PRECISE GEOLOCATION OF PERSISTENT SCATTERERS AIDED AND VALIDATED BY A LIDAR DSM

Ling Chang, Prabu Dheenathayalan and Ramon Hanssen
Email: l.chang@tudelft.nl

1. INTRODUCTION

Precise geolocation of Persistent Scatterers (PS) is of the greatest importance to avoid an improper interpretation of the targets. Due to the inaccuracies in the satellite orbits, instruments, atmospheric delay or improper interpolation, the precision of absolute 3D geolocalization can be in the order of several meters. Proper interpretation often requires sub-meter precision. Here we optimized the geolocation of PS using a Lidar-derived DSM (Digital Surface Model), and implemented our approach on Heerlen, the Netherlands using ERS-1/2, Envisat and Radarsat-2 data. This allowed us to interpret the driving mechanism for a near-collapse event in a shopping mall in this region.

2. REVIEW OF GEOCODING

Geocoding is applied to convert the radar coordinates to geocoded coordinates in a unified geodetic reference system. After the final detection of PS in the radar image coordinates and the parameter estimation, the three dimensional position—azimuth, range, and relative height of PS points—needs to be converted to the WGS84 reference system, which can be solved by using a set of Doppler, Range and ellipsoid equations [1]. As PS heights are intrinsically relative heights w.r.t a reference PS point, they need to be converted to absolute coordinates in the WGS84 reference system. The absolute ellipsoidal height H_i is expressed as a function of orthometric height of the reference point scatterer, geoid height at that location, and height difference between point i and reference PS point 0

$$H_i = h_0 + N_0 + \Delta H_{i0}$$

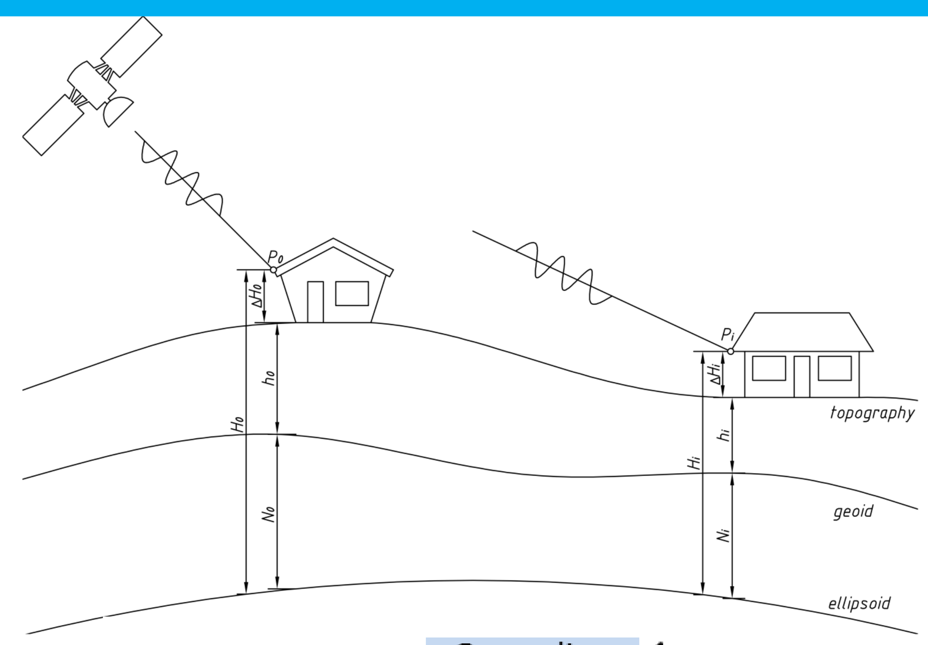


Fig1. Relationships between reference surfaces: topography, geoid and ellipsoid with two points P_0, P_i.
- Geoid undulation *N:* height of the geoid above the WGS84 ellipsoid
- Orthometric height *h*, height of the point above the geoid
- Object height ΔH which refers to the surface

