



# Rapporti tecnici INGV

A Website to Explore the  
TINITALY/01 DEM

# 174



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Francesca Di Stefano - coordinatore

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Fax +39 06 36915617

Rossella Celi

Tel. +39 06 51860055

Fax +39 06 36915617

[redazionecen@ingv.it](mailto:redazionecen@ingv.it)



# Rapporti tecnici INGV

## A WEBSITE TO EXPLORE THE TINITALY/01 DEM

Simone Tarquini, Luca Nannipieri and Massimiliano Favalli

INGV (Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa)

# 174



## Table of contents

Introduction .....	5
1. The content of the website .....	5
1.1 The TINITALY/01 DEM .....	5
1.2 Views of the DEM .....	6
1.2.1 The draping method .....	6
1.2.1.1 Draping a whole database at once .....	7
1.2.2 Creating stereo images .....	7
1.2.3 The views .....	8
2. The website technical structure.....	8
2.1 The webGIS software .....	8
2.1.1 Image format.....	8
2.1.2 Image compression.....	8
2.2 Website engineering .....	9
3. Browsing the website .....	10
3.1 Entering the website.....	10
3.2 Browsing options .....	10
3.2.1 Setting the screen size .....	10
3.2.2 Choosing the area/region .....	11
3.3 Ready to browse? .....	11
3.4 Exploring the selected area.....	13
4. Concluding remarks.....	14
References .....	15



## Introduction

In 2007, a new digital elevation model (DEM) of the whole Italian territory, named TINITALY/01, was presented by Tarquini et al. [2007]. This DEM was the final result of the DIGITALIA project supported by the Italian Ministero dell'Ambiente e della Tutela del Territorio in the framework of a general agreement involving the Istituto Nazionale di Geofisica e Vulcanologia (INGV). The whole database of this DEM, in the form of a 10 m cell size grid, is available to the INGV research community at the web portal Kharita (<http://kharita.rm.ingv.it/dmap/>). Tarquini et al. [2007] mentioned in short a dedicated website (<http://webgis.pi.ingv.it/>), where authorized users were allowed to explore full resolution nadiral or perspective shaded relief images (in stereo or conventional format) obtained from the TINITALY/01 DEM. The navigation of this website is now opened to the public. The present technical report illustrates this website, describing its content and unfolding related technological aspects.

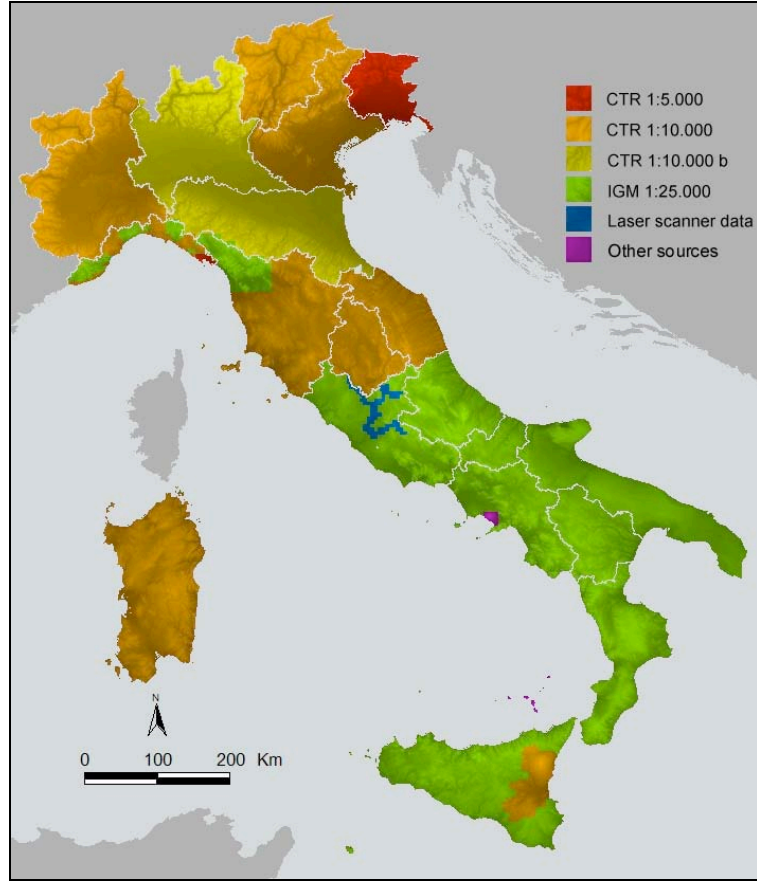
### 1. The content of the website

The website was designed and created at INGV, sezione di Pisa, to allow an online navigation of full resolution images derived from the TINITALY/01 DEM. In this section we introduce the DEM and the related images.

