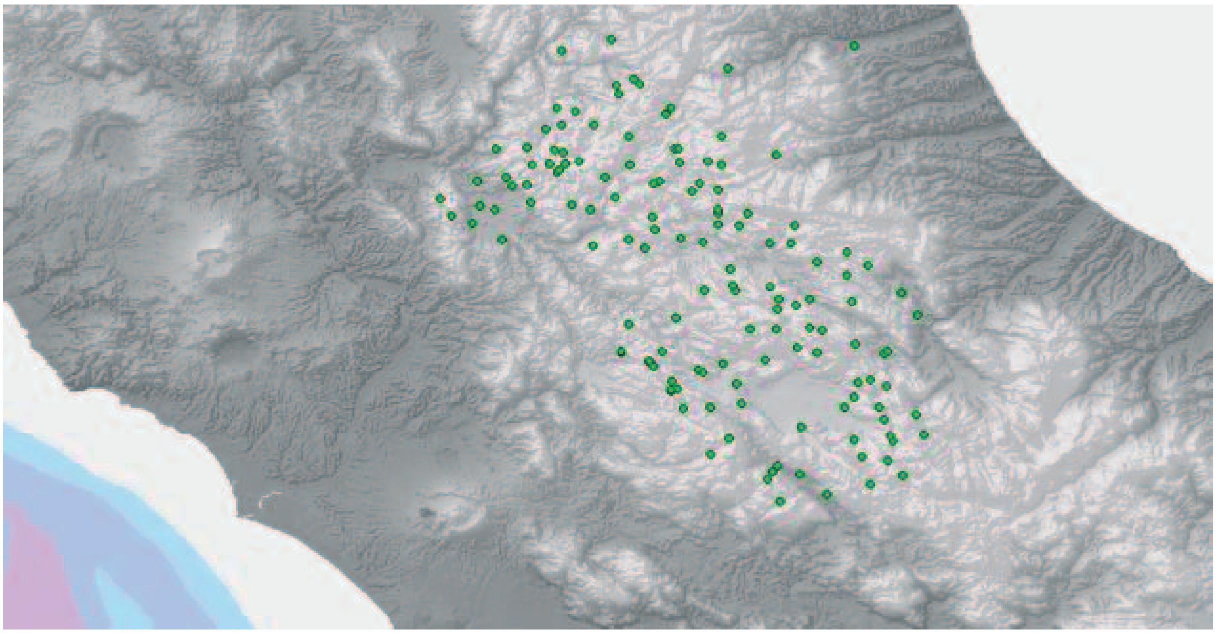


Figure 2.1 The Central Apennine Geodetic Network (CA-GeoNet).

progressively embricated toward the Adriatic sea. These structures result from different meso-cenozoic paleogeografic domains, including on the west the Umbria–Marche pelagic basin, moving east to the Lazio–Abruzzo carbonatic platform and the Monti della Laga fore deep. From Upper Pliocene extensional tectonics influenced the Apennine chain producing normal faulting bounded intramontane basins characterized by Pliocene deposit. This deformation tectonic has been conditioned in many cases by the thrust system with re-utilizations of the pre-exiting fault plane mainly oriented NW–SE and SW dipping normal and normal-oblique faults. [Galadini and Messina, 2001]. Some of these normal faults have been active during the late Pleistocene-Holocene [Galadini and Messina, 2001, D'Agostino and al., 2001] as shown by paleosismic studies [Galadini and Galli, 1999; Pantosti and al., 1996] and active tectonics.(fig. 2) Large earthquakes ($I_{max>}$ X) during the last 2000 years are broadly located along some of these faults.

Figure 2.2 Typical GPS stations equipped with 3-D INGV monument type.

The CA-GeoNet consists of 130 non permanent and 3 permanent stations (INGR, VVLO and ROSE), defining a network with an average grid of about 3-5 kilometers (fig. 2.1).

The network extends from southern Umbria (Norcia area) to Abruzzo and southern Lazio (Sora area), regions and across the Central Apennine belt from the Tyrrhenian to the Adriatic sea, with an area of about 130 km x 180 km. The vertices are located across the Plio-Pleistocene basins and ranges seismogenetic structures that influenced the morphological and structural evolution of this sector. The non permanent network is linked with ASI and INGV permanent GPS stations, to constrain the computed coordinates in a single reference frame. The mainly E – W deployment of INGR, VVLO and ROSE permanent station with AQUI (ASI permanent station) allows for highly precise estimates of the current strain rate component normal to the chain from Tyrrhenian to Adriatic.
Steel markers or concrete pillars with well anchored foundations, screwed on significant outcrops; perform station monuments (3-D INGV design monuments, fig. 2.2).

These kinds of monument provided with auto centring devices and precise antenna set up to obtain the best accuracy and

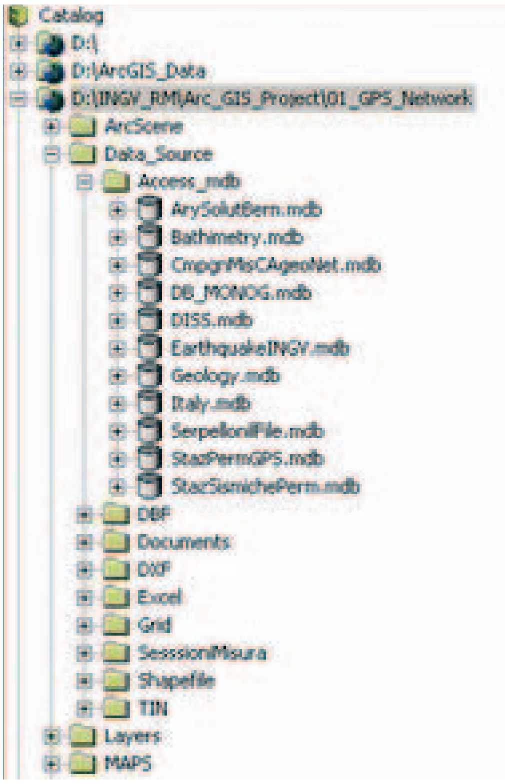


Figure 3 GeoNetGIS Architecture; main DBMS directory tree view.

reducing the biases due to wrong positioning or inaccurate height measurements by the antennas.

3. Data base architecture and data integration

For an optimal management of GeoNetGIS, we implemented and developed a Database on powerful Personal Computer platform with Windows 2000 Prof OS, using ArcGIS8.2 ESRI software and Microsoft Access vers.9.x. To insert and manage all datasets, many DB (fig. 3 and related tables) written in SQL format (Standard Query Language) have been structured with different masks that allowing the users to scroll folders containing different arguments; ArcGIS architecture, directly connect Access RDBMS with our GeoNetGIS. Data base manager perform all the updates and modifications, while the users are only allowed to data querying, analysis and printing.

DB_MONOG Access DB contains all GPS Stations information's. Reference ID (IDentification), with four character label (fig. 3.1) represents each GPS stations, which is fully described by monograph information about geog-

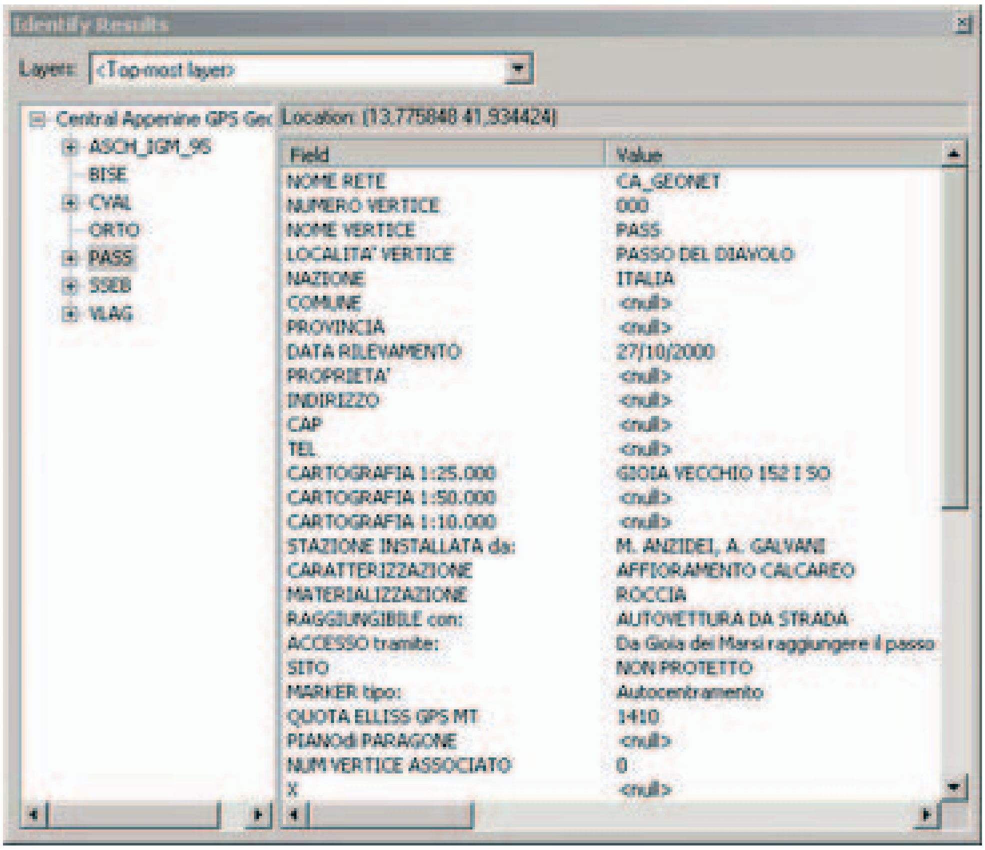


Figure 3.1 Identification tool view. Clicking on GPS stations, users can read Monograph Information's. Ex: PASS (Passo del Diavolo) GPS Station.

