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Application of CPT, an advanced DInSAR technique, to study surface displacement near Itoiz dam, Navarra, Spain.

Fernández, J.(1), Arjona, A.(1), Prieto, J.F.(2), Santoyo, M.A(1), Seco, A.(3), Monells, D.(4), Pallero, J.L.G(1), Prieto, E(3), Luzón, F.(5), Mallorquí, J.J.(4)

1) Instituto de Astronomía y Geodesia (CSIC-UCM), Plaza de Ciencias 3, 28040-Madrid, Spain. jft@mat.ucm.es, alicia_arjona@mat.ucm.es, masantoyo@pdi.ucm.es, jlgpallero@pdi.ucm.es.
2) Departamento de Ingeniería Topográfica y Cartografía, ETSI Topografía, Geodesia y Cartografía, Universidad Politécnica de Madrid, Km 7.5 Autovía de Valencia, E-28031 Madrid, Spain. juanf.prieto@upm.es.
3) Departamento de Proyectos e Ingeniería Rural, Universidad Pública de Navarra, Campus de Arrosadía s/n 31006, Pamplona, Navarra, Spain. (+34) 948 16 9682, andres.seco@unavarra.es, epc@unavarra.es.
4) Universitat Politècnica de Catalunya, Departament de Teoria del Senyal i Comunicacions. D3 - Campus Nord, UPC, Barcelona,, Spain. dmonells@yahoo.es, mallorqui@tsc.upc.edu
5) Departamento de Física Aplicada, Universidad de Almería, Cañada San Urbano S/N, 04120 Almería, Spain. fluzon@ual.es.

Extended Abstract

Itoiz reservoir is located in Navarra, northern Spain, being a newly constructed gravity dam that stores the water from the Irati and the Urrobi rivers. The dam has a total height of 121 m, a total length of 525 m and a maximum water storage volume of 410 hm^3. The aim of this work is to study the surface displacement field during the impoundment of the Itoiz water reservoir, Figure 1. Orbital SAR Differential Interferometry (DInSAR) techniques have been proven to be a useful and powerful tool in tectonic areas for surveying subtle surface deformations over several years related to geodynamic phenomena. An advanced DInSAR observation technique, Coherent Pixel Technique (CPT), has been applied to study the existence of deformation in the dam area in order to obtain mean velocities and time series of deformation.
We have studied the applicability of this technique to study the surface displacement field during the impoundment of the Itoiz water reservoir. Specifically, we focus on the analysis of the stability of the left slope of the reservoir. See [1,2] for more details. We have used ERS and ENVISAT descending and ascending images concerning to the 1992-2008 and 2003-2008 periods respectively. We compare the observation results with the displacement induced by water loading obtained using a theoretical model.

Figure 1. Location and view of the Itoiz water reservoir.

COHERENT PIXEL TECHNIQUE

We have applied an advanced DInSAR algorithm known as the Coherent Pixel Technique [3] to study the displacement in nearby Itoiz water reservoir. To obtain DInSAR displacement maps, with both linear and non-linear terms, we start with images focused from raw data. First, using PRISAR software, we carry out the co-registration between each image to obtain interferometric phase. Both satellite orbits and Digital Elevation Model are used in order to generate differential interferograms. The final result of the process is the linear deformation map from a set of low resolution interferograms (multi-looked) and after estimating the DEM errors and atmospheric artefacts. Finally, using SUBSOFT software, we calculate the non-linear component of movement and the atmospheric artefacts by means of spatial low pass filtering and temporal high pass filtering. See [3,4] for more details in CPT technique.

RESULTS

Ascending images

Due to the lack of good coherence the number of obtained interferograms is even smaller than the number of images. For this reason, the triangulation between points does not allow us to obtain coherent pixels on the left slope of the dam. Pixels with coherence greater than 0.25 in more than 45% of the interferograms are chosen. Close to the dam LOS displacements lower than ± 8 8 cm in 12 years are measured (see Fig. 2).