#### 1.1 The TINITALY/01 DEM

The TINITALY/01 DEM is the outcome of the DIGITALIA project [Tarquini et al. 2007]. The DEM is composed by a seamless Triangular Irregular Network (TIN) of the whole Italian territory in the UTM 32 WGS 84 coordinate system. Input datasets were uneven, mostly consisting in elevation contours and spot heights in vector format derived from different sources (**Figure 1**). In a first step, DEMs of single administrative regions of Italy were created in their original zone (32 or 33). Inside each region, the dataset was tiled obtaining elementary portions of data, which were easily handled by using standard PC and the ArcView 3.2 software. All the tiles were individually processed and checked by a team of GIS operators to clean up the raw input dataset (e.g., by correcting biased elevations of single features). The procedure followed during this processing assured the perfect continuity of the model inside each tile and across the edge between each tile, so that each regional DEM is perfectly seamless. After having completed the DEMs of the 20 Italian regions, the DEMs of the regions belonging to the same zone were merged together to obtain a single DEM for each zone. As a final step, the 33 zone TIN was projected in zone 32 and merged to the latter to obtain a perfectly seamless DEM in vector format for the whole Italian territory in the UTM 32 WGS 84 coordinate system.

The main characteristic of the TINITALY/01 DEM is in the robustness of the adopted quality control protocols and in the flexibility of the chosen TIN format, which provides a variable resolution according to the local density of the input vector dataset. The adopted merging procedures process input data in vector format and provide output data in the same format. Both merging of regions and merging of the two zones were carried out by using procedures that provided smoothed transitions at the boundaries between different sets of data.



**Figure 1.** Different sources of data used to build the TINITALY/01 DEM.

## 1.2 Views of the DEM

In this work we use a custom C++ program [Tarquini and Favalli, submitted] that is able to derive a single, seamless, full-resolution, perspective view of a raster draped on a very large DEM. Standard off-the-shelf software packages are able to 3D visualize image layers draped on DEMs (e.g. ERDAS, ESRI packages), but they cannot provide perspective full resolution views of images draped on very large DEMs, neither are able to produce a seamless coverage of full resolution stereo images from a very large DEM.

Our in-house program is able to produce these outputs. The main challenge in the present work was the outstanding size of the TINITALY/01 DEM (at the time of its first release). In the following sub-sections we outline how the program works, and we describe the output images.

### 1.2.1 The draping method

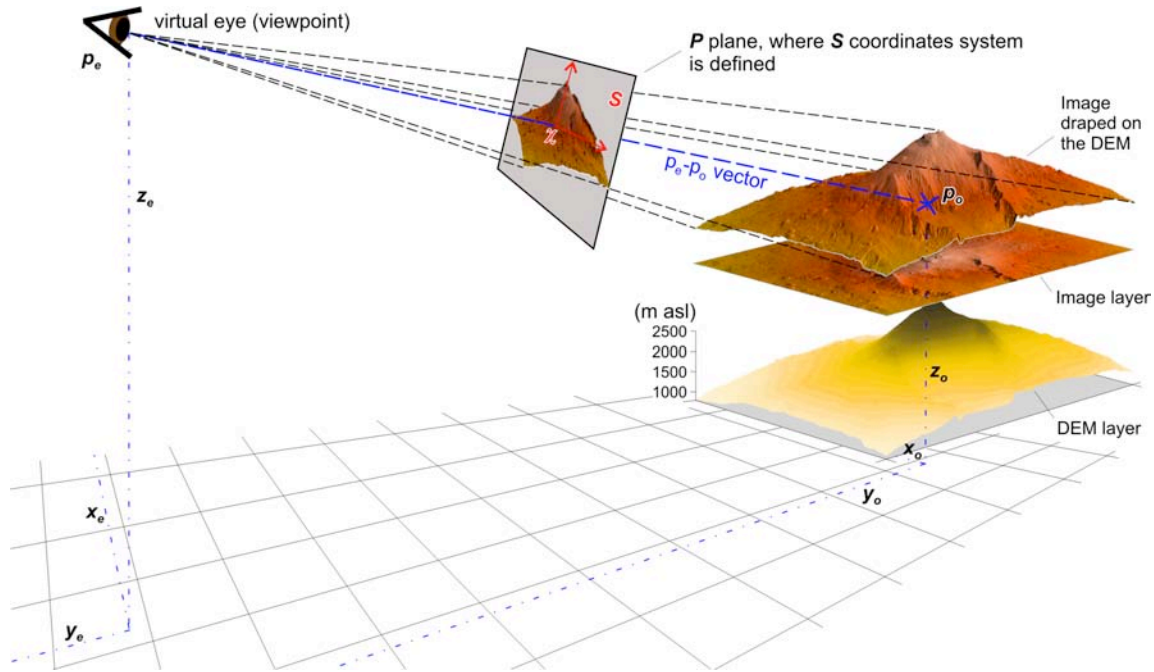
To apply the draping procedure, two items are needed: i) a DEM in grid format, and ii) an image aligned with the grid (i.e. the grid and the image must have the same number of cells/pixels and the same geographic reference). First of all, we arrange the whole TINITALY/01 DEM in a suitable format, deriving from the initial TIN DEM, a DEM in grid format composed of 193 50-km-side square elements. The cell size for the grids was set to 5 m, with 12 billion of cells to represent the thorough surface of the Italian territory. Assuming a 4-byte memory for each cell in non compressed format (e.g., standard ESRI or float grids), grid data will occupy about 50 GB of disk memory.