Figure 3.2 GPS station Monograph Information's in *html* format. Ex: ACCU (Accumoli) GPS station, site photo, topographic map and geological survey comments.

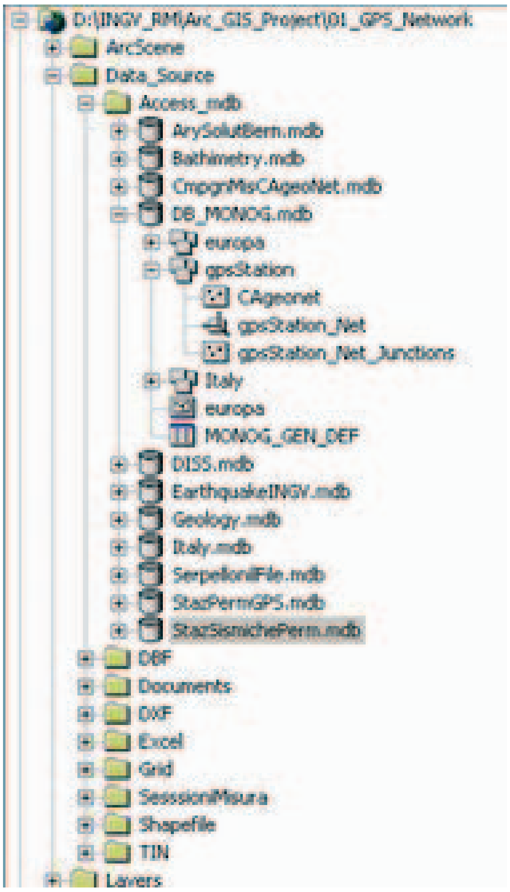


Figure 3.3 GeoNetGIS database organization. Interastion between different Feature Datasets and layers.

raphy, lithology, structural geology and site logistic.

Digital pictures, topographic and geological maps including all GPS sites, can be inserted in this section. Entire monograph documentation has been designed in *.html* format and will be available on line at *INGV.it home page*, using commercial web browsers. (fig. 3.2, ACCU GPS station monograph).

To improve geographically referenced database, GeoNetGIS links spatial data to alphanumeric information. Database layouts are organized into layers or themes (or object), each one belonging to a specific topological type and relating to a specific type of data such as geodetic data. (fig. 3.3)

We used the WGS84 coordinate system for all the layers and if two or more data layers are georeferenced to each other, have resembled to a common grid resolution and contains value expressed with respect to a common datum, and then a new database can be generated in the relationship with new data features. This method consists in a new approach to geodetic data integration.

4. GeoNetGIS: Data Base Repository and capabilities

Our GeoNetGIS is structured in eight DB (fig. 3, and related tables).

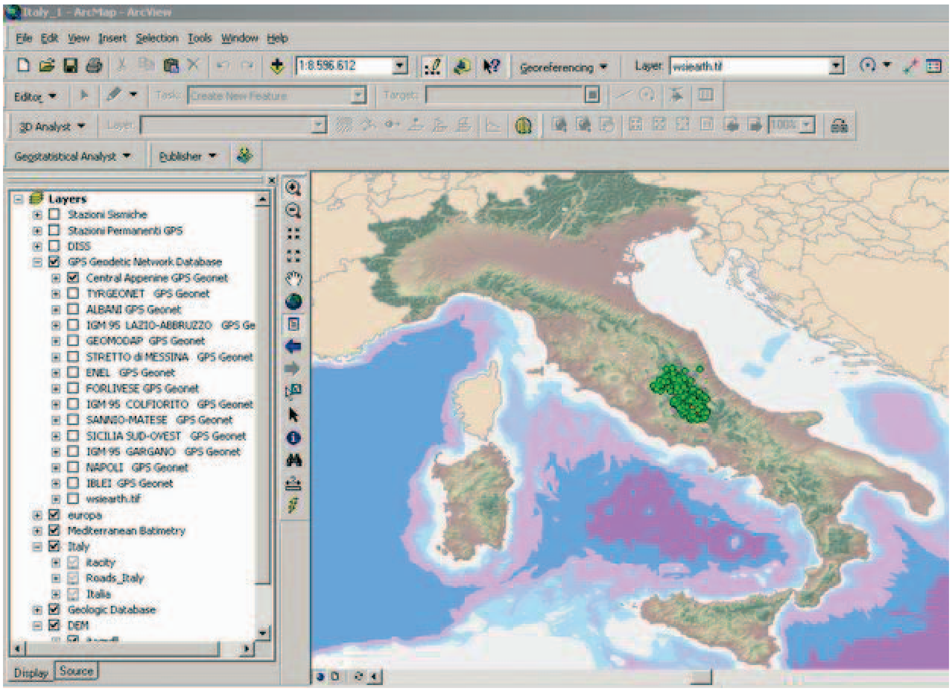


Figure 4 **GeoNetGIS** user interface view: main windows, table of contents, thematic layers properties, toolbars and query tools.

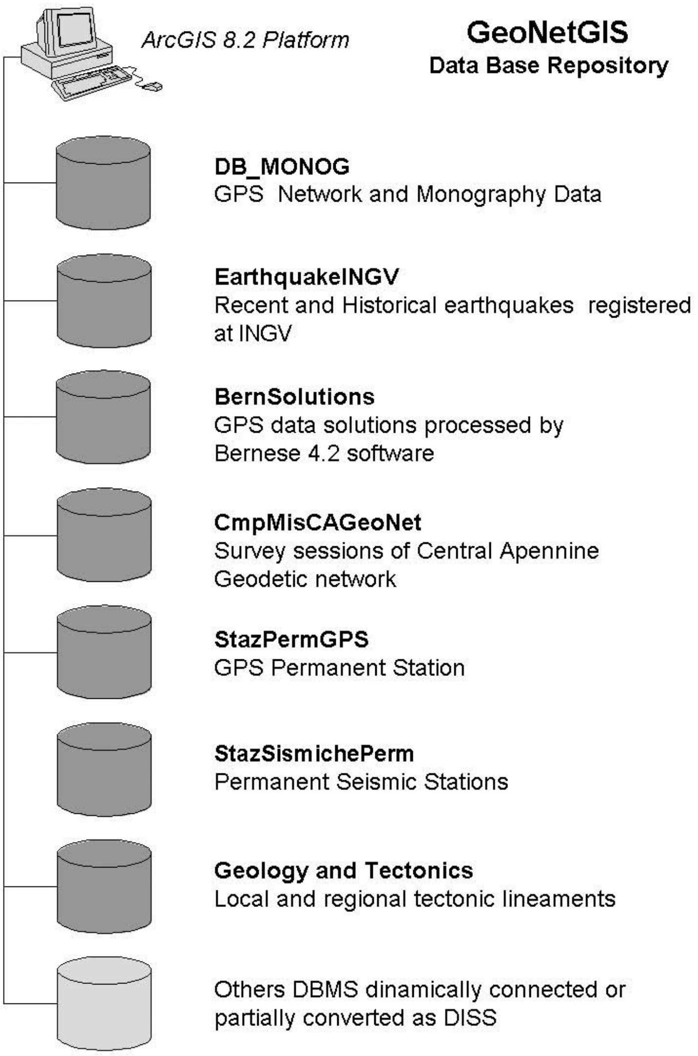
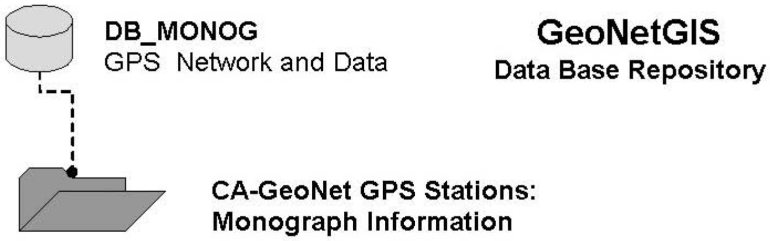


