Towards the understanding of Tropospheric Noise in InSAR data based on Combined GPS and Meteorological data

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Introduction – Research Concept

Analysis of Interferometric Aperture Radar (INSAR) satellite images is a relatively new technique very promising for the identification and modeling of ground motions like co-seismic motions, motions due to volcanic or tectonic activity and geotechnical phenomena. INSAR data are contaminated by noise mainly caused by humidity and other atmospheric effects, mainly tropospheric activity, along with local topography.

The PLATO project is jointly run by the University of Patras and Ecole Normale Superieure (ENS, Paris). Its main goal is the study of displacement time series produced by INSAR in combination with GNSS measurements and measurements from collocated meteorological stations in order to identify and model the noise affecting INSAR data.

Research Methodology

INSAR time series contain spatially correlated noise which is caused mainly by:

(i) atmospheric and ionospheric structures

(ii) water vapour

(ii) topography effects

The Covariance matrix characterizing the noise affecting a pair of points separated by distance r on an interferogram has the form:

$$C(r)=E[f(x)f(x+r)]$$

Where f(x) is the atmospheric noise at position (x) (Emardson, 2003; Lohman, 2004).

A well distributed GNSS network at the area of the INSAR image can provide constrains on the atmospheric noise.

The research methodology in the PLATON project consists of the following steps:

- Analysis of INSAR images from the area of the Patras Gulf and generation of displacement ment time-series of kinematics of Permanent Scatterers (PS) existing in the area
- Definition of atmospheric noise functions from a dense network of GNSS and meteorological stations in the same area
- Validation of atmospheric noise models using multiple collocated GNSS stations and meteorological data
- De-noising of INSAR images and direct comparison of GNSS displacement time-series with displacement time-series from INSAR.

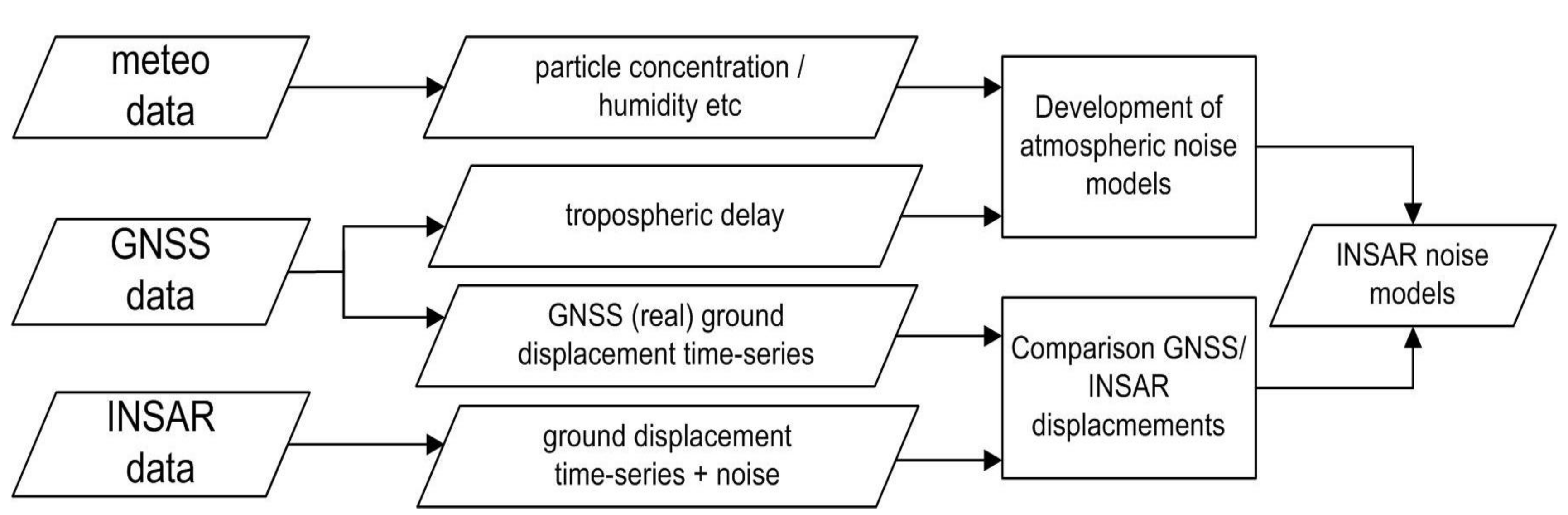


Figure 1. Methodology for assessing the noise characteristics and developing noise models for INSAR data based on constraints by GNSS and meteorological measurements