Descending images

In this case we only have obtained good interferogram from ENVISAT images, with similar processing parameters of ascending processing. Five different points (A-E) have been selected in order to represent their time deformation series (see Fig. 3). We obtain better coherence so triangulation between points allows us to obtain some points on the left slope of the dam. The points show a slight negative LOS or stability.

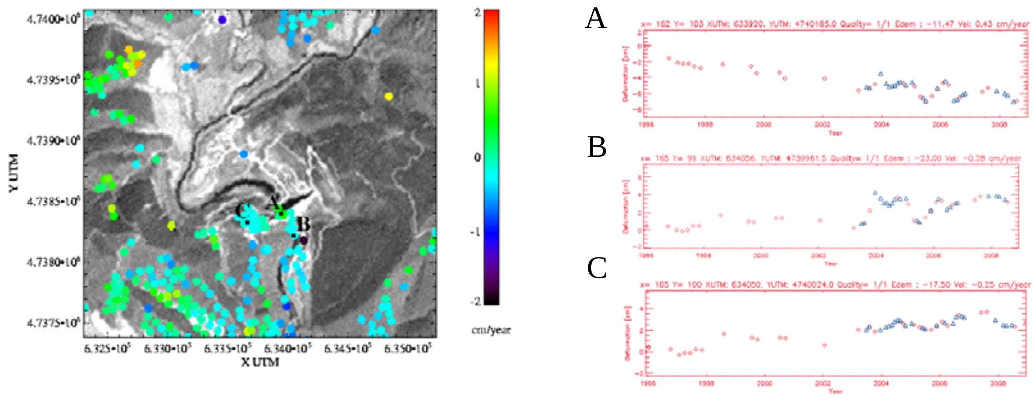

Figure 2. Deformation map. Darker colour means uplift and softer colour means subsidence. Time serie of A-C points. ERS data dates in red. ENVISAT data dates in blue.

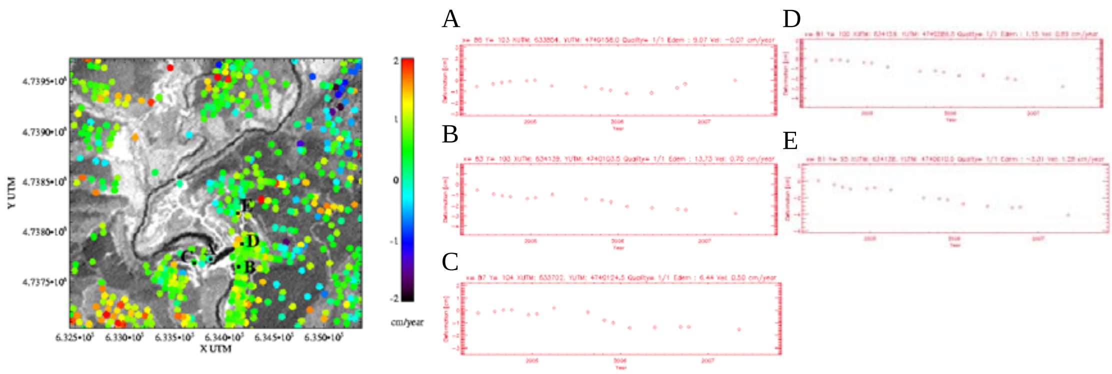

Figure 3. Deformation map. Darker colour means uplift and softer colour means subsidence. Time serie of A-E points. ENVISAT data dates.

THEORETICAL COMPUTATION OF DISPLACEMENTS

Surface water loads and the associated displacements are computed by means of the Boussinesq solution for a vertical point load on a homogeneous elastic half-space. The surface vertical forces can be expressed by means of $F(x,y,t) = \rho gsh(x,y,t)$ where ρ is the water density, g is the gravity aceleration, s is the area of the spatial sampling rate from a digital elevation model of Itoiz area and $h(x,y,t)$ is the water column height that depends on the spatial location at surface (x,y) and the time t during the reservoir impoundment [5]. Surface water loads evolution is computed based on the Time Histories of the Lake Levels (THLL) and on the Digital Elevation Model (DEM) of the zone. THLL data used covers the period between 19/1/2004 to 10/5/2008 with a daily sampling rate. The combination of these two data sets gives the opportunity to perform a highly accurate estimation of the evolution of the water loads and the space distribution in time, due to the relatively high spatial sampling rate of elevations in the DEM (25m x 25m). Given the deformation due to a surface point load, the total contribution of the entire lake water loads is computed by the sum of subsurface deformations due to the two dimensional array of forces of the lake. For the computation of elastic displacement we assumed a Poisson's ratio of υ=0.27 and a Young Modulus of 0.90 Mbar. Fig. 4 shows the vertical displacement (positive downward) at four different times. Maximum displacements occur at the maximum capacity of the dam, maximum load.