3. HEIGHT ERROR PROPAGATION

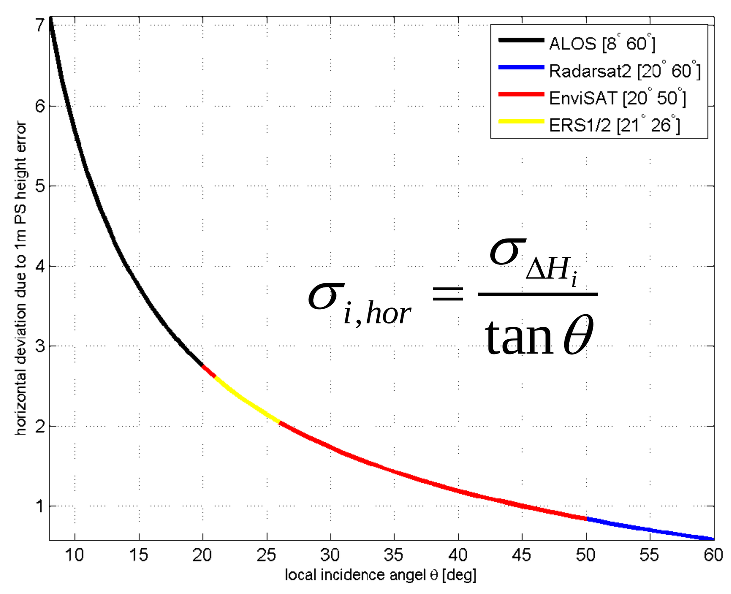


Fig2. Horizontal deviation due to PS height estimation error of 1m for ALOS, Radarsat-2, Envisat and ERS-1/2. For most sensors the horizontal shift is 1.5-3 times the vertical error.

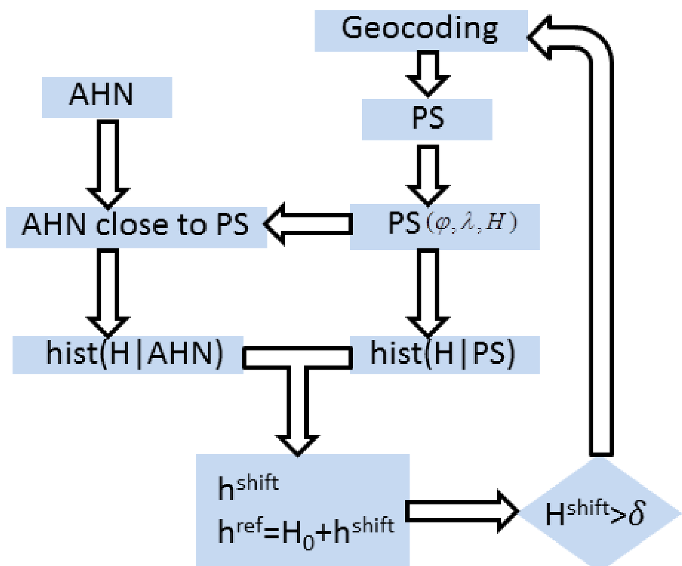


Fig3. Processing flowchart

4. GEOCODING AIDED A LIDAR DSM

In the Netherlands, detailed height measurements were carried out using laser altimetry between 1997 and 2007, resulting in the *Actual Height model Netherlands* (AHN-1). The vertical resolution is 15cm, and horizontal resolution is 5m. An intermediate product retained the heights of buildings. We used this to correct the estimated PS geolocalization by computing the offset between both height distribution histograms (see Fig.3).

$$E\{\underline{H}_i^{PS} - \underline{H}_i^{AHN}\} = h^{shift}$$

5. HEERLEN CASE STUDY

We focus on a case study over Heerlen, the Netherlands using 69 ERS-1/2, 71 Envisat, and 20 Radarsat-2 images (descending) acquired between April 1992 and October 2011, with emphasis on the dynamic interpretation of a near-collapsed shopping mall ('t Loon) [2].

