Sentinel-1 PSI Analysis of Greater Budapest Region, Hungary

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Introduction

In this study, we present the first Sentinel-1 Persistent Scatterer Interferometry (PSI) results for Budapest and its surroundings. We discuss its quality to assess Sentinel-1 performance regarding current velocity precision, point number and distribution, and present a case study together with an extensive ground based validation and comparison to results from earlier ESA sensors.

Method

The processed data consists of 4 full bursts of the same sub-swath, covering nearly 7000 km^2. Multilooking is done by factors of 10 and 2 in azimuth and range directions, respectively. The persistent scatterer processing is entirely done by the Gamma software from Single Look Complex (SLC) data to displacement time series, using the IPTA module and a single master approach (Werner et al. 2000, Wegmüller et al. 2004). The dataset consists of all 80 descending images acquired by the Sentinel-1A and 1B satellites between October 2014 and April 2017.

For the IPTA a point list with more than 1.5 million points was determined based on averaged spectral diversity and backscatter variability. To make the processing more efficient, a smaller list was used to determine the main phase terms, including atmosphere, height correction, orbital corrections and linear deformation rates. After several iterations, these were expanded to the large list and iterated again to reach the desired quality. The final solution (Fig. 1) has 1 432 547 PSI points in the area, that was reduced to 1 353 915 with a single point temporal coherence threshold of 0.65 to remove some outliers.

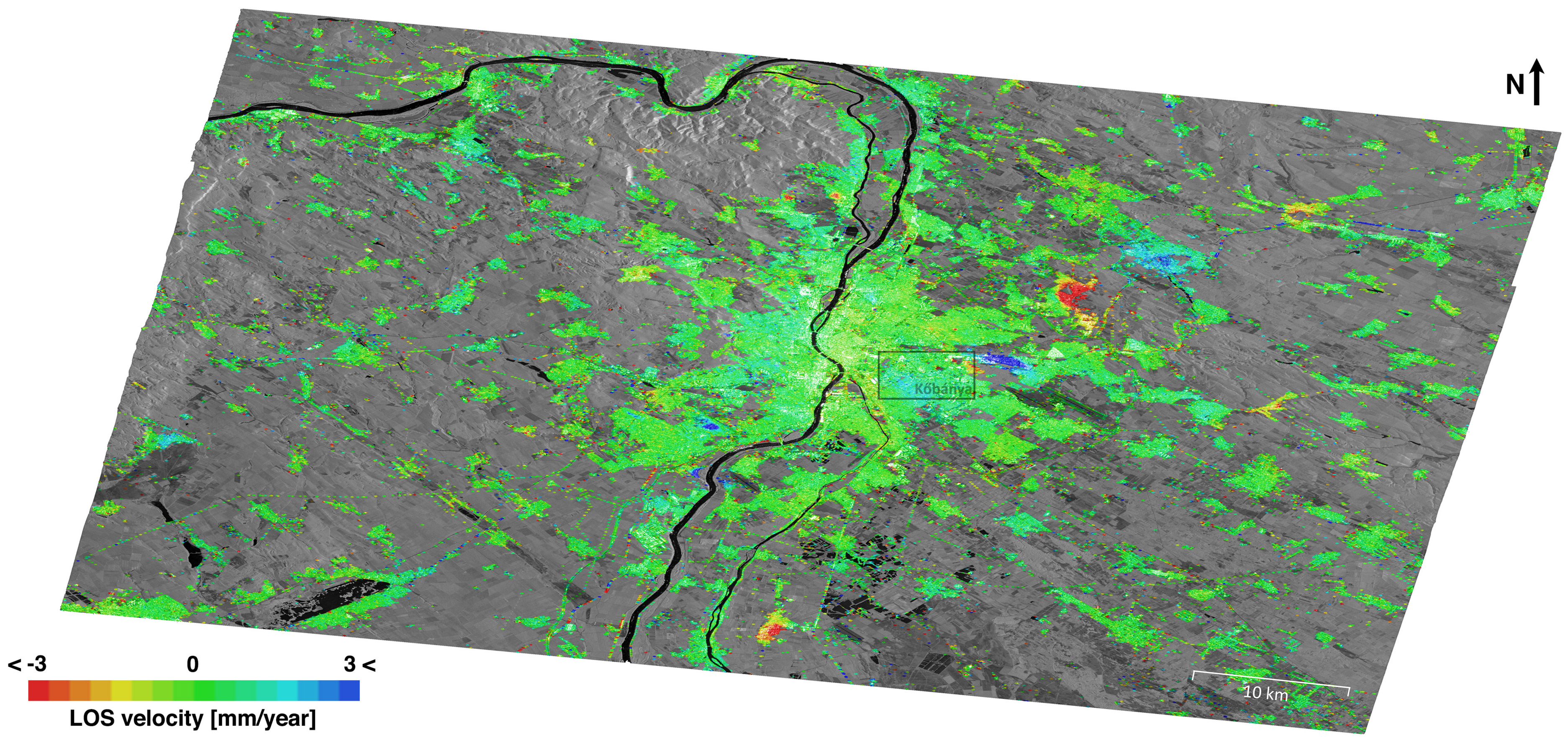

Fig. 1 Velocity map of Budapest and its surroundings determined by IPTA method based on all 80 descending Sentinel-1 observations from October 2014 to April 2017. Kőbánya area is marked with a rectangle.