We define  $d_i$  as the DEM in grid format belonging to the  $t_i$  tile. From each tile  $t_i$ , an image  $h_i$  was derived by applying a standard hillshading function in ArcView 3.2. In this way, we obtained an image for each tile, and the whole Italian territory is covered by these images. Having created an aligned database of grids and images, we can drape all the image datasets on the DEM on a tile-by-tile basis.

In the reference system of the DEM, we define a point  $p_e(x_e, y_e, z_e)$ , which is the position of a virtual eye, and a point  $p_o(x_o, y_o, z_o)$ , which is the central point targeted by the virtual eye (**Figure 2**). Hence, we define a plane  $P$  orthogonal to the vector  $p_e-p_o$ , where the final image is obtained. We define a Cartesian coordinate system  $S$  on the  $P$  plane centred on  $\chi$ , which is the intersection between  $P$  and the vector  $p_e-p_o$ . A



cell size  $s$  for the final projected image is also defined for  $S$ . Considering the cell size  $s$  with respect to the cell size of the input DEM and the relative positions of  $p_e, p_o, P$  with respect to the DEM, we obtain how the input images are sampled by the projected image on  $S$  (i.e., the resolution ratio of the output image with respect to input image). In our case we set up these parameters in order to maintain the input resolution (avoiding both over-sampling and sub-sampling).



**Figure 2.** Sketch of the projection system. The represented area is the upper portion of Mount Etna (Sicily). The image is a shaded relief combined with a colour ramp. Vertical exaggeration is  $2 \times$ . The grid on the bottom marks the geographic reference system of the input dataset.

### 1.2.1.1 Draping a whole database at once

From each tile  $t_i$ , we obtain an elementary perspective image  $h_{pi}$  by projecting the  $h_i$  image on the previously defined  $S$  reference system. Details of the projection system are in Tarquini and Favalli (submitted).

Using the same projection geometry, we process all the 193 tiles of the TINITALY database, obtaining on the  $S$  reference system a total of 193 projected images  $h_p$  representing all the input datasets.

Both when projecting single tiles and when merging projected tiles, special care is paid to solve the visibility problem, which is the problem of deciding which elements of a scene are visible, and which are hidden from the given viewpoint. We solved this problem by adopting the Z-buffering technique [e.g., Tarquini and Favalli, submitted]. At the end of this procedure, a continuous layer representing the perspective view of all the  $h$  images draped on the whole TINITALY/01 DEM from the  $p_e$  viewpoint is obtained.

### 1.2.2 Creating stereo images

It is possible to use the described procedure to create stereo images. We can obtain two views by fixing the same point  $p_v$  from two different positions for the eye  $p_{e1}$  and  $p_{e2}$ . If the relative position of  $p_{e1}$  and  $p_{e2}$  and  $p_v$  are adequate and all the others projection parameters are fixed to the same values, we obtain a stereo-couple of images. This means that if an observer looks at these images by seeing one image with each eye, it's brain can perceive the represented landscape in 3D.

The easiest and cheaper way to set up a stereo view by allowing the simultaneous vision of two images at once (a different image for each eye) is creating an anaglyph [e.g. Kamel Boulos and Robinson, 2009]. This is an old technique that works perfectly when the two stereo frames are 8-bit grey levels images. The two frames are merged in a single 24-bit RGB image by setting the right image to the R (red) channel, and

the left image to the G (green) and B (blue) channels. To see anaglyph images, anaglyph glasses are necessary. This method can be straightforwardly applied to the database of shaded relief images obtained from the whole TINITALY/01 DEM.

### 1.2.3 The views

By using our in-house program, we derived 7 different views of the Italian landscape in both anaglyph and conventional mode. These views represent 7 different areas or regions (Table 1). The viewpoint is set either along the zenith of the centre of the target region, at an almost infinite distance (type 1 images), or elsewhere along an inclined vector targeting a point on the region from a distance of 30,000 km (type 2 images). The viewpoint position of type 1 images warrants a very low planar distortion, and these images are almost perfectly georeferenced in the original projection system. Type 2 images, in contrast, are simple perspective views affected by relevant distortions.

**Table 1.** The views of the TINITALY/01 DEM on line at <http://webgis.pi.ingv.it> (modified after Tarquini et al., 2007).