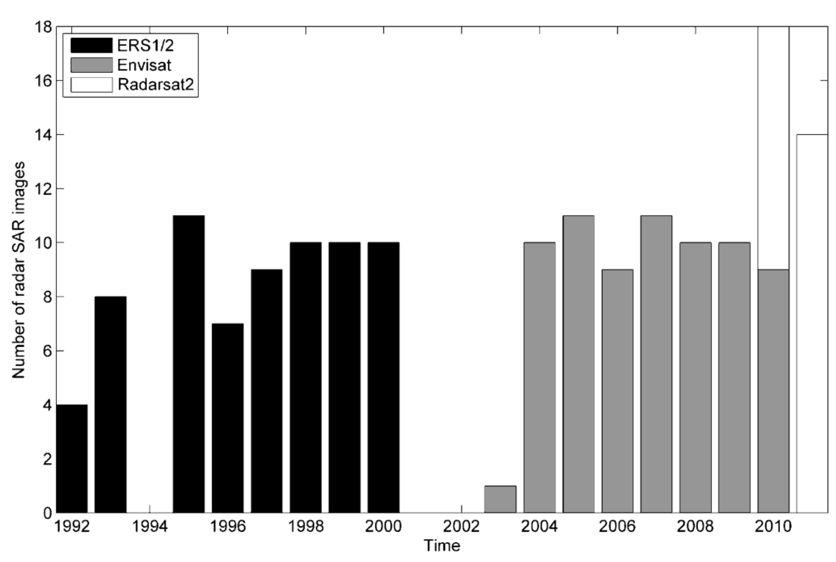


Fig4. Available SAR images during 1992 and 2011.

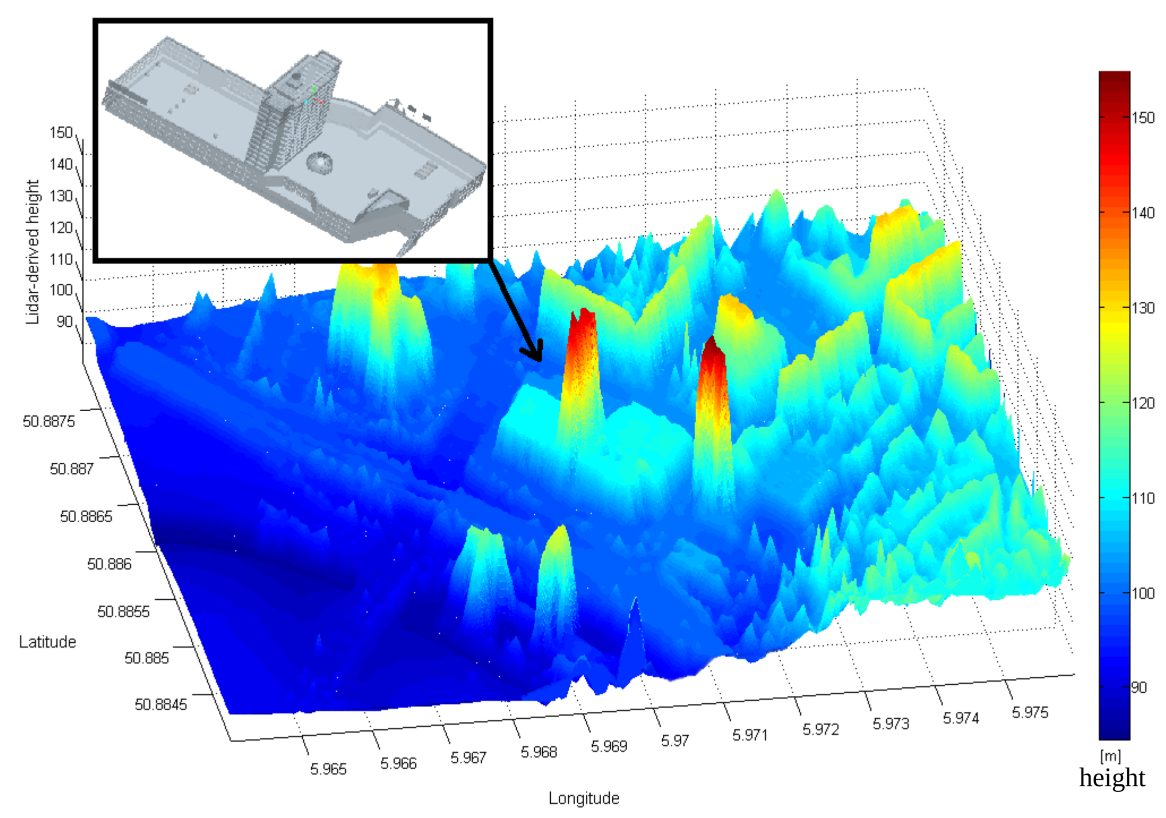


Fig5. Lidar-derived (AHN-1) height map over the area, interpolated from 5 to 0.5 m resolution. Shopping mall 't Loon (3D model inset) is indicated by the black arrow. Note that the high-rise apartment of 't Loon is smoothed by the interpolation.