Table 1



ID	DBMS identification number
NOME_RETE	GPS Network Name
ID_VERTICE	Internal GIS ID
NUM_VERT	Order Number
NOME_VERT	**Single GPS Station Identification Name**
LOC_VERT	Place
NAZ	State
COMUNE	Town-council
PROVINCIA	District
PROPRIETA'	Property
INDIRIZZO	GPS Station Address
CAP	ZIP CODE
TEL	Telephone number if available
CART_1_10	Cartography 1:10.0000 if available
CART_1_25	Cartography 1: 25.0000 if available
CART_1_50	Cartography 1: 50.0000 if available
RAGGIUNGIB	Site acces by car, 4x4 car or ...
ACCESSO	Detailed access information
STAZ_INSTALL	Technician installer
CARATTER	Lithology type
RILEV_GEOLOG	Geological Survey
DATA_RILEV_GEOLOG	Survey date
RILEVATORE_GEOLOG	Surveyor name
NOTE_RILEV_GEOLOG	Note extended
MATERIALIZZ	Rock type
SITO	Geographic Site characteristic
MARKER	Monument type
DATA_RILEV	Survey epoch
QUOTA_ELLISS_GPSMT	QUOTA_ELLISS_GPSMT
PIANO_PARAG	PIANO_PARAG
NUM_VERTASS	NUM_VERTASS
X,y,z	Delta x,y,z
LAT_ASS_WGS84	LAT_ASS_WGS84
LONG_ASS_WGS84	LONG_ASS_WGS84
WGS_84_LAT	**WGS_84_LATITUDE coordinate in DMS gained by GPS**
WGS_84_LONG	**WGS_84_LONGITUDE coordinate in DMS gained by GPS**
QUOTA	**Ellisoidic Elevation**
DEC	GIS internal use
LAT_Y_WGS84	**Y_WGS84 in Decimal Degree gained by GPS**
LONG_X_WGS84	**X_WGS84 in Decimal Degree gained by GPS**
X,Y,Z,PLAN	Planimetric details
OLE object	OLE object, contains site photos, topography maps, etc..

Table 2

Each data set, in Data Base Management System format, can be shared by different operating systems and applications. DB are stored in ArcGIS repository native format and can be easily converted in a set of tables. Logical maps may be defined, including the inter-relationship among the various DB.

We have constructed our repository and converted others database in ArcGIS format from different sources [see Bibliography]. Clicking on an object layers, lineaments or GPS stations and selecting the appropriate menu items, the user may explore monograph or numerical information; a related hyperlink, which includes geometric DB features, dimensions, location and a set of comments, can be showed.

All dataset are disposable for inspection, verification, further processing and updating. Maps can be manipulated using some GIS standard tools as zoom, panning, distance measurement, changing coordinate system, and fly by tool for 3D scenarios (fig. 4).

5. GPS DB: Network and Data

Alphanumerical, numerical, and raster data build up GPS data set.

Alphanumeric data set contains the description of each GPS station, monument type, local geology, access and site logistic. It can be edited and geo-processed, performing query analysis interactively (fig.5, fig. 5.1, fig. 5.2, fig. 5.3)

Numerical data set are organized in files for association. Consists in the GPS raw coordinates (field coordinates), adjusted coordinates (final coordinates), N-E-Up velocities and related errors. The latter derive from the survey performed during each repetition campaign. Receiver/antenna combination, receiver type, session's duration and antenna heights collect numerical database information. Each data can be plotted and elaborated separately or interactively with other different feature classes and produce thematic layers (fig. 5.4).

Raster data obtained by external applica-

Figure 5 DB_MONOG Access database user interface, GPS station monograph view. Main index window.

DB	GIS data type	Description	Data features
Topography	Numerical Raster	Digital Elevation Models from 1:25000 scale maps of the IGM	3-D DEM models at 250 mt pixel resolutions
Geography	Points Lines Vectors Raster	Geographical features of the region	Populates places, regional boundaries, main rivers, roads, Bathymetry
Structural geology	Polyline	Meso scale structural analysis Description of the geological formations obtained both from direct surveys and from geological maps	Geological formations
Tectonics	Line raster	Local and regional tectonic lineaments	Type, geometry, kinematics, age, references
Seismicity	Point	Instrumental data recorded by INGV national seismic network and historical data derived by DISS	Epicentres location, source depth, origin time, magnitude, intensity, macroseismic maps, focal mechanism (when available)
Seismogenic source	Polyline	Historical earthquakes > 5 Md	
GPS network	Point	Description of the single GPS stations	Identification, monument type, local geology access, maps, pictures
GPS data	Line Point Vectors	GPS observations	Station co-ordinates at different epochs, variance and covariance matrices,

Table 3 GeoNetGIS data features.

Figure 5.1 DB_MONOG Access database user interface, GPS identify page view.

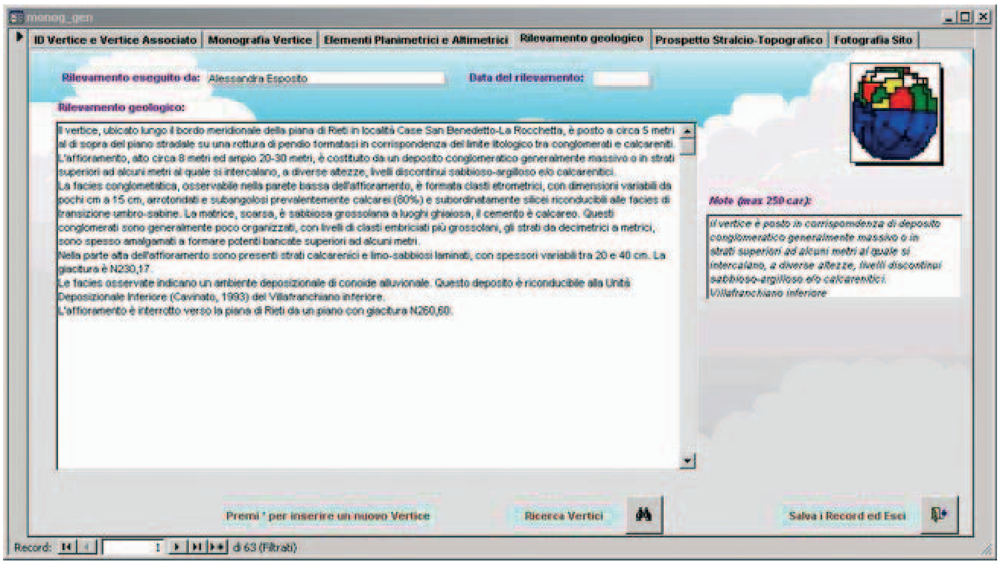


Figure 5.2 DB_MONOG Access database user interface. Geological survey information's page.
Note: extended and concise geological survey's comments.

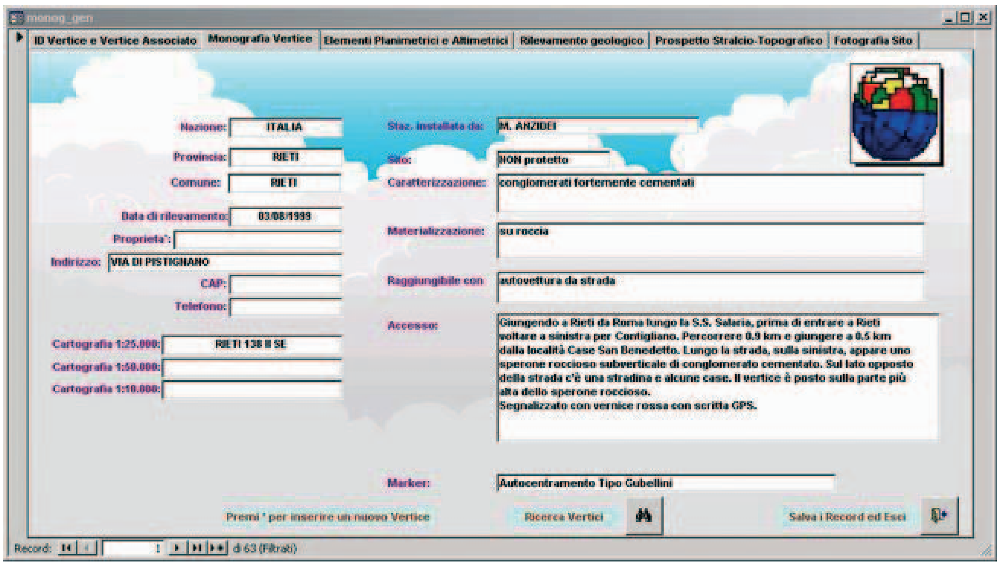


Figure 5.3 DB_MONOG Access database user interface. Site description and general information's.