Viewed Area	Illumination		View Point			GRID cell size (m)
	<i>Azimuth</i>	<i>Elevation</i>	<i>Azimuth</i>	<i>Elevation</i>	<i>Distance (km)</i>	
ALPS	90° N	45°	147° N	30°	30000	10
APENNINES	315° N	45°	225° N	30°	30000	10
SARDINIA	315° N	45°	255° N	30°	30000	10
SICILY	315° N	45°	225° N	30°	30000	10
VAL D'AOSTA	315° N	45°	90° N	90°	≈ infinite	5
ABRUZZO	315° N	45°	90° N	90°	≈ infinite	10
FRIULI	315° N	45°	90° N	90°	≈ infinite	5

## 2. The website technical structure

### 2.1 The WebGIS software

To allow the Web navigation of the described layers of images, we set up a web-GIS site based on the MapServer Open Source software (<http://mapserver.org/>). MapServer is a platform for publishing spatial data and interactive mapping applications to the Web. It was originally developed in the mid 1990's at the University of Minnesota. This platform was chosen as being completely free and as being also compatible with the Linux operative system, which is the operative system running on the server where the website is published (at the Centro Elaborazione Dati of the INGV, sezione di Pisa). When MapServer was chosen, the latest version available was the 4.8.1, supporting the visualization of images in png format with only 8 bits in colour depth.

#### 2.1.1 Image format

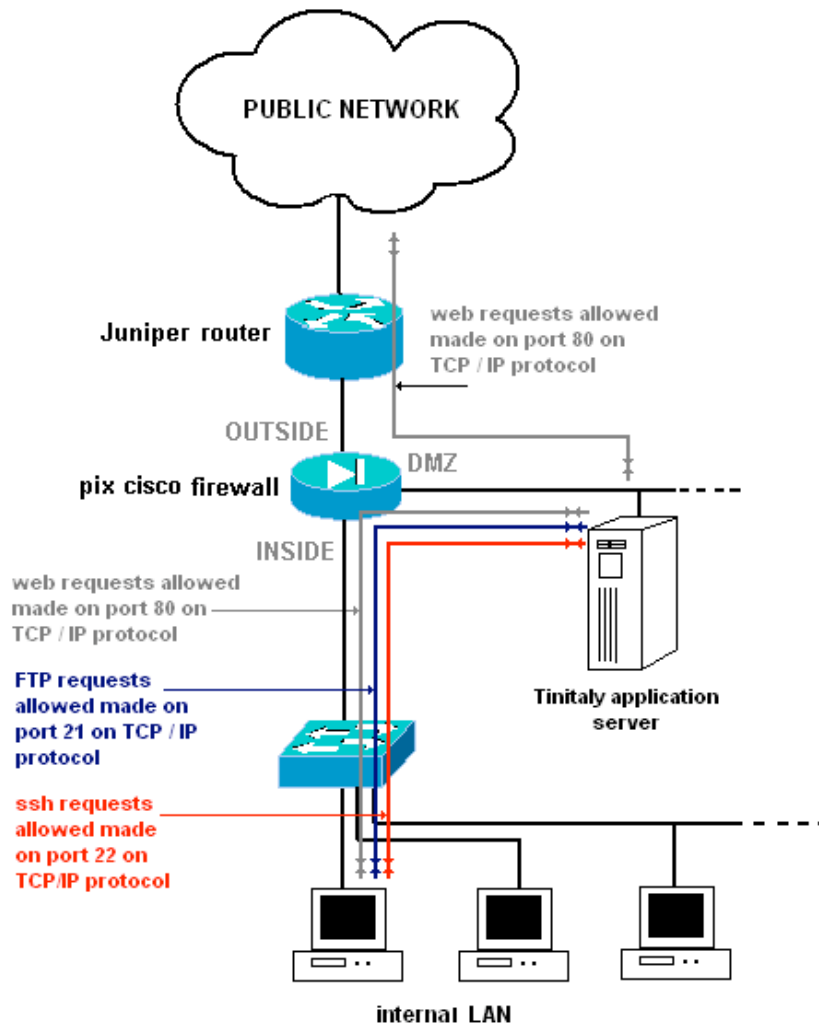
Due to the 8-bit limitation of the selected MapServer software, we set up an optimized compression of images, reducing 24-bit RGB images to 8-bit images, maintaining the best possible resolution. The obtained 8-bit images preserve almost everywhere the quality of the 24-bit images. The only exceptions are very flat areas (e.g., the Padana plain, North Italy), where the compression clearly lowered the quality.

#### 2.1.2 Image compression

To optimize the loading of the image database, MapServer uses the method of the pyramidal levels and images are divided in tiles. In addition to the full resolution level, several compressed levels are created by progressively doubling the pixel size. In this way, MapServer loads the level having the resolution adequate for the zooming scale.

## 2.2 Website engineering

The Web interface is supported by the Apache software, which publishes full resolution images created by MapServer upon request from Web users. Apache supports the HTTP [HTTP, hyper text transfer protocol] protocol on the TCP/IP transport protocol using port 80. The updating and the administration of the application is made through FTP [FTP: file transfer protocol] on the TCP/IP protocol by using port 21, while the SSH [SSH: secure shell] on the TCP/IP protocol by using port 22. A Cisco PIX firewall allows all users to access the application via the Web, while administration and system updating is possible only through the LAN. Figure 3 shows the engineering of the website.