Quality assessment

There are no overall spatial trends that can be observed in the linear deformation rate, values are around 0 for much of the area. Errors related to atmosphere increases with distance from the reference point to values around 1.5 mm/year. The atmospheric phase contains a small (max. 1-2 mm/yr) deformation component that is starting from zero near reference point and increasing mainly with distance from it, but also shows some other patterns.

Spatial coverage is almost complete, solution retrieved for almost all villages and along some linear infrastructures as well.

The height correction has pointwise corrections of up to 20 m, that is the effect of the difference between height of different scatterers (e.g. building height) and the SRTM height that has been used as a reference (Jarvis et al. 2008). The error of the height correction is below 3 m for the majority of points. This is quite high compared to ERS/Envisat stacks, despite the large stack that has been used. This is explained by the small baselines of Sentinel-1 observations that result in a relatively low height sensitivity.

We can also assess the quality of the determined solution statistically, by calculating unweighted linear regression for the time series of each PS and investigate its standard deviation. The sizes of the 95% confidence interval for most points are below 1 mm/yr at 0.65 coherence level (Fig. 2).

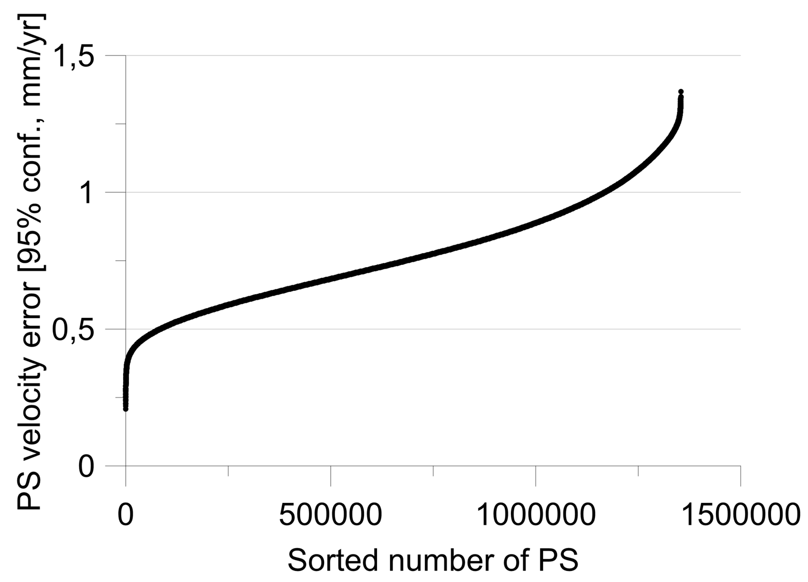

Fig. 2 Calculated size of 95% confidence interval of unweighted linear regression for each PS in the final solution with a coherence over 0.65.

Validation

The largest anomaly known to-date located at Kőbánya district of Budapest. Extensive data available for the area as the anomaly was detected, validated and tracked by several earlier levelling surveys, GPS measurements as well as earlier InSAR observations (e.g. Grenerczy et al. 2008, 2010). These show a ~36 km^2 uplift in the previous decades with velocities reaching 1 cm/yr in its center (Fig. 3, left).

Ground based validation surveys along the existing line show that high precision levellings and velocities of ERS/Envisat have very similar trends. The general magnitude difference is most probably due to the fact that levelling looks 13 year longer to the past including data of less water table increase.

The recent surveys of a shorter section in 2014/2015 and 2017 cover nearly the same time period as S1. Velocities are similar to PSI at most locations, though higher differences reaching about 1 mm/yr are present at some points. These could be explained - beside the uncertainty of both datasets - by the self-movement of that particular building holding the benchmark compared to the the selected neighboring PSs for collocation.

