ATMOSPHERIC DELAY ANALYSIS FROM GPS AND INSAR

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ABSTRACT

In the paper we proposed a comparison methodology between GPS delay and SAR Atmospheric Phase Screen (APS) in both differential and pseudo-absolute mode. ENVISAT ASAR and synchronous GPS campaign data in Como, Italy were collected and processed. APS from PSInSAR has been divided into even groups according to their height for analysis of stratification sensitivity. Then the stratification and assumed turbulent terms from SAR APS and GPS were compared. The stratified ratio from GPS and SAR APS in differential mode is in agreement of 7.7 mm/km with bias of 3.4 mm/km, with a correlation coefficient higher than 0.7 in the ascending case. The atmospheric total delay coincides with STD of differences smaller than 4 mm (~ 0.65 mm PWV) with correlation coefficients higher than 0.6. The results predicted the extent on which atmospheric measurements from GPS and InSAR are comparable.

Index Terms— GPS, InSAR, APS, Atmospheric delay

1. INTRODUCTION

Decorrelation and artificial phase on Satellite SAR interferometry (InSAR) due to inhomogeneity of atmospheric compositions, especially water vapour, is a critical limitation for high accuracy earth surface measurements retrieving in geophysical studies [1]. Besides filtering of atmospheric noise with enormous amount of data set [2], calibration of such noise with meteorological measurements retrieved from GPS regional network, as declared with precision of millimeter level, have been widely used as complementary way in InSAR applications. Several case studies in last decade introduce how GPS derived Zenith Wet Delay (ZWD) or Precipitable Water Vapour (PWV) be employed in atmospheric calibration in InSAR. Williams et al. assessed this possibility using Southern California Integrated GPS Network (SCIGN) data [3]. Wadge et al. performed a comparison between GPS-derived zenith delays estimated from a 14 station continuous GPS (CGPS) network and InSAR measurements over Mt. Etna, the result shows that the equivalent values of InSAR-GPS gave an RMS value of 19 mm with a mean of +12 mm [4]. The main drawback of this study as well as subsequent comparison results between GPS and InSAR lies in two aspects: 1) atmospheric phases in InSAR are always not sufficiently accurate and reliable, and 2) the comparison methodology is only simplified and related effect (e.g. stratification) are less considered. Therefore, with the motivation of making up the deficiency of previous studies and better understanding how useful GPS atmospheric retrievals meet requirements of InSAR atmospheric correction, in this paper we at first time proposed a comprehensive methodology of comparison and performed elaborate experiment with more than 60 SAR Atmospheric Phase Screen (APS) maps as well as high-precision data from co-located GPS Campaign for agreement study of atmospheric measurements between GPS and InSAR

2. EXPERIMENTAL SCHEME AND DATA SET

In order to quantitatively analysis how much the two dataset agree with each other, we in this paper schemed an experiment of intercomparison between GPS Zenith delay and InSAR atmospheric phase. The data acquisition for this experiment is supported as one part of METWAVE project funded by ESA. In the experiment, SAR time series imagery and GPS observations from GPS campaign have been partially synchronous collected in COMO, Lombardy, at the north of Italy.

The ENVISAT ASAR images were acquired from ESA in two selected tracks, ascending track 487 and descending track 480. The spatial coverage of two tracks is shown in Figure 1. Totally 38 ascending and 28 descending ENVISAT ASAR imagery during the period 2003-2008 are preferred as interferometric analysis and selected. APS for each SAR are estimated by PS-InSAR technique with Matlab tool 'SAR PROZ' [5][6].

GPS data are collected in the GPS campaign in Como, where a local GPS network was set up for this project. Fig. 1 sketches the location and distribution of Eight GPS stations in COMO. Hourly GPS Zenith delays are processed from phase observations with precise IGS orbits and BERNESE by POLIMI DIIAR group.

