

## PSInSAR™ data

Product general features

Version 2.0 – January 2008



## Permanent Scatterer (PS) InSAR measurements

TRE has developed a range of **service products**, based on its proprietary PSInSAR™ technology, to assist their customers in selecting the most **appropriate type of analysis**.

There are four main classifications of our service products:

- Local area - PS analysis
- Regional area - PS analysis
- Linear structure - PS analysis
- Single building - PS analysis

For all types of analysis, **PS** data are digitally recorded in a **database (.dbf file)**, readable within any spreadsheet and delivered in electronic format. PS data can be easily visualized on a GIS platform and, once superimposed on a high resolution optical image, can give a striking picture of the dynamics of the area of interest.

The information that is provided for each PS includes:

- **Geographical coordinates** with respect to the local ellipsoid or GPS-like WGS84;
- A **quality index** (coherence), ranging from 0 to 1;
- The **average displacement rate** in mm/yr;
- The time series of the displacement values.

In addition to the database of the results and a technical report, the Client can receive - upon request - technical printouts (sheet map) and the visualization software "**tre-explorer**".

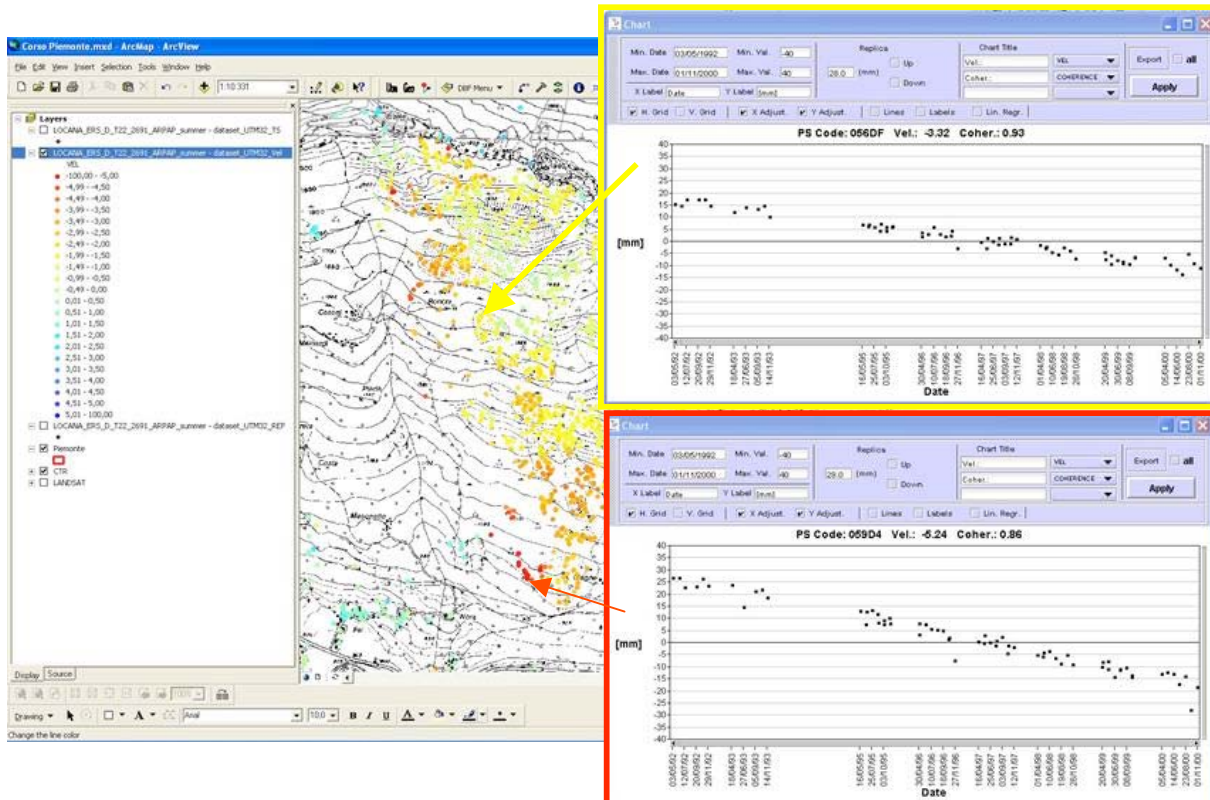


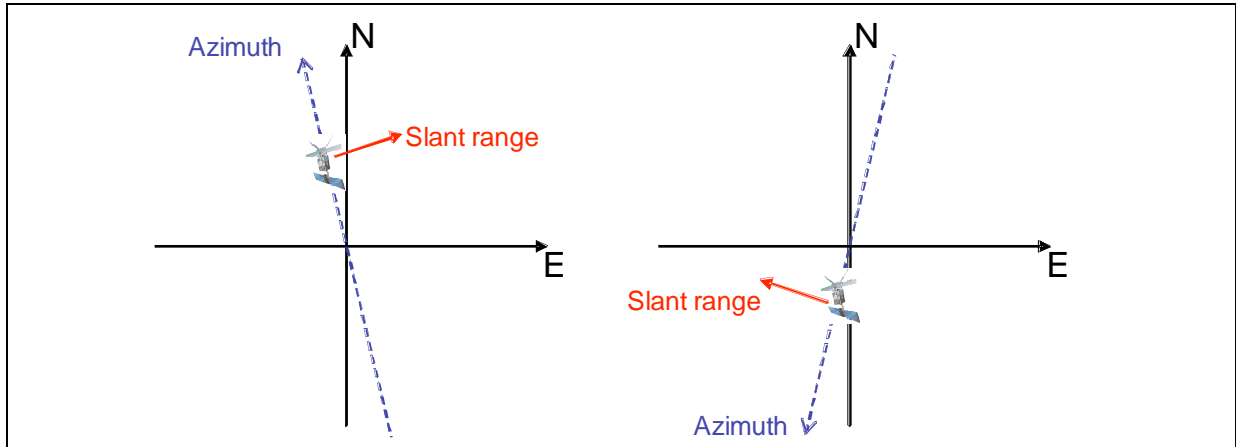
Figure: an example of PS information data downloaded onto a GIS platform.

### What is possible to measure

All PS measurements are *differential* measurements with respect to a reference radar target (motionless and of known coordinates) and to a reference epoch, typically the time of the first available acquisition.