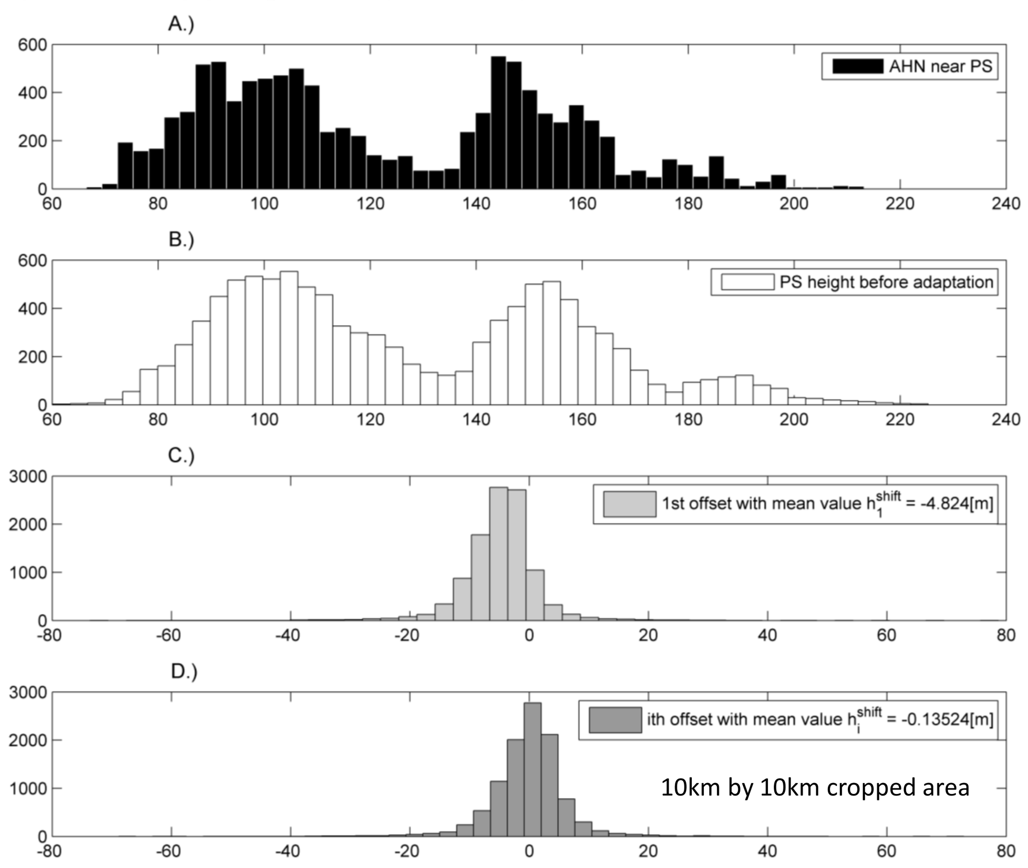


Fig7. A.) Height distribution of Lidar points closest to PS points (<5m). B.) Original distribution of PS height. C.) height difference distribution between Lidar and PS, yielding an initial offset value of -4.824m. This yields new horizontal positions of the PS. D.) Final offset after the iterative estimation. The iteration will continue until the offset value is below AHN vertical resolution (15cm).

