SCANSAR INTERFEROMETRY ALONG THE SOUTHERN SAN ANDREAS FAULT SYSTEM

Xiaohua Xu
David Sandwell

Tokyo, Japan, Nov 19, 2015

- ALOS-2 ScanSAR will provide second look direction for San Andreas Fault interseismic deformation
- Geometric calibration
- ScanSAR burst alignment problem and example of the 2015 Nepal Earthquakes
- Stacking example for SSAF
- Conclusions
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• Conclusions
Major Earthquakes on the San Andreas Fault System
ALOS-1 provided and interseismic velocity map of the San Andreas system but only from the ascending look direction.

**ALOS-2 ScanSAR** could provide the descending look direction needed to discriminate between horizontal and vertical velocity. (8-10 Scenes)
• ALOS-2 ScanSAR will provide second look direction for San Andreas Fault interseismic deformation

• Geometric calibration with SanSAR

• ScanSAR burst alignment problem and resolution and example of the 2015 Nepal Earthquakes

• Stacking example for SSAF

• Ionosphere or orbit error?
Pinon Flat Radar Corner Reflectors
2.4 m corner reflectors
D1, D2 installed 1996
A1 installed Nov, 2005
photos November 2015

Table 1. Coordinates of Radar Reflectors

<table>
<thead>
<tr>
<th></th>
<th>lat</th>
<th>lon</th>
<th>height</th>
<th>azimuth</th>
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<tbody>
<tr>
<td>A1</td>
<td>33.612246</td>
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<td>257.5°</td>
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<td>102.5°</td>
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</tbody>
</table>

Latitude and longitude in decimal degrees and elevation in meters relative to the WGS-84 co-ordinate system and ellipsoid. The survey point is the apex (lowest corner) of each reflector.
### Average of ScanSAR Results

<table>
<thead>
<tr>
<th>filename</th>
<th>CR</th>
<th>Ri</th>
<th>Ai</th>
<th>Ro</th>
<th>Ao</th>
<th>dR(m)</th>
<th>dA(m)</th>
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<tbody>
<tr>
<td>ALOS2053922950-150523-WBDR1.1__D-F5</td>
<td>D1</td>
<td>5982.5</td>
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<td>1.24</td>
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<tr>
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<td>51118.5</td>
<td>5932.98</td>
<td>51117</td>
<td>4.43</td>
<td>3.72</td>
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<td>51117</td>
<td>4.435</td>
<td>3.72</td>
</tr>
</tbody>
</table>

- **range bias** 8.35 m +/- 4.05 m
- **azimuth bias** 0.00 m +/- 2.67 m

Non-zero in range, ionospheric delay?

7 reflectors?

~ 30 m
Cross correlation between master and slave vs. azimuth shift
ALOS-2 ScanSAR will provide second look direction for San Andreas Fault interseismic deformation

Geometric calibration

ScanSAR burst alignment problem and example of the 2015 Nepal Earthquakes

Stacking example for SSAF

Conclusions
ScanSAR interferometry requires that the reference and repeat images have significant overlap in their bursts on the ground.
ALOS-1 results:
Need > 0.2 burst overlap
to recover phase from
ScanSAR to ScanSAR
interferometry.

[Tong et al., 2010]
NAPA – Post Seismic
OK coherence!

Bursts have 33% overlap according to orbit
ALOS-2 burst alignment drifted from June 2014 until February 8, 2015.

bursts not aligned
burst overlap by chance

pre-earthquakes
bursts aligned
> 70% overlap

post-earthquakes
bursts aligned
> 70% overlap

ALOS-2 CALVAL team (Ryo Natsuaki – JAXA) detected the alignment problem in November 2014 and JAXA implemented fix in February.
Southern San Andreas Fault - 90% overlap after February, 2015

No phase adjustment of subswaths
Southern San Andreas Fault - 90% overlap

No phase adjustment of subswaths
Single 350km by 350 km interferogram.

Note phase is continuous across the subswath boundaries with NO adjustments!

Note good phase coherence even in snow-capped mountains.

2 parameter alignment is adequate.
Co-seismic interferograms used in this study. Note small baselines and large burst overlap.

<table>
<thead>
<tr>
<th>Track Mode</th>
<th>Reference Date Product</th>
<th>Repeat Date Product</th>
<th>B. perp. (m)</th>
<th>Az. shift (pixel)</th>
<th>Burst overlap</th>
<th>Mean coherence</th>
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<td>FEB 22 2015 ALOS2040533050-150222</td>
<td>APR 05 2015 ALOS2046743050-150405</td>
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<td>48.0</td>
<td>-106</td>
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<td>4.3</td>
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<tr>
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<td>T157 Swath</td>
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<td>MAY 02 2105 ALOS2050810540-150502</td>
<td>-118.6</td>
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<td>T156 Swath</td>
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<td>-39.9</td>
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</table>
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• Ionosphere or orbit error?
2 parameter alignment

ashift from orbit 113

70%?
4 parameter alignment (3 in azimuth)
4 parameter alignment (3 in azimuth) ashift from orbit 14
2 parameter alignment
Tricky Alignment Issue

• Reasons:
  – Long stripe-like images with amplitude scalloping is not so easy to align.
  – The xcorr result is affected by the amplitude scalloping and does not give accurate estimate.

• Solutions:
  – Threshold in time/baseline or azimuth shift to decide to use how many parameters.
  – Or maybe simply use more sampling points/larger window size for xcorr to make the estimates robust.
MOD[(phase12+phase23 –phase13),2pi]
Recovering low-amplitude deformation signals with InSAR time series

- InSAR estimation of low-amplitude deformation signals is significantly limited by the phase perturbations due to the troposphere and ionosphere.
- With dense data catalogs and regular repeat times, it is possible to estimate propagation delays due to the atmosphere with an iterative common point stacking method, taking advantage of the fact that all interferograms that share a common date must share the same atmospheric contribution.
- Propagation delays can be calculated for each scene, and subtracted from corresponding interferograms prior to forming time series to improve estimates of deformation.

\[ \alpha_i = \lim_{N \to \infty} \frac{1}{2N} \sum_{j=1}^{N} \Delta \phi_{i(j-i)} - \Delta \phi_{(i+j)i} \]

[Tymofyeyeva and Fialko, 2015]
• Geometric calibration can be done with ScanSAR and no significant bias were found

• ScanSAR burst alignment problem are resolved and ALOS-2 is proven very useful for large earthquakes

• Alignment for ScanSAR is tricky but should not be a problem. Stacking along San Andreas is valid.

• Ionosphere or orbit error?
SCANSAR INTERFEROMETRY ALONG THE SOUTHERN SAN ANDREAS FAULT SYSTEM

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• Thanks for the Attention!

• Questions & concerns?
Average of all Results

<table>
<thead>
<tr>
<th>filename</th>
<th>CR</th>
<th>Ro</th>
<th>Ao</th>
<th>Ri</th>
<th>Ai</th>
<th>dR(m)</th>
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<td>9270</td>
<td>-70.830262</td>
<td>-3.298280465</td>
</tr>
</tbody>
</table>

- range bias -68.3 m +/- 1.62 m (corrected)
- azimuth bias 2.4 m +/- 4.3 m (corrected)
- no compensation for ionospheric delay in range (Should we use an ionospheric model?)
ALOS-2
NAPA1
No coherence!

Bursts have 0% overlap according to orbit