**Figure 3.** Scheme of the website engineering.

### 3. Browsing the website

#### 3.1 Entering the website

The website is accessible at <http://webgis.pi.ingv.it>. In the home page (**Figure 4**), the user decides to browse either the two types of images: stereo views or simple perspective views. To adequately visualize the stereo views with a full 3D perception, users must wear proper anaglyph glasses (e.g., <http://pagesperso-orange.fr/alpes-stereo/lunettes/testelunettes.html>), otherwise anaglyphs are just blurry images. Who is not provided by the anaglyph glasses can visualize the standard perspective (non-stereo) images.

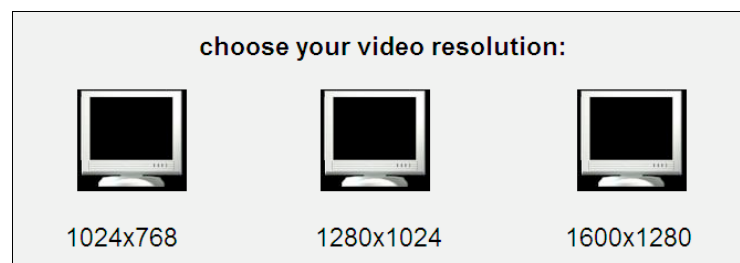


**Figure 4.** Home page of the website, where users select the type of images to browse: stereo or standard.

#### 3.2 Browsing options

##### 3.2.1 Setting the screen size

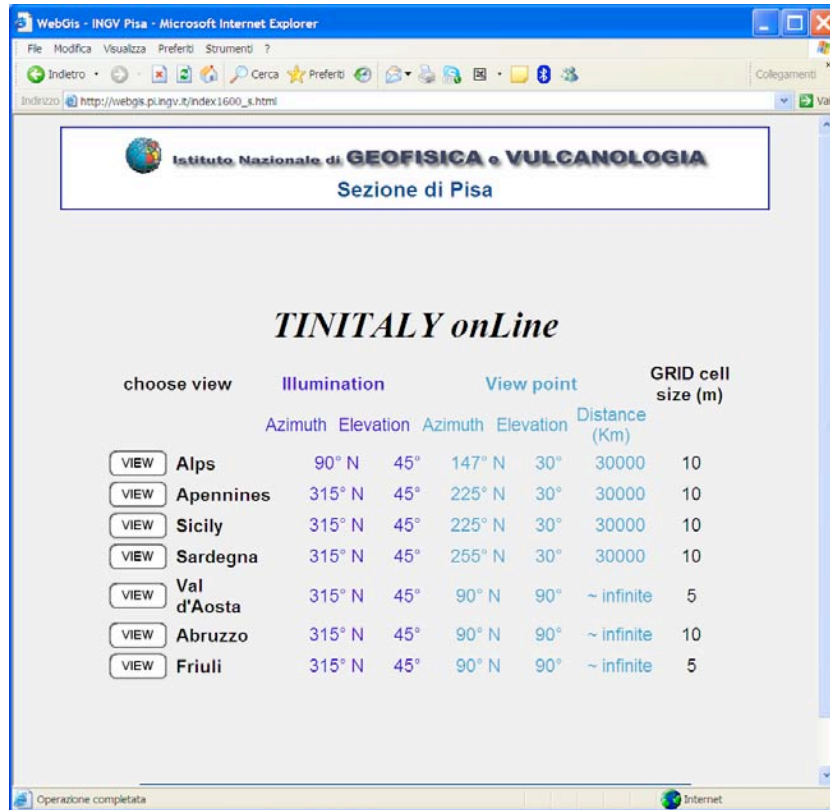
Once the image type is chosen, users have to choose the resolution of their monitor (**Figure 5**), so that the dimension of the frame where GIS layers will be displayed is optimized accordingly.