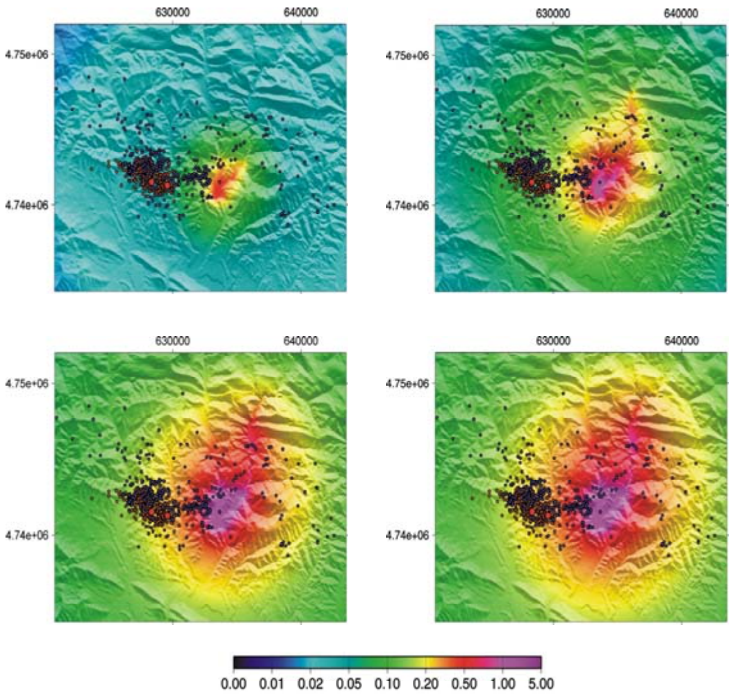

Figure 4. Vertical surface elastic displacements due to water loads (cm). Top left shows results for date 18/09/2004 (earthquake mainshock, Mw=4.7); top right for 01/06/2006; bottom left for 01/07/2007; and bottom right for date 18/04/2008 (maximum capacity).

CONCLUSIONS

We have applied the advanced radar interferometry Coherent Pixel Technique in order to study the possible surface displacements in the area of Itoiz water reservoir. For this purpose, we have used a set formed by ERS and ENVISAT ascending and descending images for the 1992-2008 time period. The DInSAR technique cannot estimate deformation in a complete way within the surrounding of Itoiz dam due to existing vegetation, the low coherence found, layover, foreshortening and shadowing effects.

Despite those problems some interesting results have been obtained. They show a clear need of installing corner reflectors which will allow having control points in order to improve displacements detection capability. Installation of these corners in the surroundings of the Itoiz dam has been done during August 2009. See Fig. 5 for some locations as a way of example.

For ascending images from Itoiz, we have processed ENVISAT and ERS images from the 1996-2008 period. The results show slight LOS deformation. The pixels closer to dam has a maximum LOS displacement of about -7 cm in 12 years. We cannot obtain coherent pixels on the left slope of the reservoir. Concerning descending images from Itoiz, we only have used ENVISAT images from 2004-2007 period due to the absence of good interferograms obtained using ERS images. Significant LOS displacements are located in the left slope of the Itoiz reservoir with a maximun value of about -4 cm in 3 years.

On the other hand, theoretical vertical displacements in the vicinity of the Itoiz dam has maximum values of about -1.0 cm, occurring when the dam is at its maximum capacity, located near and around the lake, as expected.

Figure 5. Some examples of corner reflectors installed in Itoiz reservoir area.

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