Attributes of XYValVel990001

OBJECTID*	cod	NOME_VERT	LONG_X_WG	LAT_Y_WGS84	QUOTA_SL	VEL_EST	VEL_NORD	QUOTA_DIFF	Shape*
1	77	POGB	12,873041	42,514511	1017,6467	3,9	-3,13	-9,3	Point Z
2	4	AQUI	13,350247	42,368239	713,1261	2,52	0,47	-7,68	Point Z
3	20	CDAQ	12,990840	42,590459	1056,2874	2,67	-1,68	-8,93	Point Z
4	97	INGR	12,514799	41,828083	104,44	-0,58	-0,7	19,41	Point Z
5	50	LEON	12,959828	42,564754	1021,6455	-2,88	-6,66	-11,47	Point Z
6	115	TERM	13,010020	42,469446	1851,8004	-2,84	-1,64	-6,44	Point Z
7	303	UNPG	12,355702	43,119391	351,1362	-1,17	0,03	-21,37	Point Z
8	25	CLAC	12,975976	42,546014	1674,0373	-2,27	4,18	-10,89	Point Z
9	31	CPSE	12,906851	42,603831	980,9358	0,72	-0,63	-9,07	Point Z
10	34	CUMU	13,028204	42,569246	1171,5473	0,39	-2,05	-15,03	Point Z
11	60	MOSP	12,949421	42,646762	984,2879	5,89	0,21	1,32	Point Z
12	68	OCRE	12,971311	42,596905	886,8148	3,4	1,68	-2,04	Point Z
13	123	VCAR	12,996246	42,565588	946,1111	-2,97	-6,05	-9,54	Point Z
14	21	CEPP	12,854991	42,530089	990,1418	-1,13	0,77	-7,35	Point Z
15	120	TRIV	12,988318	42,655910	1023,3232	-2,27	1,45	-4,31	Point Z
16	128	VTFU	12,918040	42,563801	1212,6522	-1,13	-1,89	-4,9	Point Z
17	42	FRLC	12,975360	42,696447	1004,652	6,52	2,05	-8,23	Point Z
18	54	MERA	13,019544	42,686469	1441,0351	3,27	3,92	-2,73	Point Z
19	18	CASB	12,849266	42,389687	447,7387	9,41	0,82	-7,56	Point Z
20	16	CANT	12,915719	42,476028	957,4107	7,4	1,1	-9,21	Point Z
21	44	GREC	12,731077	42,445466	1263,748	-2,76	0,93	-5,98	Point Z
22	47	IPRA	12,705166	42,484253	973,6544	-2,44	0,87	-5,22	Point Z
23	48	LABR	12,791021	42,524285	640,8866	2,4	4,06	-6,95	Point Z
24	61	MPET	12,833372	42,600420	1310,1869	-1,24	0,97	-8,11	Point Z
25	66	NICO	12,830995	42,458405	424,7963	-3,81	1,08	-33,62	Point Z
26	99	SETC	12,796125	42,468293	421,9984	-2,29	4,24	-8,61	Point Z
27	116	TERR	12,779101	42,426171	441,6239	-5,98	3,35	-18,41	Point Z
28	7	AVEN	13,059889	42,758214	1077,2883	-1,23	-9,29	0,16	Point Z
29	14	CAME	13,123997	43,111985	498,7001	4,46	7,35	4,29	Point Z
30	15	CAMP	13,101176	42,854295	945,5081	8,14	-3,47	3,04	Point Z
31	64	MTSN	13,154224	42,761053	995,4208	-16,26	-1,81	1,39	Point Z
32	80	PRET	13,316286	42,382489	732,4016	6,82	1,11	5,17	Point Z
33	88	RIFP	13,176411	42,762724	1501,6527	3,17	3,63	10,47	Point Z
34	93	SAVE	13,120878	42,726977	958,1395	-6,57	-0,34	-5,09	Point Z
35	129	VVLO	13,623228	41,869646	1045,8216	1,01	1,42	3,42	Point Z
36	22	CHIA	13,061553	42,654056	1130,6736	-4,26	-7,38	-3,66	Point Z
37	27	CORT	12,987072	42,827333	1268,7768	6,03	-5,35	6,32	Point Z
38	108	SROT	13,141801	42,627544	1442,7002	-12,65	5,24	-4,88	Point Z
39	92	S260	13,256906	42,601408	975,2709	-1,96	3,37	-1,33	Point Z
40	95	SCRO	13,146537	42,561675	821,1699	0	0	0	Point Z
41	96	SCUO	13,358872	42,629343	1433,9433	-9,52	6,17	15,54	Point Z
42	102	SLUC	13,260901	42,567336	1040,7069	-1,17	-5,85	-5,05	Point Z
43	2	ACCU	13,241239	42,696125	939,3202	6,09	-5,28	8,61	Point Z

Record: 1 Show: All Selected Records (0 out of 130 Selected) Options

Figure 5.4 GPS DB Numerical dataset. Ex: CAGeoNet preliminary data gained by Bernese software elaboration: coordinates, N-E and UP velocities and related errors.

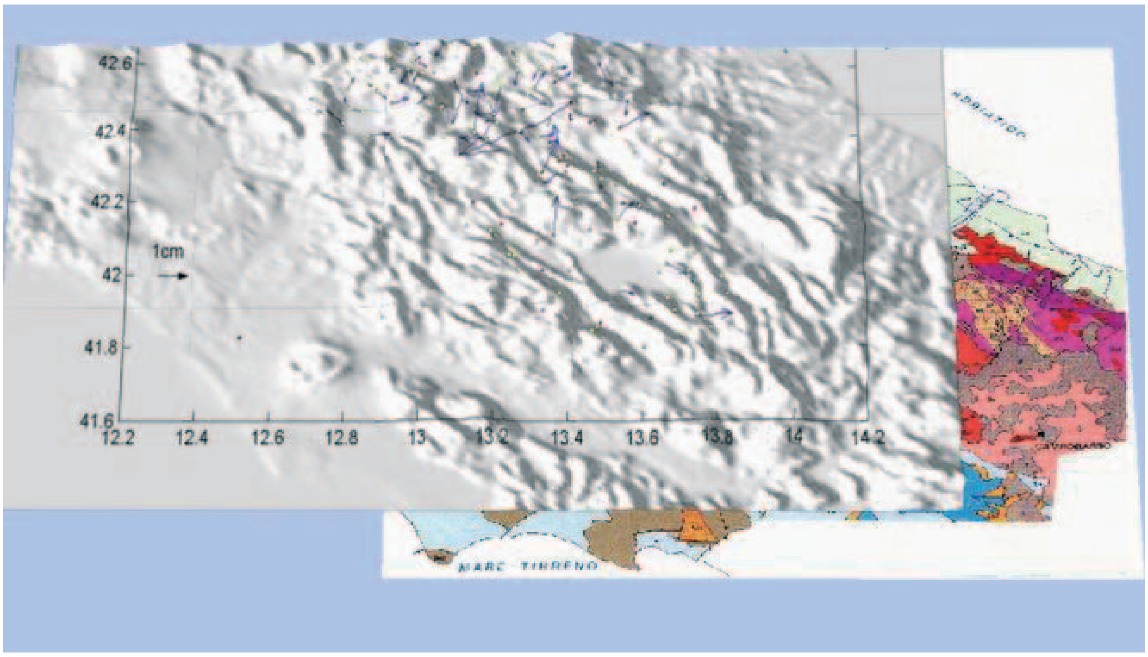


Figure 5.5 GPS DB. Raster dataset overlapping; vectorial information about geodetical velocity data, intersect dataset over Central Apennine region, using a 3-D surface D.E.M. (GeoNetGIS evaluating test).

Figure 5.6 Geology DB. Geological-Structural database, over Central Apennine region, edited in vectorial format.

tions such as *Matlab* or *Surfer* software. Raster layers project vectorial information about velocity and strain vectors, after they have been georeferenced and plotted on the morphological and geological layers. The raster data format is the most appropriate GIS data structure for use in reconstructing relations between geological-geomorphological and geodetic vector surfaces, because it is ideally suited for arithmetic using multiple spatial datasets (fig. 5.5)

Mapping of GPS DB can be also supported trough a HTML or JAVA viewer.

5.1 Geology DB

The geologic-structural database contains polyline, line and point, respectively tectonic

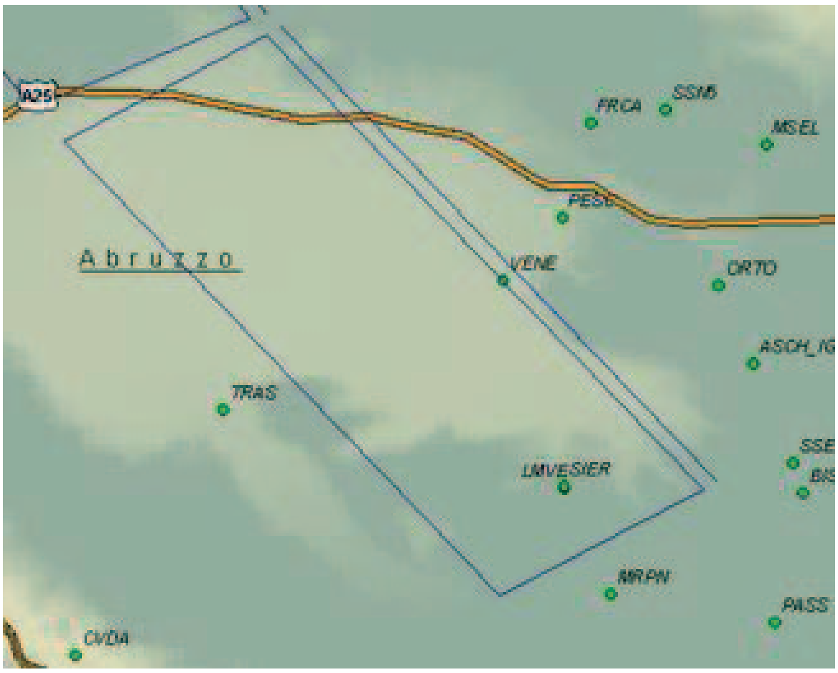


Figure 6 Query tools: Ex: GPS station's located all around Fucino-Basin seismogenic source (*DISS, SourceGeol*) and accessibile roads.