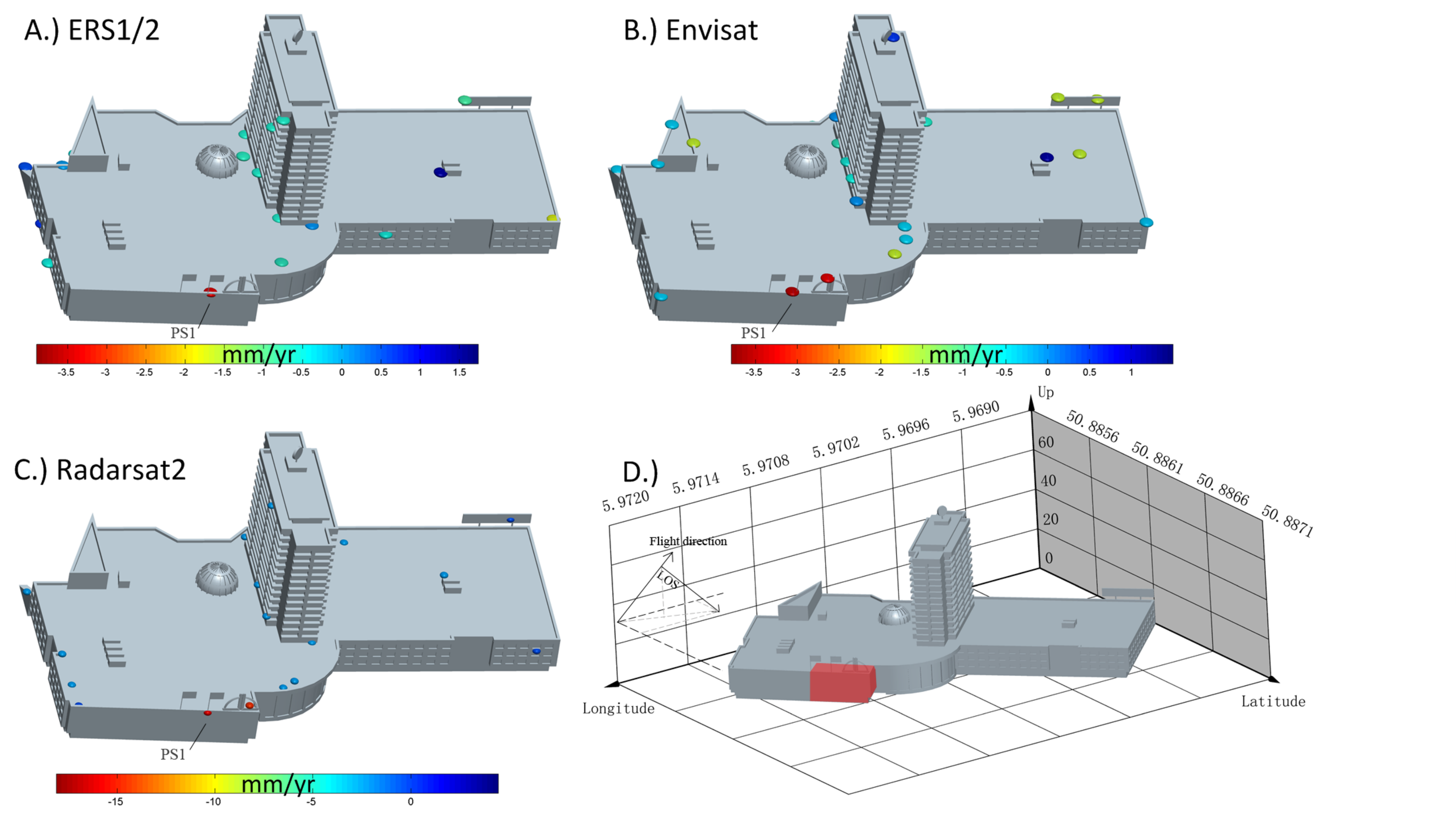
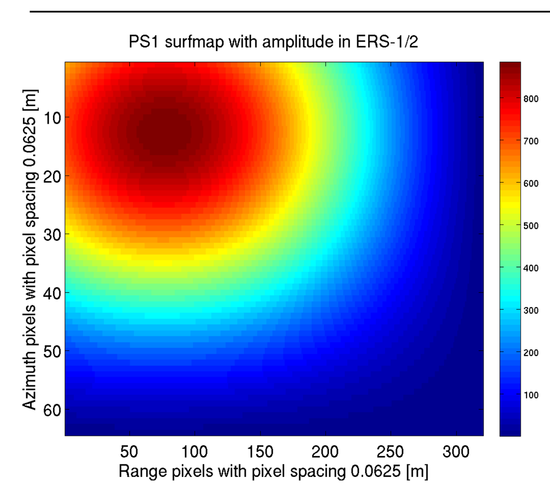
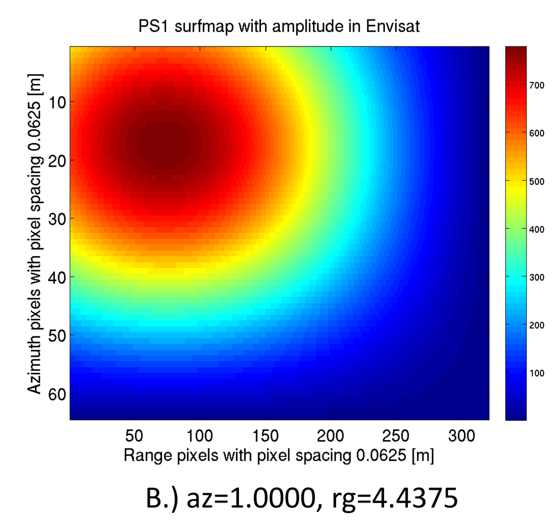