**Figure 5.** Select the video resolution between three possible format.

### 3.2.2 Choosing the area/region

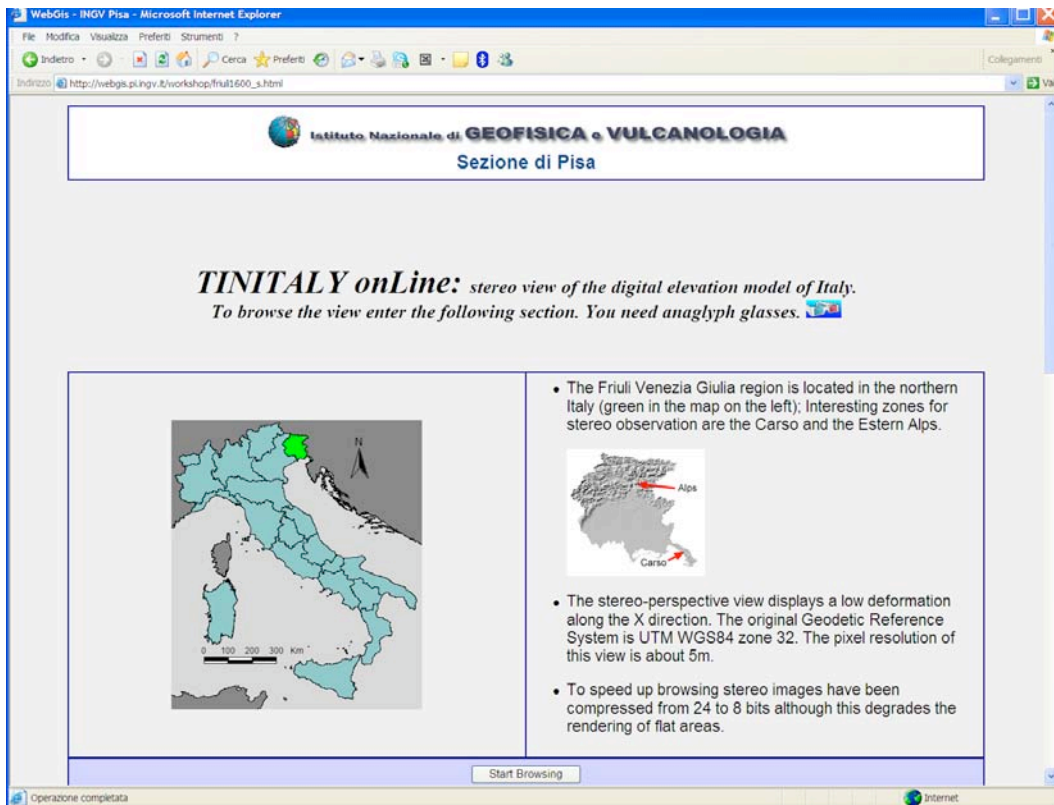
The next step is selecting one of the views listed in Table 1 (**Figure 6**). These views cover areas that were particularly interesting due to the higher quality of the input datasets or to the relevance of the local morphology. For example, one view covers the whole Alpine chain included in the northern, continental portion of Italy, while another view shows the whole Apennine chain in the peninsular portion of Italy. Six more views are available for the Italian regions of Abruzzo, Friuli Venezia Giulia, Valle d'Aosta, Sicily, Sardinia.



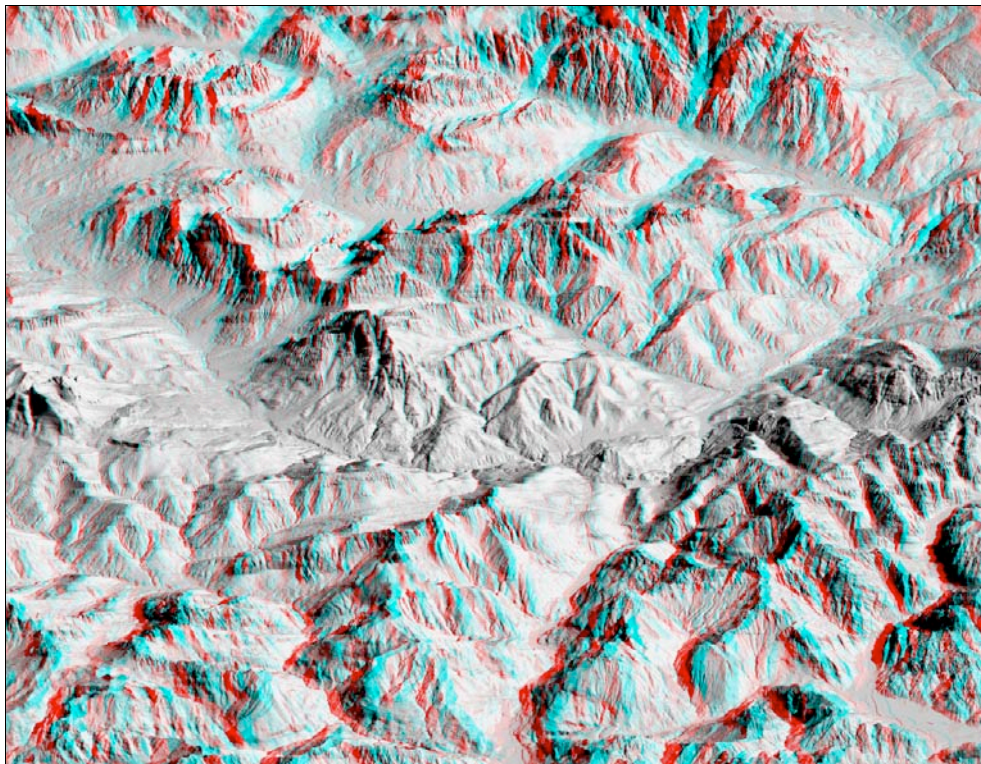
**Figure 6.** Select one out of the seven views.

### 3.3 Ready to browse?

After selecting the area, the following web page (**Figure 7**) contains a short introduction to the chosen area/region. The geographic location is shown and the main features of the area are highlighted. If stereo mode was previously selected, in the bottom of the page there will be an anaglyph test-image (**Figure 8**) that can be used to test whether the anaglyph glasses are suitable for the images of the online database. If the non-stereo views option was previously selected, a simple perspective image is displayed instead of the anaglyph image of **Figure 8**.