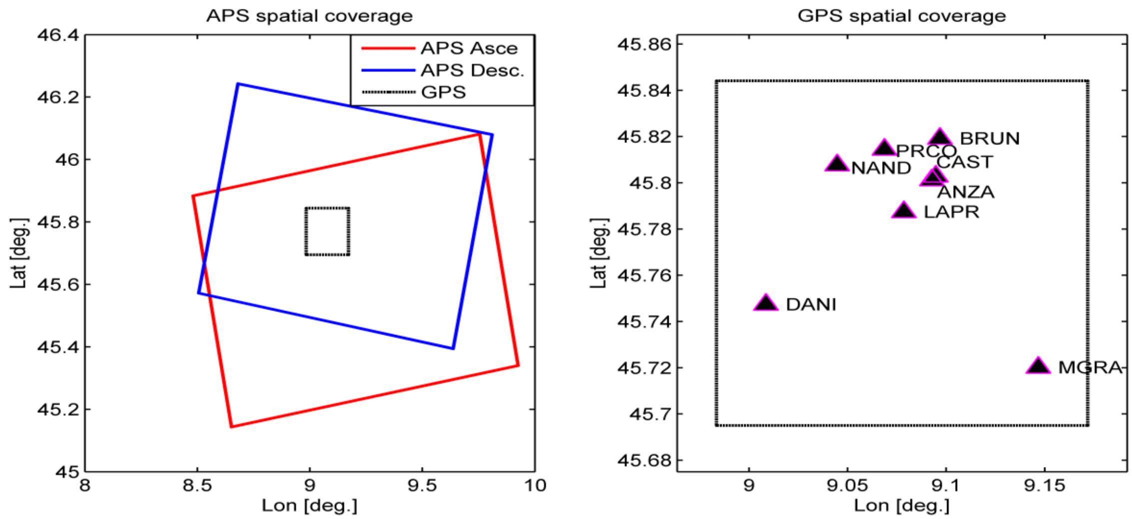

Figure 1 Map of SAR imagery and GPS data. Left: Red and blue rectangular box give the spatial coverage of SAR imagery for ascending and descending tracks respectively. Right: locations of GPS Stations in COMO, Italy, which are marked with blank triangular with an outer boundary given in black rectangular box.

3. INTERCOMPARISON METHODOLOGY

With a following theoretical model, atmospheric signal in APS can be regarded as the composition of four parts: spatial linear plane, mixing turbulence, height dependent stratification and ground feature related term [7].

$$\begin{aligned}\alpha_i(x,y) &= a_i + b_i x + c_i y + \varepsilon_i(x,y) \\ &\quad + k_i \cdot h(x,y) + w_i \cdot z(x,y)\end{aligned} \tag{1}$$

In equation (1), $a_i + b_i x + c_i y$ is a spatial bi-linear plane due to satellite orbit inaccuracy; $\varepsilon_i(x,y)$ is turbulence term. The last part $w_i \cdot z(x,y)$ stands for the ground feature related term, e.g. the land cover.

SAR APS derived from PS-InSAR are differential values relative to master reference, while zenith delays derived from GPS are spatially and temporally absolute values. In order to get comparable atmospheric quantities, we either transform GPS into differential values or make SAR APS into absolute values, and then compare them in corresponding two modes: differential and absolute pseudo mode.

The differential mode of comparison was implemented by subtracting GPS ZTD at APS master time from original GPS delays. If original APS master was not covered by GPS data series, then a differential operation between corresponding pair in SAR (temporally to GPS) was required. The differential operation cancels out the common unknown master delay. The general realization of absolute comparison is to estimate the SAR Master APS from GPS time series and then to compensate all SAR APS for such master delay with approximately estimated ones. The first implementation is to estimate the SAR atmospheric delay of master time as average of all GPS temporal series data. The second one is extracting GPS ascending and descending time series according to their passing time, and then to estimate the master delay with average of synchronous GPS temporal series.