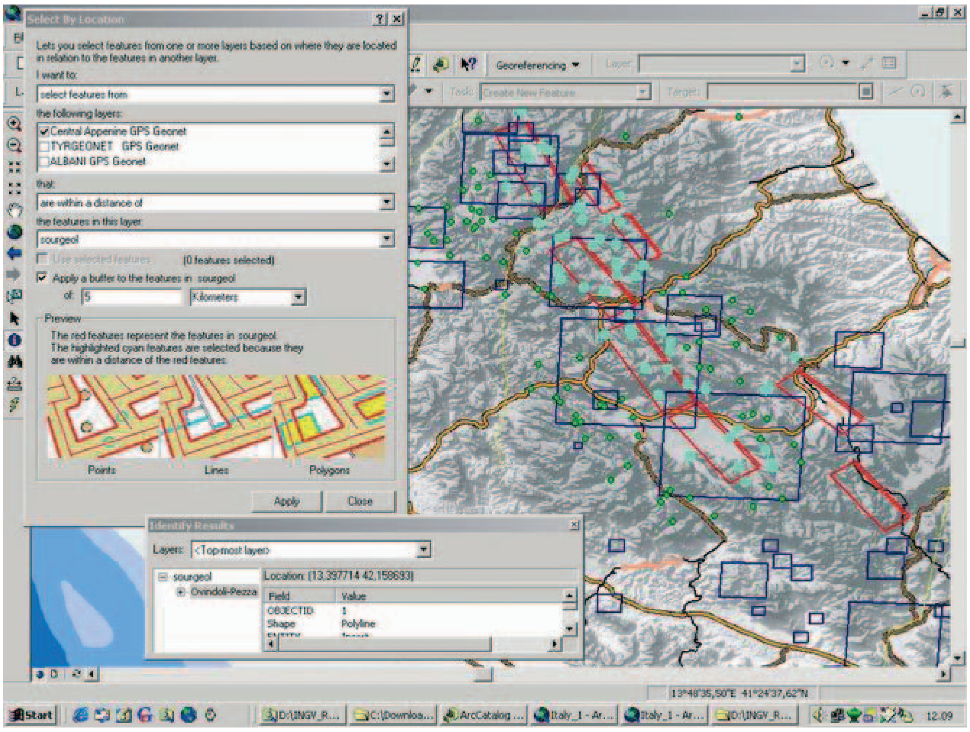


Figure 6.1 Data analyses facilities. Ex: GPS stations located around seismogenetic sources (*DISS, SourceGeol*) within 5 km buffers and accessible roads.

structures, tectonic lineaments, and seismogenic sources information's. It has been carried out elaborating the well-know data from literature and referenced with geological studies done in Central Apennine sector [see related bibliography, fig. 5.6, fig. 5.7).

6. Methods

To analyze data in our GeoNetGIS we applied some methods and software tools to facilitate a rapid data processing and management; due to large data amount it runs on a fast PC computer.

6.1 Standard Query Tools and Data Analyses facilities

Logical interaction, between the different database and topology layers, can be created with query tools. For example, spatial data, obtained from GPS network positions, and historical seismological data-sets, can interact with temporal data such as GPS campaigns or single survey sessions. Thematic Maps, using an interactive method selection between the different data sources can be analyzed. Feature classes, with SQL standard query language, can be selected, either by attribute or by spatial location (fig.6, fig. 6.1)

Geodetic velocity vectors, with geological or historical seismicity dataset can intersect, merge and join producing an innovative data treatment and new geodetical mapping display.
Moreover, GeoNetGIS can be point out the request for a new campaign or plan new GPS stations in uncertain area (fig.6.2).

6.2 Crustal Deformation Data management

Geodetical data set can be plotted in raster format or analyzed in numerical vector formats and easily related with all DB contained in GeoNetGIS.

Different data-sets can interact or intersect together in order to display and aid interpretations of the observed crustal deformations, with the respect of tectonic setting in the investigated area (fig.6.4).

Complex information, such as geodetic velocity vectors or strain vectors, can be plotted on geological-structural, geomorphological and seismological Thematic Layers and measured.

In this paper we show some crustal deformation analysis to underline the interdisciplinary characteristics of our platform and the wide range of information managed by our GeoNetGIS. We display an application using the preliminary results gained from three different

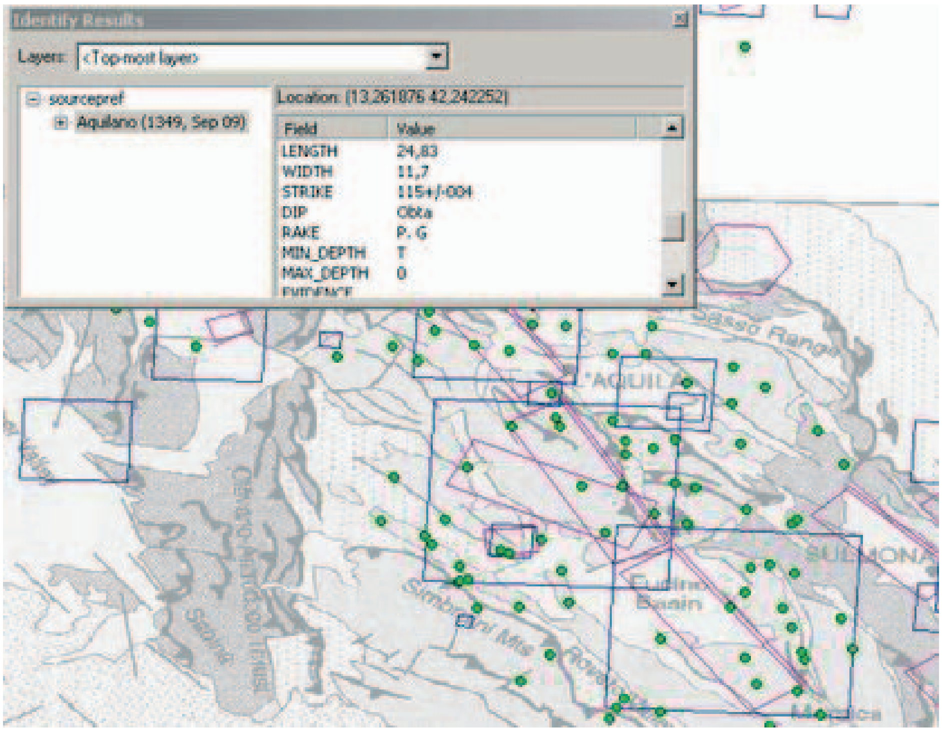


Figure 6.2 Data analyses facilities. Ex: GPS station's located all around Fucino-Basin seismogenic source (*DISS, SourceGeol*) and accessibile roads.