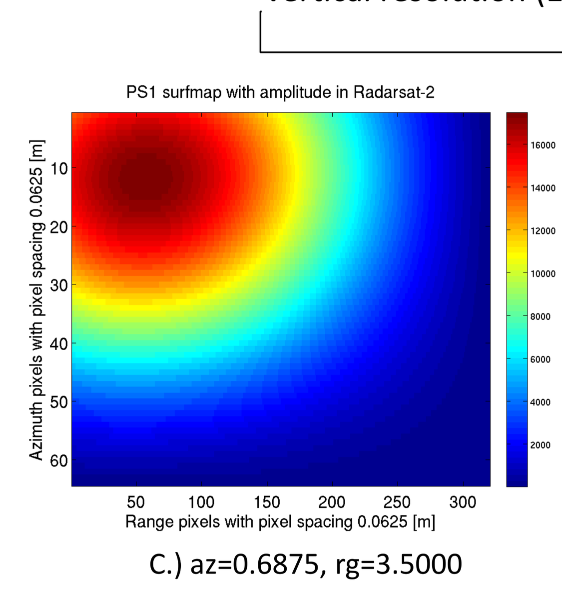
Fig8. Improved PS location and vertical velocity map using histogram matching with Lidar DSM data. The subfigures A, B and C show the results derived from ERS-1/2, Envisat and Radarsat-2, respectively. Colour represents vertical deformation rates (mm/yr) of those PS points located on the building. Subfigure D shows the orientation of the building with the near-collapsed part indicated in red. This proves that we observe structural deformation of the building (in stead of the subsidence of the ground), many years before the near collapse.



A.) az=0.6875, rg=4.7500



B.) az=1.0000, rg=4.4375



C.) az=0.6875, rg=3.5000

Fig6. Sub-pixel position correction for PS1 (see Fig.8) with the offset az [m] in azimuth and rg [m] in range w.r.t its upper-left corner, by mean of oversampling method by factors [32,160].

6. CONCLUSIONS

In this study, we considered the error sources and propagation in the Geocoding/PS geolocation. Using a Lidar 15cm precision DSM, we improved vertical absolute positioning to about ~14cm precision, yielding a horizontal absolute precision of ~0.32m. The influence of the sub-pixel position adds an uncertainty of ~6m and ~1m horizontally, east and north respectively, and ~2m vertically. Combined, this yields ~2m vertical precision, ~6m horizontal precision (east) and ~1m horizontal precision (north). To pinpoint PS to infrastructure, we conclude that both sub-pixel positioning as well as DSM improvement are absolutely required, but may still be insufficient for medium resolution SAR systems.

REFERENCES:

[1] D. Geudtner and M. Schwabisch, *An algorithm for precise reconstruction of InSAR imaging geometry: Application to "flat earth" phase removal, phase-to-height conversion, and geocoding of InSAR-derived DEMs*, European Conference on Synthetic Aperture Radar, Konigswinter, Germany, 26–28 March 1996, Konogswinter, Germany, 1996.

[2] Ling Chang and Ramon Hanssen, *Near real-time, semi-recursive, deformation monitoring of infrastructure using satellite radar interferometry*, Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International, pages1876-1879, 2012

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