References

Emardson et al. (2003), Journal of Geoph Res 108(B5)

Elias et al. (2009), Sensors, 9(1), 46-55

Lohman (2004), Phd Thesis, Caltech

Mirault et al. (2008) GPS World, September 2008, 60-64

Abstract

An array of GPS/GNSS stations has been established in order to investigate the tropospheric, hydrological etc. bias in satellite positioning signals in various meteorological conditions. The study area is next to the Patraikos and Corinth Gulf (NW Peloponnese, Greece), which is characterized by a spatio-temporal sequences of hydro-atmospheric effects, from snow to sunshine, due to its particular geography and topography.

The idea is to analyze GNSS recordings from stations with very high vertical separation (with altitude up to 1600m and with a gradient of up to 20%) as well as collocated and nearby stations, so that there is some control in both the vertical and the horizontal variability of the atmospheric effects, and also a control in the noise of geodetic sensors.

Results from GPS data are planned to be combined with meteorological data, as well as satellite radar data, in order to evaluate tropospheric noise in INSAR.

This project takes advantage of GPS stations established in wider study area in the framework of the Corinth Rift Laboratory (http://crlab.eu/) and has been partly funded by the PLATO Project of the Greek Secretariat for Research and Technology.

Station Array/Studied Area

The project is implemented the wider area of the Patras Gulf (NW Peloponnese, Greece). This area combines vital characteristics for the purposes of the study. In particular:

- It has been intensively studied using INSAR images and as a result a large archive of high quality images along with results from permanent scatterers exist (Elias et al., 2009).
- 6 GNSS stations exist in the area, two of them with a separation ~700m. Stations are run by the Laboratory of Geodesy (Dept. of Civil Engineering, University of Patras), the Corinth Rift Laboratory (CRL), EUREF and the National Observatory of Athens (NOA) (**Figure 2**).
- 3 meteorological stations collocated with GNSS and INSAR permanent scatterers maintained by the National Observatory of Athens and the Laboratory of Environmental Engineering Laboratory (Dept. of Civil Engineering, University of Patras) exist in the area (**Figure 2**).
- The topography of the studied area combines shallow relief near the coast with high altitudes close to 2000m (top of the Panachaicon mountain) (**Figure 3**)
- The study area is affected by a wide variety of meteorological phenomena ranging from high humidity and rainfall close to the city of Patras to heavy snowfalls at the top of the Panachaicon mountain (**Figure 3**).