The satellite moves along its orbit, while the Earth rotates around its axis. Combining the two motions, it is possible to see the same area of interest (AOI) under two different geometries, that is:

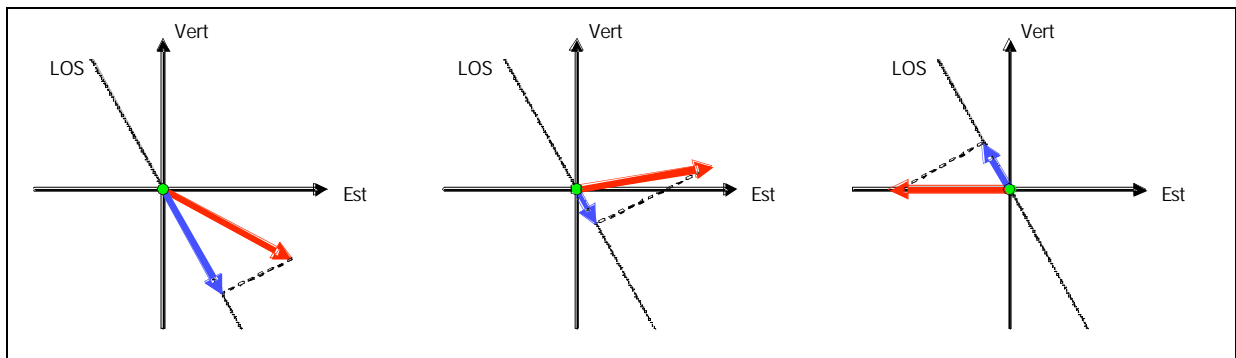
- an ascending mode, when the satellite moves from South to North along its orbit and illuminates the AOI from West towards East;
- a descending mode, when the satellite moves from North to South along its orbit and illuminates the AOI from East towards West.



**Figure:** acquisition modes: the ascending – on the left – and the descending – on the right - orbit directions.

It is important to point out that all displacement measurements are carried out along the satellite Line Of Sight (LOS), which has an inclination from to the vertical axis dependent on the satellite used and ranging from 20 to about 50 degrees. Positive velocity values typically correspond to motion towards the satellite, while negative values correspond to motion away from the satellite.

Since the satellite, along a certain orbit, can measure only one component of the displacement vector (i.e. that along the LOS) affecting the measurement point, the actual deformation can be more significant than what is estimated from PS data (see picture below). When the movement is perpendicular to the LOS direction, no motion can be detected.



**Figure:** LOS displacement components as a function of different directions of the displacement vector. Actual displacement vector in red and LOS displacement in blue.