4. HEIGHT SENSITIVE STRATIFICATION

When atmospheric delay caused by spatial linear trend, stratification and turbulence are mixed together, the reliable stratification can not be directly estimated from APS. In order to analysis stratification effect from derived SAR APS with least error, in this section, we employ some tips as following: 1) Firstly we divided SAR APS into even groups acoording to APS height with step of 160m for ascending and 100m for descending; 2) and then we calculate the mean vlalue and STandard Deviation (ATD) of APS within each group; 3) At the third, we regard the high STD at smaller APS height due to spatial linear trend and mixing turbulence, whire dominate at lower surface as 'Head effect' error, and regards the small number samples under higher APS height as 'Tail effect' error of stratification analysis; 4) After removal the 'Head effect' and 'Tail effect' error, we regressed the Phase to Height ratio (or stratified slope) from mean values of grouped APS and average of grouped APS height.

5. COMPARISON RESULTS AND CONCLUSION

In the last section, we analyzed the height sensitive stratification slope under mixture of all terms, following figure 2 illustrate the comparable stratification slopes from GPS and SAR APS.

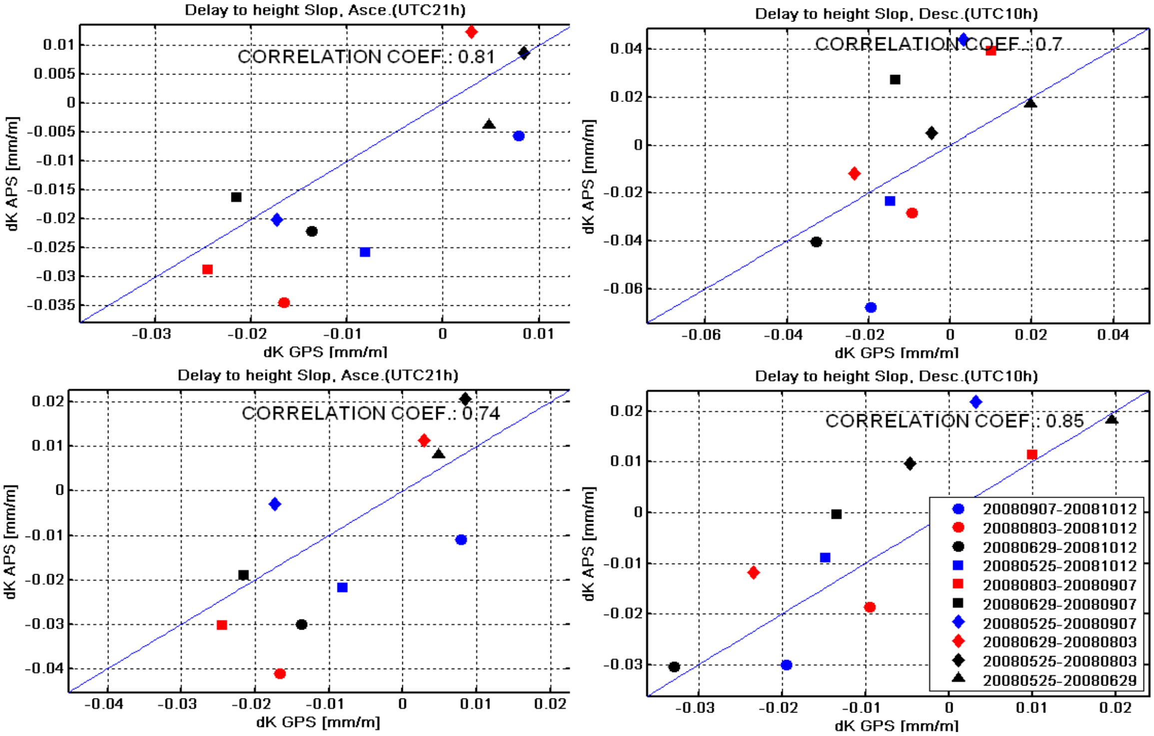

Figure 2 Cross plot and correlation coefficient of estimated stratified slope between delay from original GPS ZWD and from original SAR APS. Upper: stratified slope are estimated from original SAR APS, as illustrated in section 4. (Left) ascending and (Right) descending pass. Lower: stratified slope are estimated from interpolated SAR APS points which are overlapped with GPS stations. (Left) ascending and (Right) descending. Unit of stratified slope is mm/m.