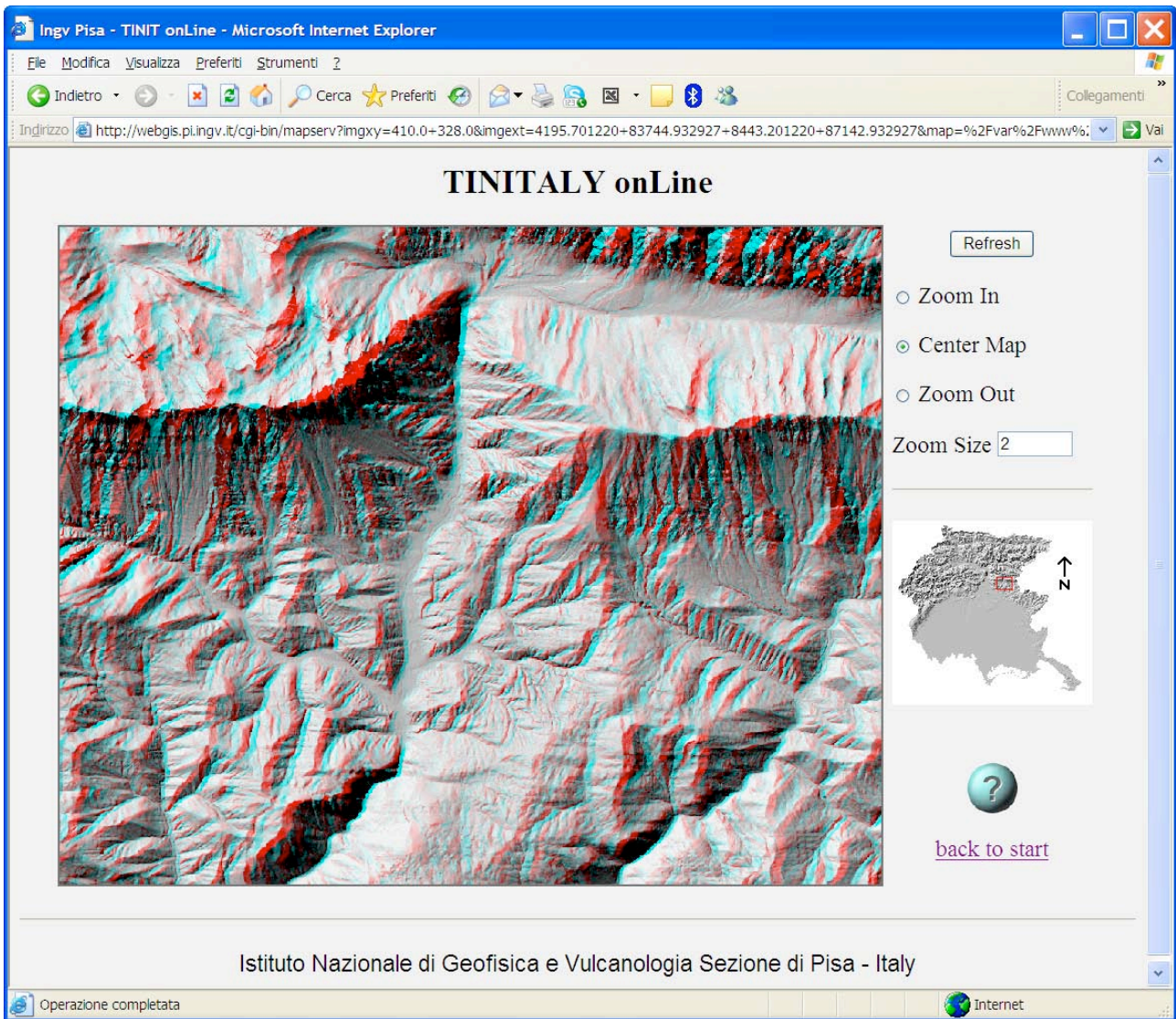
**Figure 7.** Displaying a selected view: an overview of Italy with the selected region on the left, and the chosen area on the right with a short description (in this example, the Friuli Venezia Giulia Region).



**Figure 8.** Below the description of the area, there is an example of the type of image users will see when browsing: a stereo view (in the figure), or a simple perspective view. The area selected for the example is the Dolomiti massif, Northern Italy.

