

1 **Discussion**

2 In an effort to investigate potential earthquake-induced deformation to Mornos earth
3 dam (Central Greece) we applied multi-temporal SAR interferometry using AMI/ERS
4 and ASAR/ENVISAT scenes which together cover the period 1993-2010 following an
5 “hybrid InSAR” methodology which combines elements from “conventional
6 DInSAR”, SBAS and PSI.

7 In the present study, starting from the multi-reference stack of unwrapped phases we
8 derived a time series of deformation using Singular Value Decomposition (SVD) to
9 obtain the least-squares solution for the phase time-series. Using a big volume of multi-
10 reference differential interferograms the temporal uncorrelated errors are being
11 reduced. Tropospheric turbulences being uncorrelated in time have been reduced. On
12 the other hand tropospheric noise due to variable phase delay linked to the altitude
13 (smaller phase delay values in higher altitudes) is not reduced by this estimation
14 procedure. For this reason heavily suffered interferograms have been removed for the
15 procedure. Therefore, the obtained time series of unwrapped phases still includes the
16 atmospheric phases as well as non-linear deformation phase. Tropospheric phases as
17 well as phases relating to non-linear motion are part of the deviation of the time series
18 from the linear regression. Moreover Ferretti et al., 2000, used a least-squares estimator
19 and linear deformation phenomena are remained.

20 The products of multitemporal interferometric analysis are time series of deformation
21 history, temporally referenced to the date of the oldest acquisition (containing both the
22 linear and non-linear deformation components) and the (linear) deformation rate
23 (velocity) for each scatterer. Non-linear deformation can be estimated without any
24 modeling and prior knowledge using the SVD as stated by [Goel K. et al., 2011 and
25 Tao L. et al., 2013]. In order to have a numerical estimation of the statistical dependence
26 between the water level and the deformation we sampled the values of the water level
27 at the acquisition dates and correlated them with the deformation values at the same
28 dates. Thus the resulted correlation value is an index of causation.

29 Results show that deformation measured by SAR interferometry is clearly related to
30 water level changes but also is associated with some of the earthquakes that struck the
31 broader area during the period of monitoring. Three characteristic points that we
32 considered and distributed along the crest of the dam show identical deformation

33 behavior. Specifically when the lake's level is rising deformation rates of points on the
34 dam take negative values while in case of falling level the deformation values of the
35 points decreased. This correlation is suddenly changed and this change coincides in
36 time with some of the earthquakes that occurred in the region.

37 The above findings are consistent with geodetic results carried out by Gikas et al. 2005.
38 Authors used precise leveling and GPS measurements on the dam's crest for the periods
39 2002-2004. They also found a clear relation of Dam behavior and variations in water
40 volume also in a seasonal scale. Unfortunately during the period 2002-2004 had not
41 occurred any important seismic event in the area which could be recorded by the
42 geodetic measurements.

43 The present study is important, in that it provides that SAR interferometry can monitor
44 of an earth-dam behavior in this case Mornos dam as this structure is exposed in an area
45 of seismic hazard. The safety of infrastructures and the associated mitigating measures
46 requires a good knowledge of the causes of deformation. Future research should be
47 direct in using (very) high spatial and temporal resolution radar data, i.e. TerraSAR-X
48 or Cosmo Sky Med as well as to test more experimental interferometric processing.

49 Finally, the results of this case study certainly create the basis for further research with
50 the contribution of seismologists and engineering geologists in investigating queries
51 resulting such as why certain events have an effect and/or what are their characteristics.