Figure 2. The study area with the array of GNSS and meteorological stations

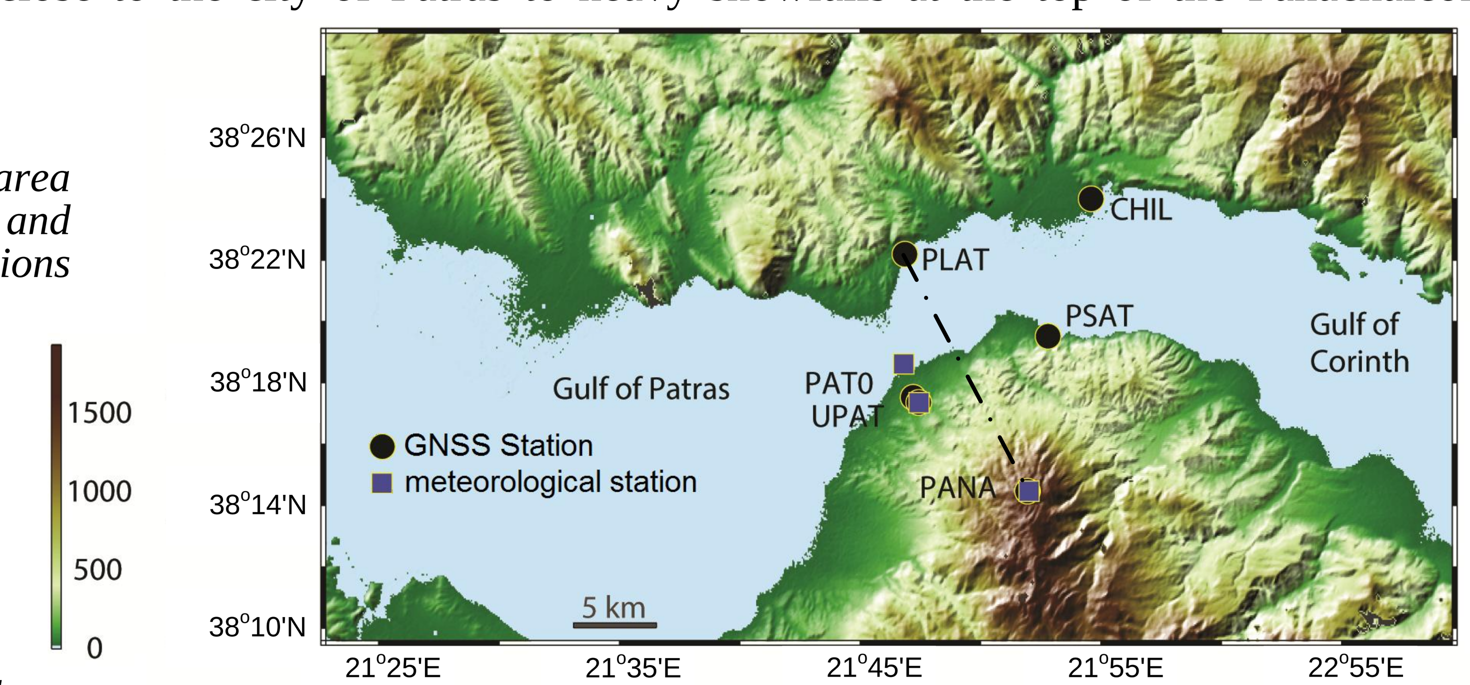
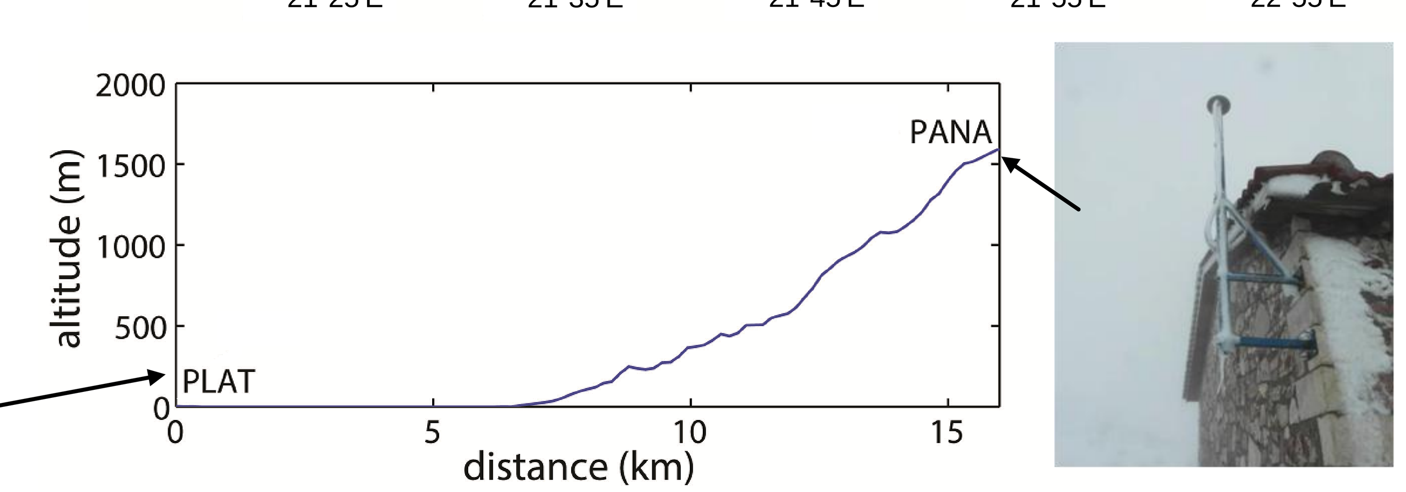