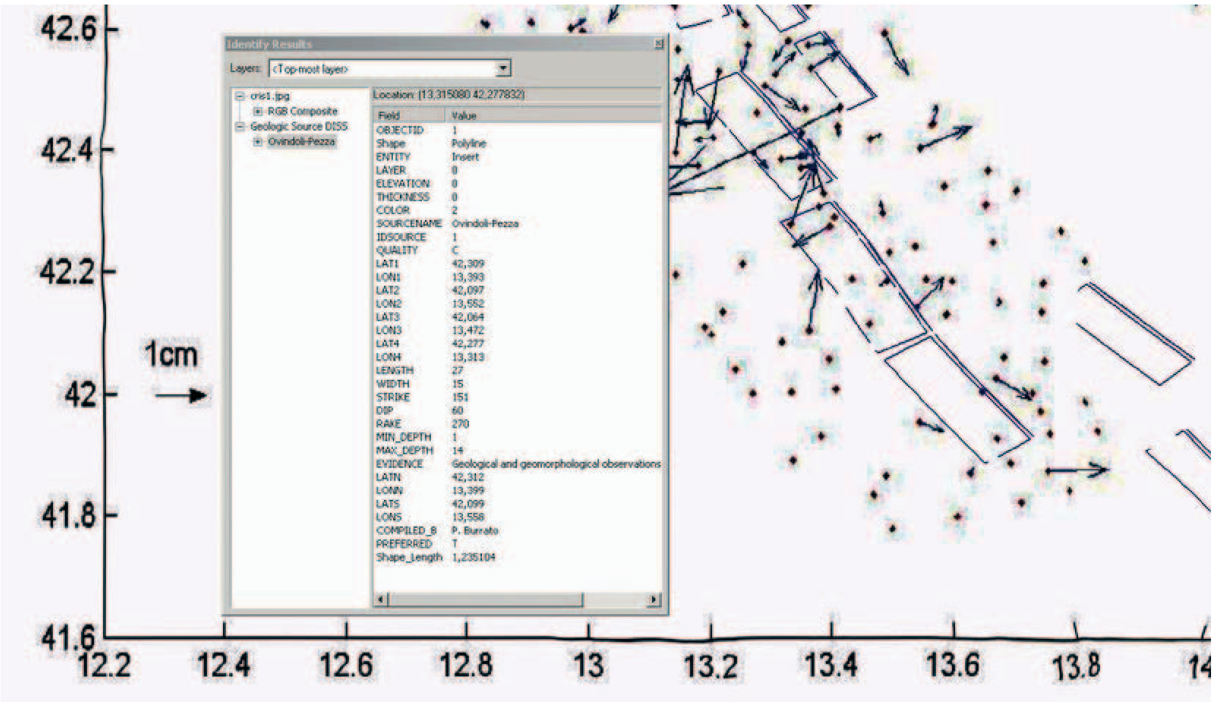


Figure 6.3 Crustal deformation data management. Ex: we show a preliminary CAGeoNet velocity vectors, related with well-know seismogenic sources (DISS, SourceGeol). Velocity datasets can be numerically analyzed with faults relationships and seismological constrains, to improve geodetic explanation (GeoNetGIS evaluating test).

GPS campaigns performed during the time span 1999-2001 [Anzidei et al., 2003] over the CA-GeoNet. Raster and Vectorial data were entered in our geographical information system and elaborated. We like to underline some trends in North and East velocity vectors and trend anomalies in SFRA (San Franco) GPS stations, probably due to local instability or not modelled errors (fig.6.5).

Analysis deformation results may be strongly conditioned by site problems, such as local instabilities, measurement errors, seismic displacements, landslides, vandalism, etc.

6.3 Statistical analysis

To better investigate all different features data sets, statistical analysis can be deduced.

GeoNetGIS allow us to compute the spatial distribution of CA-GeoNet on the Central Apennine surface region and evaluate interest-

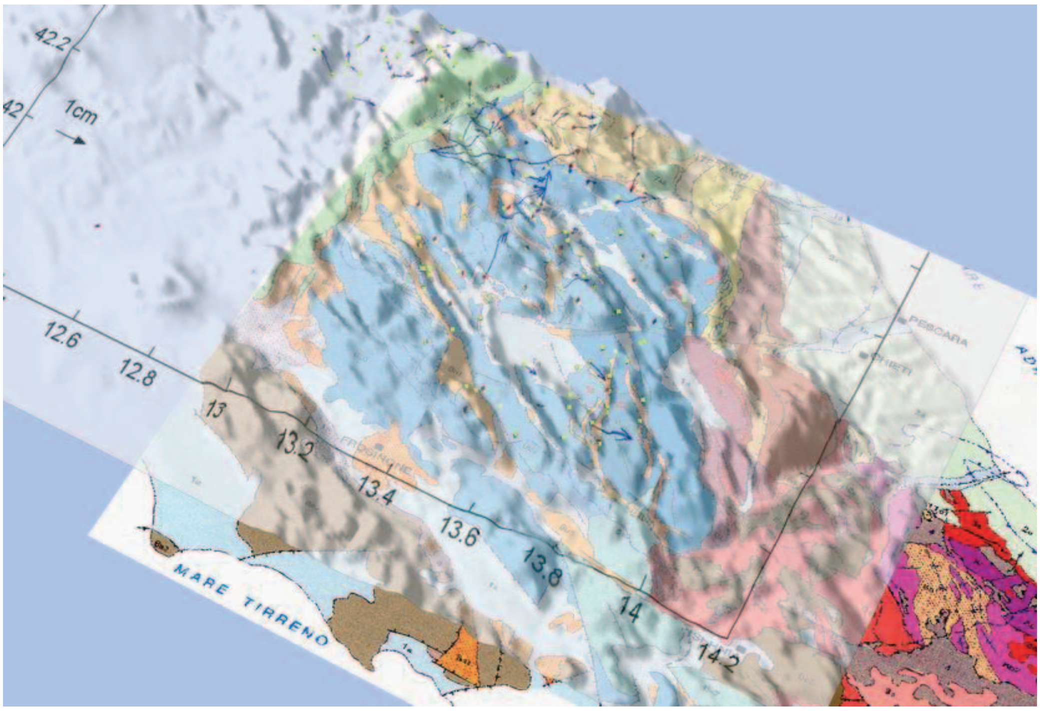


Figure 6.4 Crustal deformation data managment.
Ex: CAGeoNet preliminary velocity vectors dataset and geological constrains.

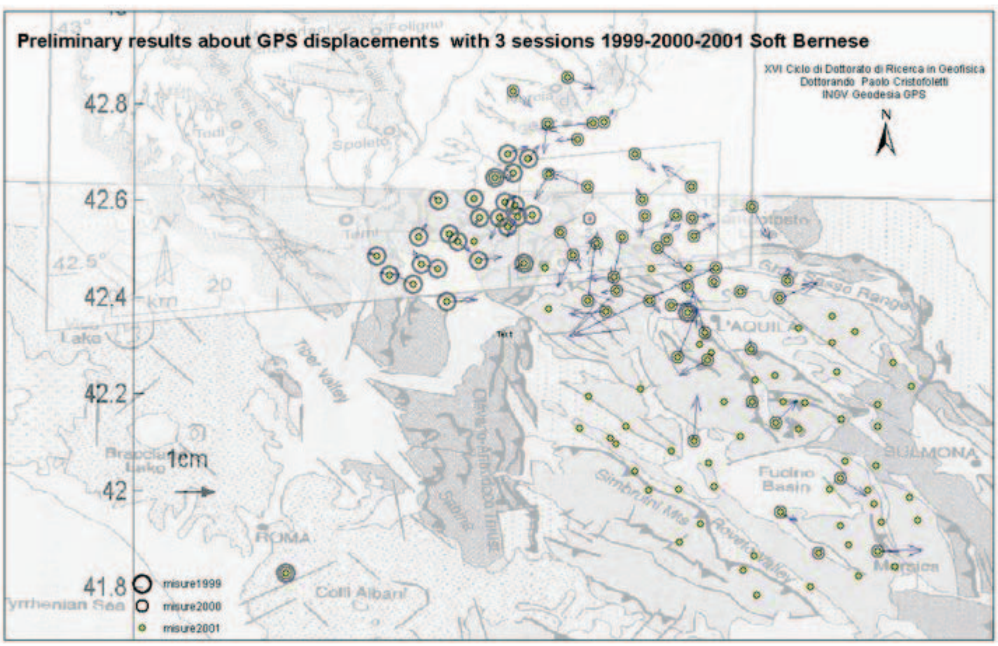


Figure 6.5 CAGeoNet velocity vector dataset overlapping geological-structural layer, to show GPS station with different survey's sessions database (GeoNetGIS evaluating test).

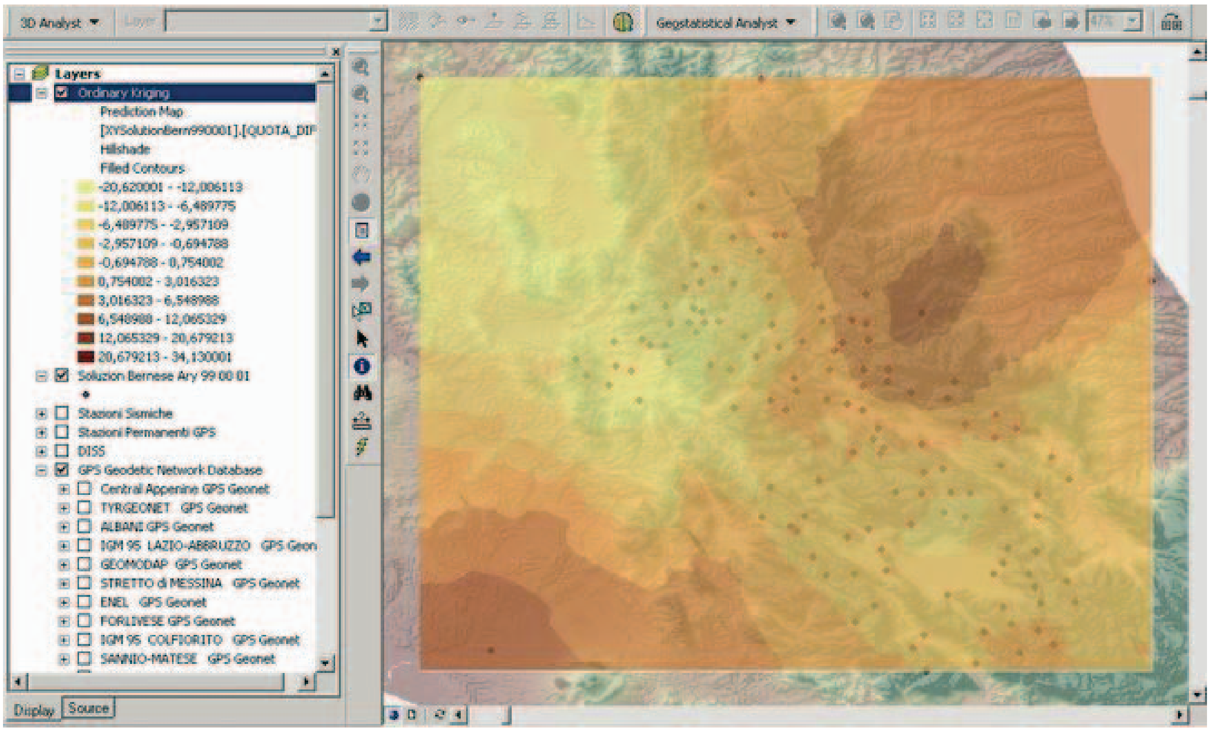


Figure 6.6 Ordinary Kriging and statistical analyses. Displaying a statistical UP and DOWN vertical displacement over CAGeoNet, gained from preliminary numerical results of GPS station's eight displacement with 3 survey sessions (Geodetical results showed only to underline GeoNetGIS capabilities).

ing areas. This method can be successfully applied to plan new GPS stations or new entire networks in critical zones not previously investigated.