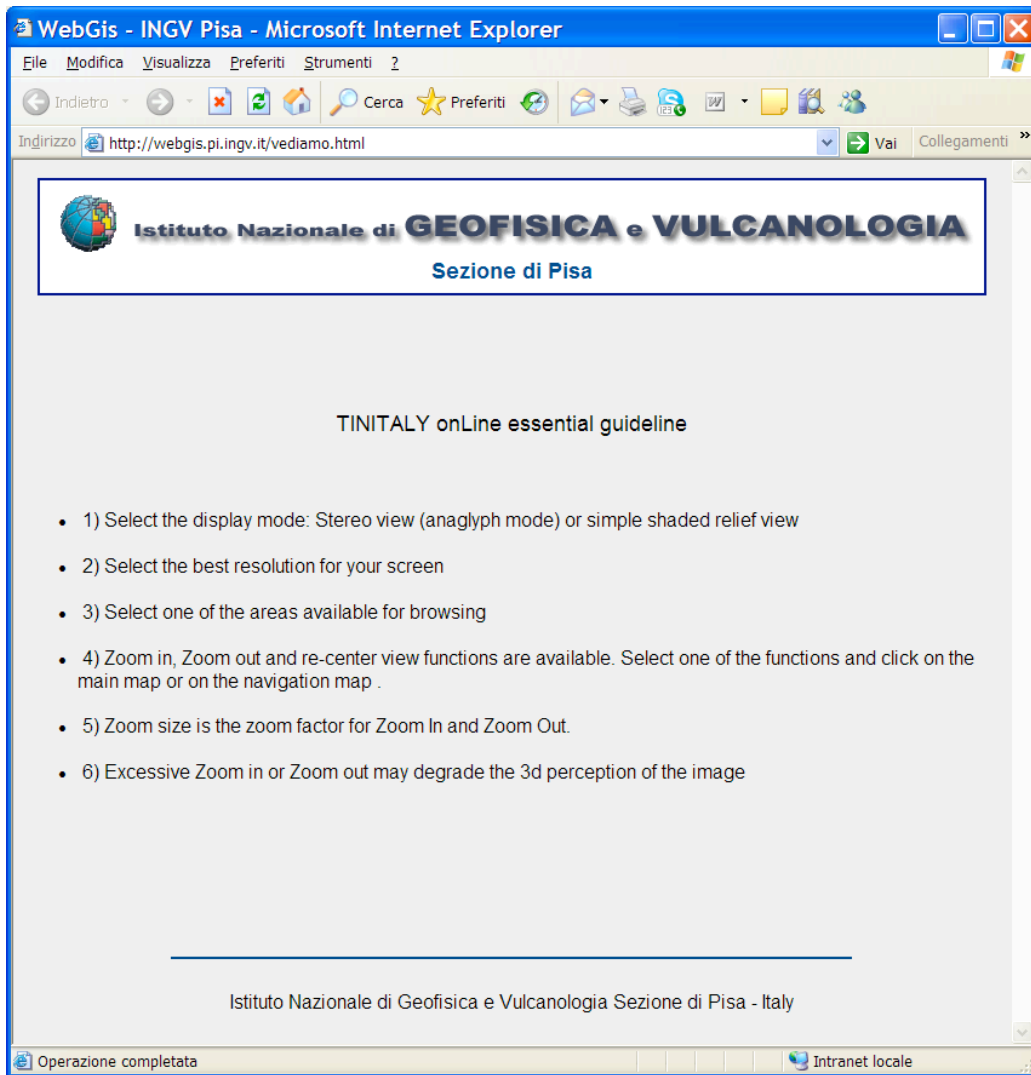
### 3.4 Exploring the selected area

Once selected the *Start Browsing* button in the previous web-page, the navigation with MapServer starts (**Figure 9**), and the elementary WebGIS functions implemented in the current version of the website may be used to explore the TINITALY/01 DEM through stereo or shaded relief images.



**Figure 9.** The view created by MapServer with the WebGIS interface.

WebGIS commands are listed on the right of the view frame in the WebGIS page. We implemented only a few essential commands in the present version of the website: a Refresh button, Zoom In, Center Map, Zoom Out and the capability to set a zoom factor (Zoom Size). The small map below the listed tools is a navigator. When users left-click on it with the mouse, MapServer redraw the full frame centred on the clicked point. The green button with a question mark is a link that opens a page with the guidelines for the WebGIS navigation (**Figure 10**).



**Figure 10.** The help page of the website.

#### 4. Concluding remarks

We presented a website (<http://webgis.pi.ingv.it/>) that allows the exploration of 5 or 10 m resolution images derived by the TINITALY/01 DEM [Tarquini et al., 2007]. These images are perspective or anaglyph-mode views obtained by using a specifically designed program [Tarquini and Favalli, submitted] that is able to drape very large datasets of images over a DEM without losing the input resolution.

The online views, especially the ones in anaglyph mode, provide a comprehensive picture of the Italian landforms, at the full resolution of the TINITALY/01 DEM. After having previewed via the Web the DEM database, internet navigators who are interested in downloading portions of the TINITALY/01 DEM can register at the Web portal Kharita (<http://kharita.rm.ingv.it/dmap/>) to obtain an account.



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FTP protocol: Request for Comments: 765 <http://www.ietf.org/rfc/rfc765.txt> (FTP protocol).

HTTP protocol: Request for Comments: 2616 <http://www.ietf.org/rfc/rfc2616.txt> (HTTP protocol).

Kamel Boulos, M.N., and Robinson. L.R. (2009): *Web GIS in practice VII: stereoscopic 3-D solutions for online maps and virtual globes*. International Journal of Health Geographics 8, 59. doi:10.1186/1476-072X-8-59.

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Via di Vigna Murata, 605

00143 Roma

Tel. +39 06518601 Fax +39 065041181

**<http://www.ingv.it>**



**Istituto Nazionale di Geofisica e Vulcanologia**