Figure 3. Vertical profile of the studied area



Dust outbreak over Greece – preliminary results

During the first days of February 2015 an outbreak of Saharan dust has largely affected the Eastern Mediterranean (**Figure 4**) by transporting large amount of mineral particles into the atmosphere. Several areas in Greece have been largely affected including the study area (Gulf of Patras - **Figure 5a**). Time series of Zenith Tropospheric delay were calculated from three GNSS stations in the Patras Gulf (two of them -UPAT and PAT0 separated by ~700m distance) equally affected by the dust outbreak (**Figure 5b**). Zenith Tropospheric Delay was calculated using GNSS measurements sampled at a 30sec rate using the PPP method implemented by the CSRS (Natural Resources of Canada) online service (Mirault et al., 2008).

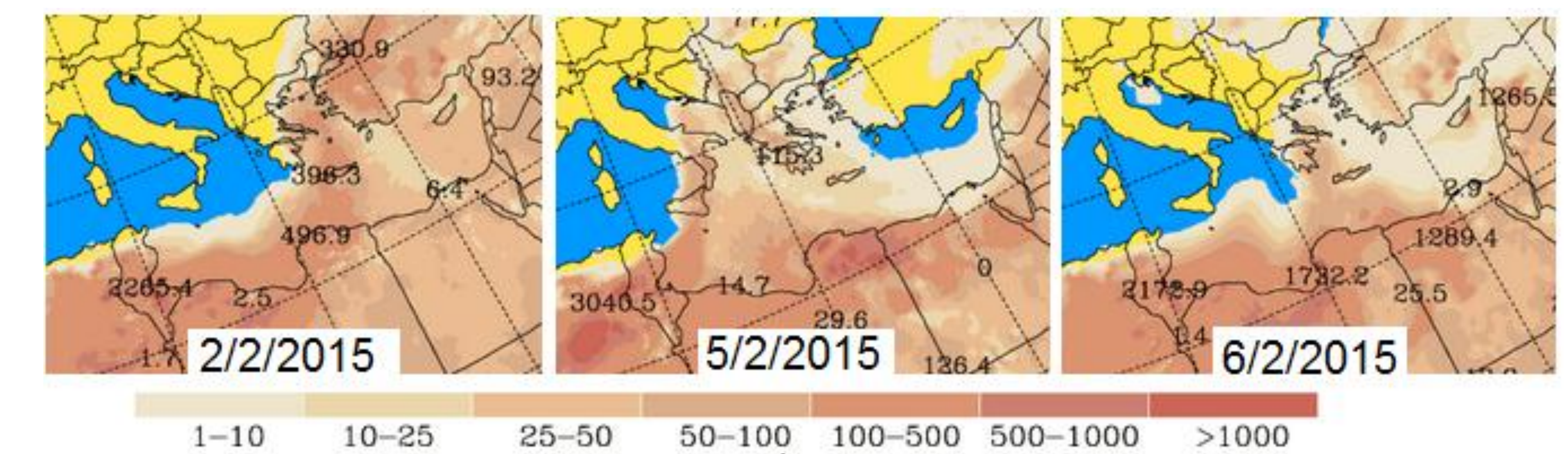


Figure 4. Dust concentration over Greece (ugr/m^3) for three days in February 2015 characterized by high dust concentration (source: University of Athens Skiron Forecast)

Results are preliminary; yet they indicate a good correlation between the stations showing an increase in the Tropospheric Zenith Delay (TZD) during the dust outbreak. The last provide evidence that atmospheric activity may be well mapped through a dense GNSS network and provide corrections for INSAR data.

a.

b.

