Approaches to mitigate atmosphere artifacts in SAR interferograms: GPS vs. WRF model

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GPS data analysis

Weather Research & Forecasting (WRF) Model

InSAR data

Results (GPS vs WRF, GPS and WRF vs InSAR)

Conclusions
GPS network over Lisbon region

![Map of GPS network over Lisbon region](image)
The GPS network consists in 12 stations. All stations were installed between 1997 and the early 2009.

The Total Zenith Delay (TZD) was estimated by means of GAMIT software (v10.34).

The wet zenith delay for each station are modeled by a piecewise-linear function over the span of the observations.

The IGS precise orbits were used in solution and the cut-off angle chosen for the GPS data was 20°.

For each site the tropospheric TZD was determined at each GPS site every 15 min.
Weather Research and Forecasting Model (WRF-ARW), version 3

Setup:

1. Four two-way nested domain at 27×27, 9×9, 3×3 and 1×1 km horizontal grid resolutions.

2. Top atmosphere located at 10 hPa level

3. 50 vertical levels

4. Lowest model layer 40m thick.

<table>
<thead>
<tr>
<th>Grid</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>27×27 km</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>9×9 km</td>
<td>50 layers</td>
</tr>
<tr>
<td>III</td>
<td>3×3 km</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>1×1 km</td>
<td></td>
</tr>
</tbody>
</table>

✓ Initial and time-dependent boundary conditions derived from the European Centre for the Medium range Weather Forecasting (ECMWF) high resolution analysis.

✓ Simulations referred to the 12 hours preceding each SAR image acquisition.
The atmospheric refractivity $N$ is computed as

$$N = N_{dry} + N_{wet} = k_1 \cdot \frac{P}{T} + e \cdot \left( k_2' + \frac{k_3}{T} \right)$$

The following values were used for the constants

$$k_1 = 77.6 \text{ K} \cdot \text{hPa}^{-1}$$
$$k_2' = 23.3 \text{ K} \cdot \text{hPa}^{-1}$$
$$k_3 = 3.75 \cdot 10^{-5} \text{ K}^2 \cdot \text{hPa}^{-1}$$

The atmospheric delay at the time acquisition of the SAR data is

$$\Delta R_{atm} = \Delta R_{wet} + \Delta R_{hyd} = \frac{10^{-6}}{\cos \vartheta} \cdot \int_0^h \left( N_{wet} + N_{hyd} \right) \cdot dh$$
GPS vs WRF - Time (1)

GPS (blue) TZD vs WRF (red) ZTD at April 12, 2009.
GPS vs WRF – Space (1)

Zenith delay differences (mm)
Dry and wet components
(April 12, 2009)

<table>
<thead>
<tr>
<th>Station</th>
<th>Hydrostatic</th>
<th>Wet</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>RMS</td>
</tr>
<tr>
<td>MAFR</td>
<td>2.2</td>
<td>2.4</td>
</tr>
<tr>
<td>GRID</td>
<td>0.0</td>
<td>1.2</td>
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<tr>
<td>ALCO</td>
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<td>2.3</td>
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<tr>
<td>FCUL</td>
<td>-0.5</td>
<td>1.0</td>
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<tr>
<td>PARC</td>
<td>13.8</td>
<td>13.8</td>
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<tr>
<td>IGPO</td>
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<td>3.2</td>
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<tr>
<td>VNOV</td>
<td>-0.9</td>
<td>1.4</td>
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<td>-10.0</td>
<td>10.1</td>
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<tr>
<td>SMAR</td>
<td>4.1</td>
<td>4.3</td>
</tr>
<tr>
<td>CASC</td>
<td>3.6</td>
<td>3.8</td>
</tr>
</tbody>
</table>
GPS vs WRF – Space Variation (1)

Difference of TZD (May 17, 2009 – April 12, 2009)

**DRY**

**WET**

**WRF**

**GPS**

→ FRINGE 2009 WORKSHOP  30th November - 4th December 2009 | ESA-ESRIN | Frascati (Rome) Italy
Zenith delay differences (mm)  
Dry and wet components  
(May 17, 2009 - April 12, 2009)
A total amount of 25 SAR interferograms with a 35-day temporal baseline were processed using the DORIS (Delft object-oriented radar interferometric software) software.

The SAR data was acquired by ENVISAT/ASAR over Lisbon region during the period from 2003 to 2005 and from 2008 to 2009 along and ascending orbit.

Terrain deformations related to known geological phenomena in Lisbon area are negligible at this time scale of 35 days.

These interferograms give an estimate of the variation of the total atmospheric delay occurred between the acquisition $D_{\text{ATM}}$ of the two SAR images

$$\varphi_{\text{ATM}} = \frac{4\pi}{\lambda} D_{\text{ATM}}$$
ENVISAT/ASAR interferogram (May 17, 2009 - April 12, 2009)
Spatially averaged to 160x160m to reduce phase noise
Synthetic “interferogram” from WRF TZD (May 17, 2009 - April 12, 2009)

\[ \varphi_{ATM} = \frac{4\pi}{\lambda} D_{ATM} \]
Synthetic “interferogram” from GPS TZD (May 17, 2009 – April 12, 2009)

\[ \varphi_{ATM} = \frac{4\pi}{\lambda} D_{ATM} \]
Conclusions

- GPS measurements and WRF forecasts of atmospheric phase delay are in agreement with phase patterns in SAR interferograms with 35-day baseline.

- When available, GPS data are more effective to capture local variations of atmospheric delay.

- In regions without GPS data, WRF information is a promising tool to mitigate atmospheric delay effects in SAR interferograms.