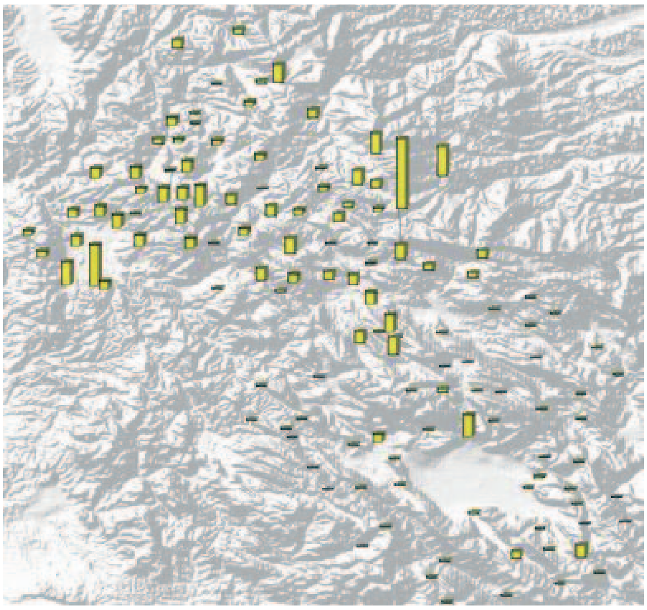


Figure 6.7 Statistical analyses graphical bar display UP and DOWN displacements of single GPS stations (Geodetical dataset showed only to underline GeoNetGIS capabilities).

Combining temporal and spatial data, GeoNetGIS is capable to manage the geodetic results obtained by different surveys; for example GPS data can be related with seismic events. As shown in fig. 6.6, we propose a statistical analysis based on Ordinary Kriging, gained from the height displacements on the CAGeoNet stations. Advanced geostatistical interpolation techniques such as Kringing, in some cases will be preferable alternatives to the other specific algorithm, especially when producing interpolation from relatively sparse datasets. Geostatistical methods of interpolation can be very effective in producing smooth vertical trends surfaces from widely spaced datasets. We are aware that still stand an uncertainty on the GPS heights, being the most critical parameter to estimate by GPS. Numerical geodetic data are completely integrated in our Geodetic DB and elaborated.

Also, by GeoNetGIS we can compare the different GPS data solution analysis provided by data reduction software (Bernese, Gamit, etc.) and their related displacement and velocity vector maps produced. These procedures can be applied to planar velocities, height displacements, strain vectors and related errors (fig. 6.7, fig. 6.8, fig. 6.9).

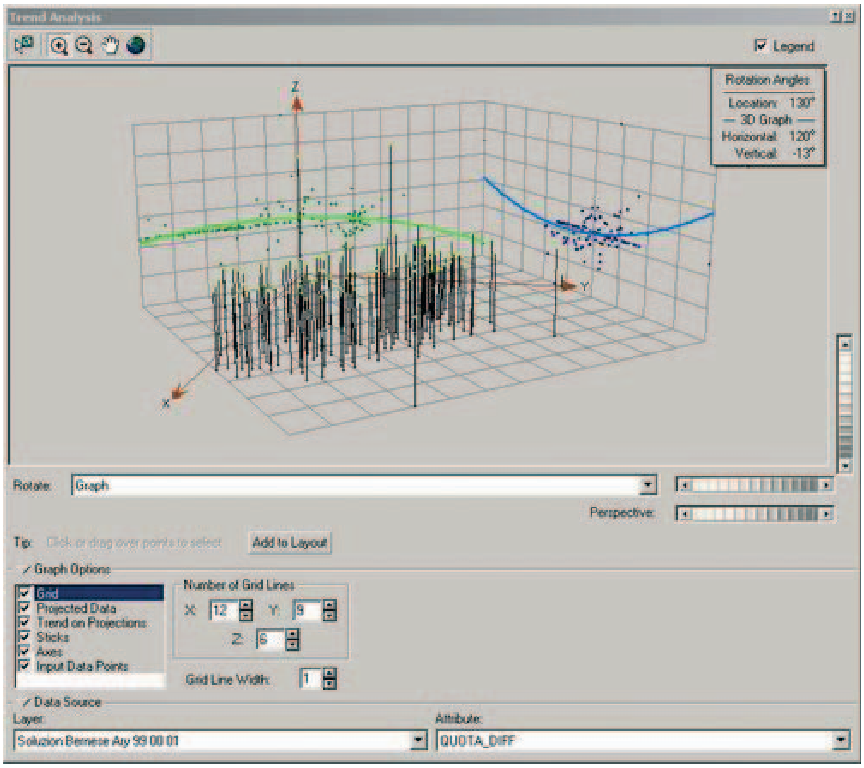


Figure 6.8 Statistical analyses: 3-D graphical plot of UP and DOWN displacements values. Medium values in X, Y, and Z components (Geodetical dataset showed only to underline GeoNetGIS capabilities).

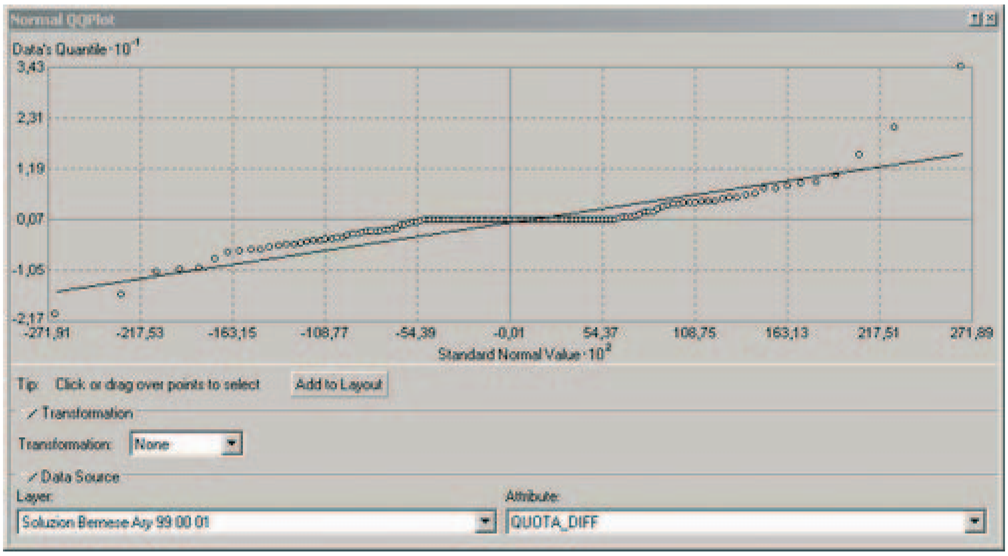


Figure 6.9 Statistical analyses: standard normal values (*10²) of UP and DOWN vertical displacement over CAGeoNet.

6.4 Three-dimensional scenery

To deduce the relationships between GPS stations distribution and tectonic lineaments, 3-D scenery is performed on geological layers and aerial photography; since for 2-D images cannot represent adequately the large amount of data entered in the GeoNetGIS.