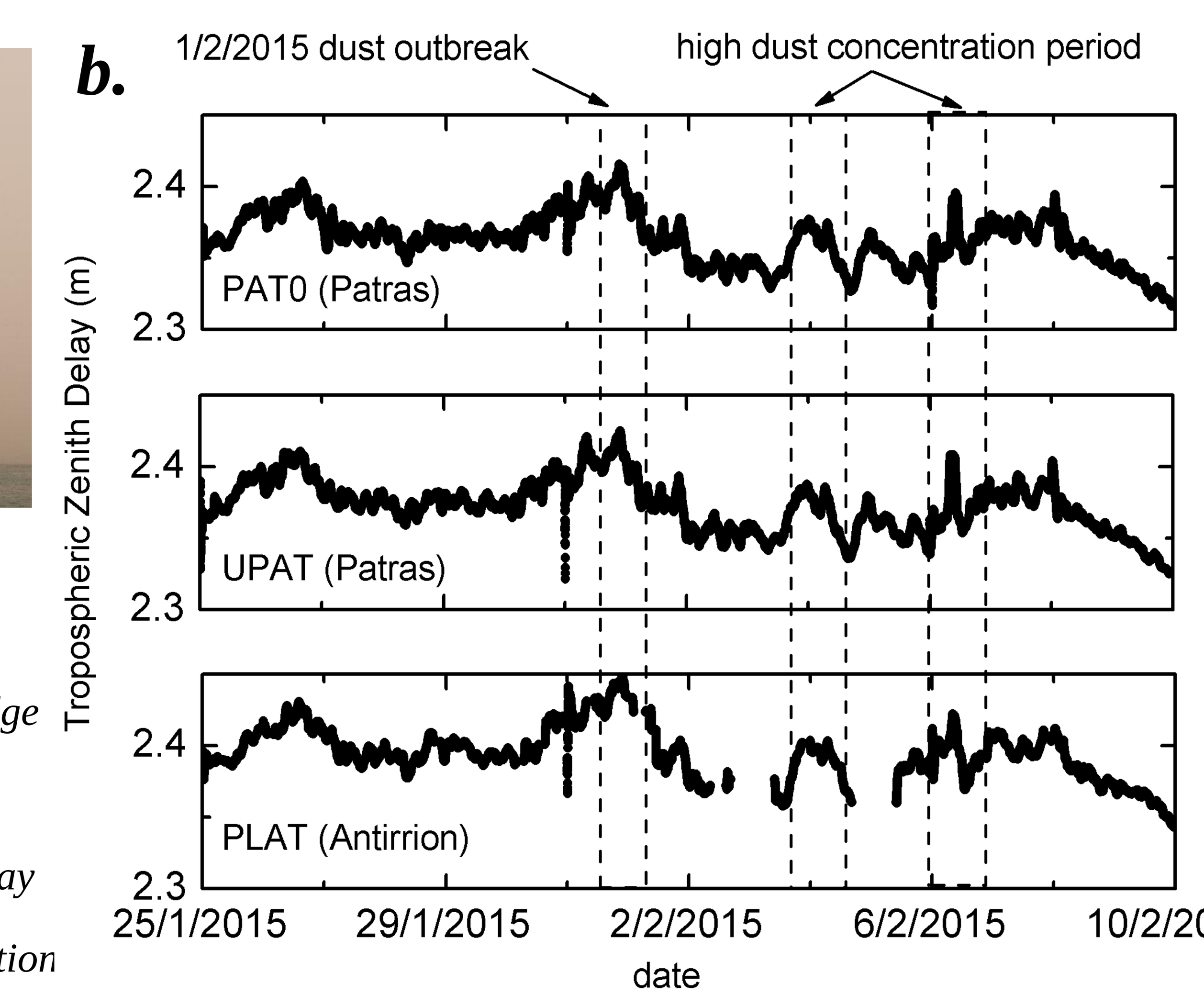


Figure 5.
a. Picture of the Rion-Antirrion Patras bridge during the February 2015 dust outbreak

b. Zenith Tropospheric delay computed from three permanent GNSS station in the Gulf of Patras.

Aknowledgements

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