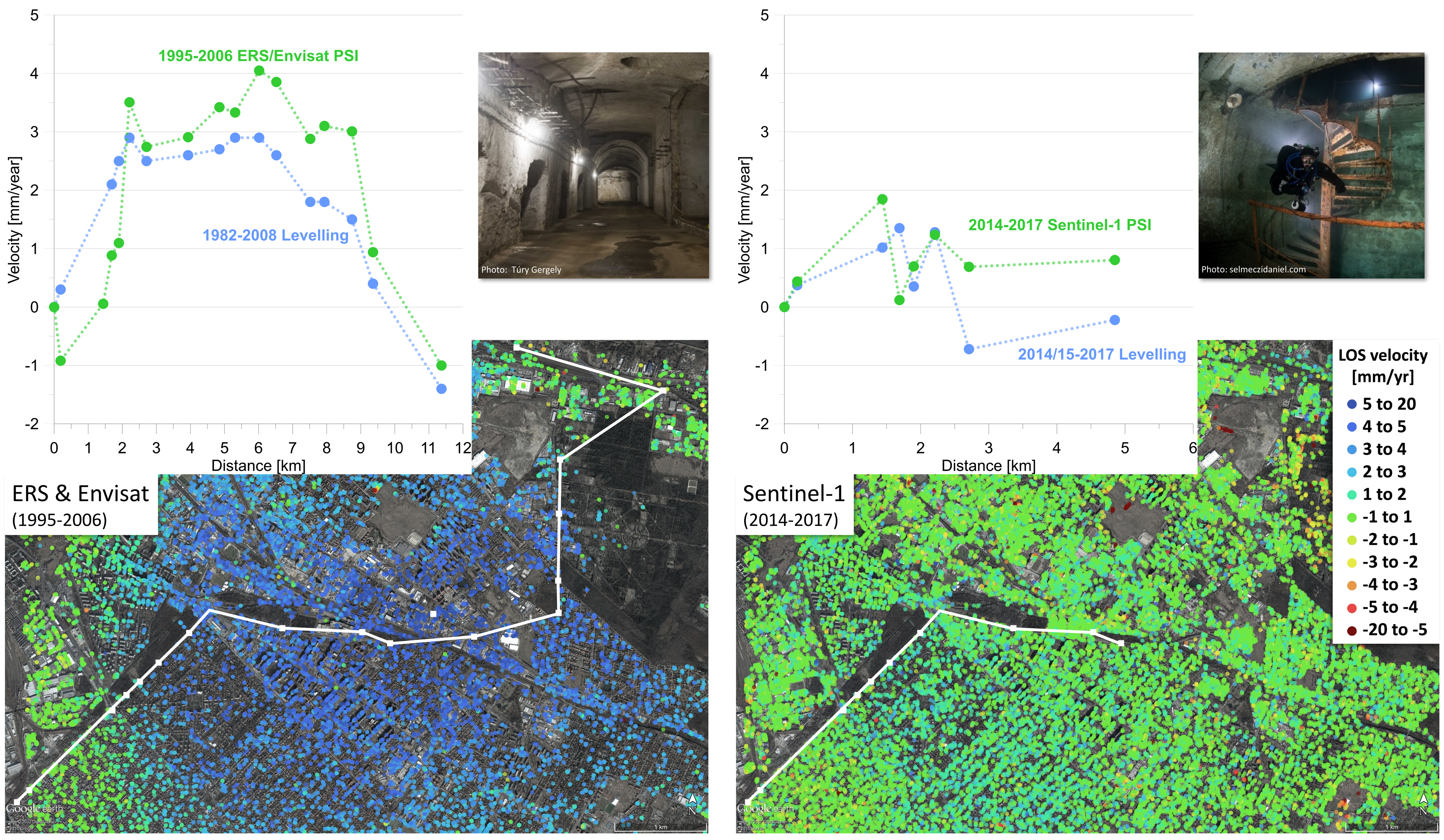

Fig. 3 LOS velocity maps of Kőbánya region based on ERS and Envisat (left) and Sentinel-1 data (right), displayed with the same color scale. Levelling lines and points are indicated with white. Top: vertical velocities of levelling points along the indicated lines, starting from the southwestern point, determined by levelling campaigns and unweighted averages of the nearest PSs, assuming that there are no horizontal velocity components.

Conclusion

All Sentinel-1AB descending data were IPTA processed for a 6900 km^2 area around Budapest. Velocities of 1 432 547 point targets have been determined based on 80 observations over 2.5 years. Average 95% confidence interval of unweighted linear regression for all point targets is 0.9 mm/yr. The Sentinel-1 PSI dataset can be validated using high precision leveling surveys as well as GPS, because both networks with earlier survey results are available for nearly the same time interval. The largest anomaly in Budapest, the Kőbánya uplift was analyzed based on more than two decades of data, using earlier ERS-1, ERS-2, Envisat sensors, Sentinel-1 and ground based high precision levellings. Generally, Sentinel-1 provided 77 % more PSI targets than obtained for the previous ESA sensors. Ground based validation proved Sentinel-1 velocities are reliable. Sentinel-1 results as well as leveling surveys show 1-2 mm/yr uplift remaining only at the SW parts of the Kőbánya anomaly. The extensive uplift reaching 10 mm/yr has stabilized as the increase of water table is most probably slowed down.

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