Table 1 Statistics of differential comparison between GPS and SAR APS

Total delay (10 Pairs)	Ascending				Descending			
	STD GPS	STD APS	STD Diff.	Corr. Coef	STD GPS	STD APS	STD Diff.	Corr. Coef
	3.02	5.44	3.99	0.69	3.58	3.86	3.16	0.64

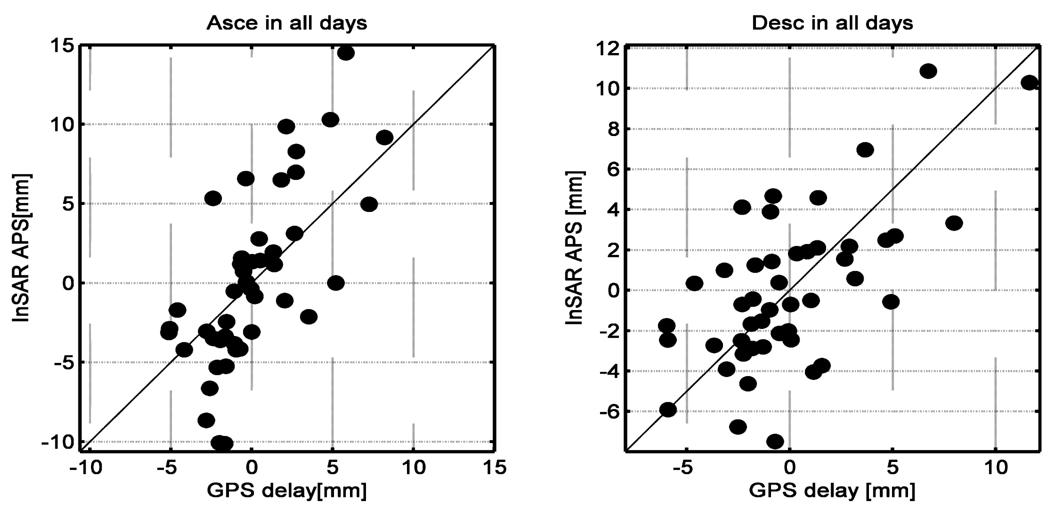

Figure 3 Cross Plot of zenieth atmospheric delay (total delay) between GPS and SAR on all temporal pairs in differential comparison. (Left): ascending track. (Right): descending track. Individual spatial average on available overlapped stations for both dataset is removed for comparative demonstration.

Then we compared the atmospheric total delay and turbulence delay in both differential mode as well as pseudo absolute mode. Figure 3 illustrates the total delay between GPS and SAR APS in differential mode. From statistics of 40 scatter points of 10 pairs, we get STD of APS and also STD of difference referring to table 1.

The comparison results in our study show that, the height stratified slope of delay from GPS and from SAR APS, as well as that from interpolated points of SAR APS maps agreed well with STD of 10 mm/km with correlation coefficients higher than 0.7 in both ascending and descending cases. The atmospheric total delay in differential mode between GPS and SAR APS coincide with STD of difference smaller than 4 mm (~ 0.6 mm PWV) and with correlation coefficients higher than 0.6. Above comparison results provided in this paper prove the first founding that atmospheric measurements from GPS and SAR APS are comparable. A second significant founding is that it is possible to restrain atmospheric noises in SAR interferometry with high precision GPS meteorological products, which are direct evidenced by that STD of delay difference (between GPS and SAR APS) are mostly slightly smaller than STD of SAR APS itself in both comparison modes.

6. ACKNOWLEDGEMENT

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