However, by combing two datasets (one ascending and one descending), it is possible to measure both the vertical and the horizontal (in the East-West direction) component of the displacement vector. The sensitivity to any North-South displacement is extremely low for all satellite currently in use.

## Number of radar data for a PS processing

Typically, a minimum of 15-20 radar images, acquired over the same AOI along the same nominal orbit (i.e. same acquisition geometry), are necessary to perform a PS analysis. The actual number depends on the characteristic of the area of interest and the type of sensor to be used.

## Extension of the AOI

Depending on the product requested and the problem at hand, a PS analysis can provide deformation data for large areas of interest (AOI), even exceeding 10,000 km<sup>2</sup>, but it can be extremely valuable also to extract information over small areas, with a minimum extent of 1 km<sup>2</sup>.

## Type of analysis

TRE offers a range of service levels and various processing options within each level. These service levels arise largely to ensure that a client isn't swamped with data. For example, in urban areas, where the PS density will be between 300 and 500 PS per Km<sup>2</sup>, the service level is appropriate to small areas between 1 and 100 Km<sup>2</sup>. In TRE terminology, we refer to this service product as Local PS Analysis (LPSA). In contrast, if a client is looking to establish seismic or tectonics effects over large areas, an alternative service level is offered that typically might yield PS densities in the range of 25 to 50 PS per Km<sup>2</sup>. TRE refers to this service product as Regional PS Analysis at Low Resolution (RPSA-LR). Between these limits are other service levels.

## PS density

According to the type of analysis and the number of radar data available, it is possible to get a PS density even exceeding 1,000 PS/ Km<sup>2</sup> within urban areas.

The following table shows some statistical figures:

	ERS [PS/km <sup>2</sup> ]	RADARSAT [PS/km <sup>2</sup> ]
Urban area <sup>1</sup>	565	730
Mixed area <sup>2</sup>	170	240
Regional territory	85 <sup>3</sup>	150 <sup>4</sup>

<sup>1</sup>test carried out over an urban area (Rome, Italy), using single-geometry datasets.

<sup>2</sup>test carried out over an area of 1,000 km<sup>2</sup>, covering mountain and hill territories and some villages.

<sup>3</sup>test carried out over an area of 25,000 km<sup>2</sup> corresponding to the entire Piemonte region (Italy).

<sup>4</sup>test carried out over an area in the Northern part of Lombardy (Italy).

## Data Precision

The quality and accuracy of results obtained with the PSInSAR™ represent two of the most important goals of TRE. Extensive analysis of the results of commercial and research projects performed by TRE and the Politecnico di Milano has made it possible to strongly improve our quality levels.



Two parameters characterize the PS results:

1. Precision of the estimated displacement values;
2. Precision of the positioning of the measurement points.

The standard deviation of the estimated PS velocities depends on many factors, the most important being the distance from the reference point. The relative positioning error is given by the resolution of the SAR system in use and the number of data available in the data-stack. Typical figures are  $\pm 5$  m in *Easting* and  $\pm 2$  m in *Northing*.

The table below summarizes typical precision values for a PS located within 2 km from the reference point, for a data-set covering at least 2 years:

RELATIVE POSITIONING	<b>Easting</b>	<b>Northing</b>	<b>Height</b>
Precision ( $1\sigma$ )	5 m	2 m	1.5 m

LOS DISPLACEMENT	<b>Average Displacement Rate</b>	<b>Single Displacement</b>
Precision ( $1\sigma$ )	< 1 mm/year	< 5 mm

## Satellite

Today TRE can take advantage of the radar data acquired by the ERS and Envisat satellites of the European Space Agency (ESA), and the Radarsat-1 satellite operated by the Canadian Space Agency and MDA. All these satellite platforms mount C-band sensors.

In the near future, new sensors will be available for PS analysis, namely:

- *Cosmo Sky-Med*: a 4-satellite constellation mounting X-band sensors (wavelength  $\sim 3$  cm) operated by the Italian Space Agency (ASI). Two of the four satellites have been already launched during 2007. When the whole constellation will be in orbit and fully operational, it will pave the way to new products and services, in particular for civil protection applications.
- *TerraSAR-X (X-band)*: a German space agency (DLR) mission. It will be valuable for projects concerning limited areas where it is important to have very high resolution data.
- *RADARSAT-2 (C-band)*: it is the follow-on to RADARSAT-1, launched in 1995. The new satellite was launched in December, 2007, and has been designed with significant and powerful technical advancements, compared to its predecessor.