The third dimension can represent the spatial variation of topographic elevation, bathymetry and GPS heights variations. In GeoNetGIS, a virtual environment highlights the relationships between geodetics, 3D morphology, structural and geological data and maps (fig. 6.10, fig. 6.11). Hill shade elevation has been computed from Shaded Relief analysis extracted from Italy's DEM with 250 meters resolutions. To make more comprehensive the

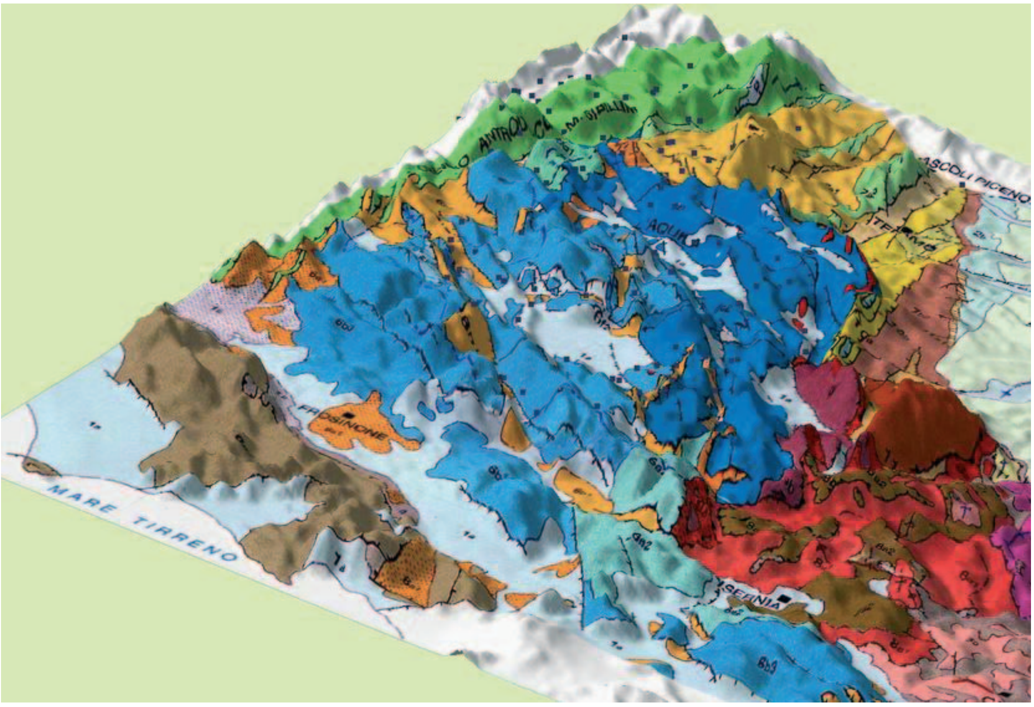


Figure 6.10 3-D Geological-Structural virtual scenery. Ex: CAGeoNet over Central Apennine Geological thematic layer project upon Italy's D.E.M

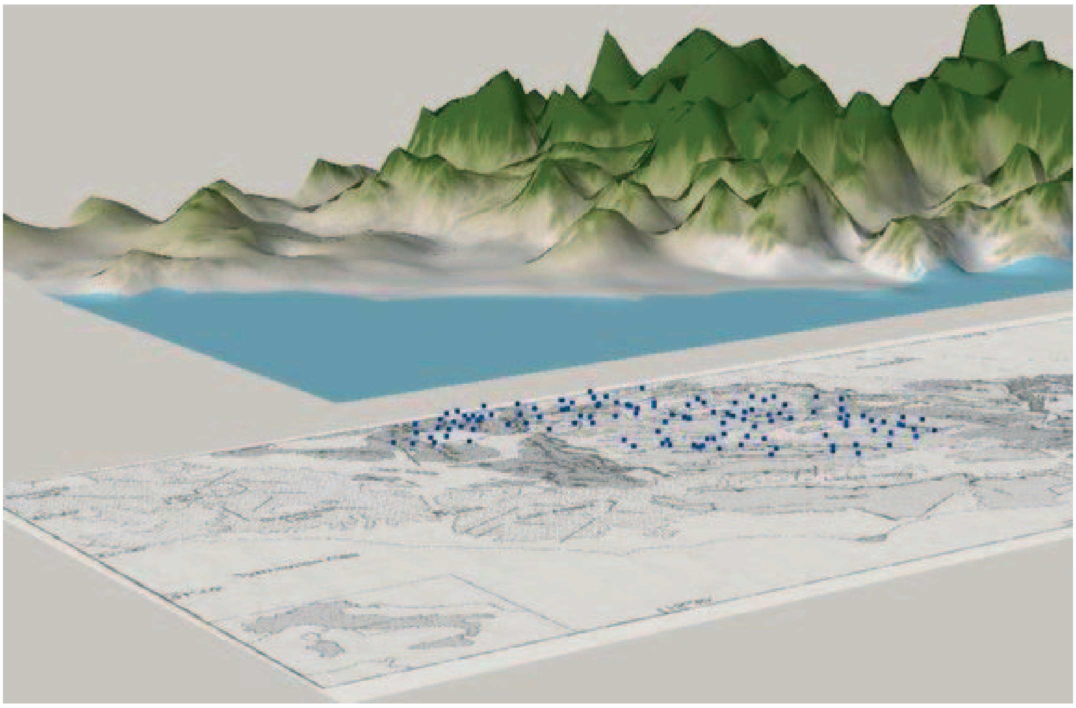


Figure 6.11 3-D Geological-Structural virtual scenery. Ex: CAGeoNet, D.E.M. and Geology-Structural raster layer.

relations between geological structures and topographic surfaces and to analyze those joining geodetic data-sets, we suggest this method (fig. 6.4).

In order to use CA-GeoNet in co-seismic or inter-seismic surveys, using GeoNetGIS we can see how the network is related with topography and measure the average extension grids of GPS stations near well-known faults and seismogenic structures. To investigate general morphology features, geographical place and land-access possibilities, we overlap GPS network data projections on the high resolution's Photo

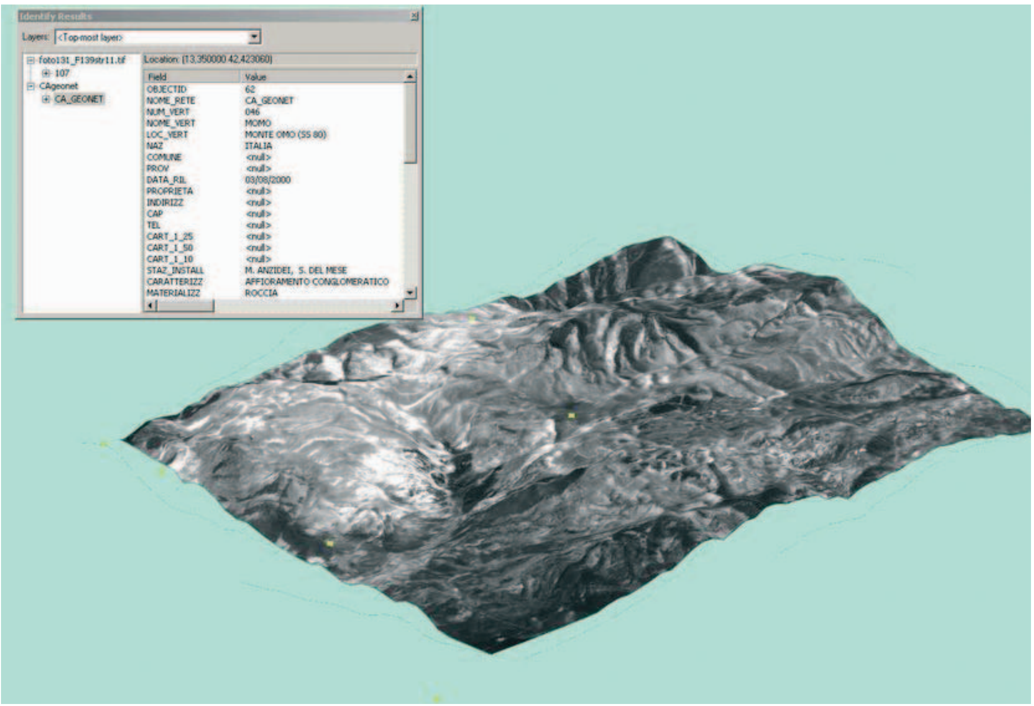


Figure 6.11 3-D Aerial Photo in high resolution virtual views.

Aerial Views (fig.6.12)

6.5 Geodetic Server, Web GeoNetGIS, and tailor made applications

GeoNetGIS capabilities allow us to create and deliver a wide range of maps, data and applications for geophysical users, also distributing them on the World Wide Web. We can integrate data from multiple and different data sources. In the next future the users will be able to build queries to derive specific information about geodetical and geological data and extract real geographic data from the GeoNetGIS server. Wireless connection can be realized by PDA computer.

To support and modelling co-seismic deformations scenarios, related with historical and instrumental earthquakes and seismic sources, we are developing a tailor made applications in FORTRAN and Visual basic languages. These applications will be directly integrated in our GeoNetGIS through specific routines.

7. Conclusion

In this paper we present an overview of the methodologies and issues involved in the GIS techniques uses. The relative ease and rapidity management of comprehensive geophysical datasets and their logical-scientific interaction became the principal utility of GeoNetGIS.

The flexibility and broad range of tools available in GeoNetGIS, make it an attractive platform for geodetical problem solving; we can manipulate the original geodetic data, acquired during specific surveys, relate them with seismical or geological datasets and generate new georeferenced database. To identify well-known faults or geological-structures related with GPS observations and suggest new evidences of active tectonics, GeoNetGIS represents a powerful geophysical research method.

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