Feedbacks on some present DINSAR\(^1\) processing suites:

An overview on interferometric SAR\(^2\) software and a comparison between DORIS and SARSCAPE packages

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L2G (Laboratoire de Géodésie et Géomatique)

\(^1\) Differential Interferometry of SAR data
\(^2\) Synthetic Aperture Radar
Content

1. Context and objectives
2. An overview on satellite sensors
3. An overview on software
4. A comparison between DORIS and SARSCAPE
5. Conclusions and current works
1. Context and objectives

**Context: interferometric SAR techniques**

These remote sensing techniques allow producing DEM and ground deformation map using at least two SAR images.

- **INSAR**
  - DEM

- **DINSAR**
  - Ground deformation map (displacement in mm between two dates or averaged deformation rate in mm/year)

- **A-DINSAR**
  - PS-INSAR
  - Stack-DINSAR
  - SB-DINSAR
DINSAR applications:

- Many applications and possible clients in urban monitoring, post-mining, civil engineering, gas and petrol field surveillance, aquifer system analysis, earth science (seismic activity, volcano, glacier) …

- Example: local authorities need more and more spatial data to provide risk maps concerning flooding zones, extend of ground instabilities and ground motion, …

**Difficulties:** atmospheric artefacts, noise, impact of orbital inaccuracies

Need of expert appraisal
Objectives of this work:

1. To assess the pertinence of a software for research purposes in our laboratory.
   - Choice of a software,
   - Validation of our use of this software.

2. To give information for interested user in DINSAR.
SAR (Synthetic Aperture Radar) image requirements

Image formation in *stripmap* mode:
Important requirements in our context:

• same characteristics: pixel size, wavelength, polarisation mode,

• same viewing condition: antenna position and viewing direction, descending or ascending mode.

→ here, two-pass satellite DINSAR under interest
Two-pass DINSAR

- Master SLC data
- Slave SLC data
- DEM
- Reference topographic contribution
- Differential interferogram
- Unwrapped differential interferogram
- Unwrapped geocoded DINSAR map
- Radar-coded DEM
- GCP
- Radar-to-ground geocoding tables
DINSAR map to displacement map:

\[ \Phi_{\text{mvt}} = 4\pi \frac{e}{\lambda} \]

Line-Of-Sight (LOS) direction from \( S_1 \)
### 2. An overview on satellite SAR sensors

<table>
<thead>
<tr>
<th>Launch date</th>
<th>status</th>
<th>satellite name</th>
<th>country</th>
<th>repeat cycle in days (or life time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>mission ended</td>
<td>SEASAT</td>
<td>USA</td>
<td>life time: 105 days</td>
</tr>
<tr>
<td>1981</td>
<td>mission ended</td>
<td>SIR-A</td>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>mission ended</td>
<td>SIR-B</td>
<td>USA</td>
<td>life time: 8.3 days</td>
</tr>
<tr>
<td>1991</td>
<td>mission ended</td>
<td>ERS-1</td>
<td>ESA</td>
<td>3, 35, 176</td>
</tr>
<tr>
<td>1992</td>
<td>mission ended</td>
<td>JERS 1</td>
<td>Japan</td>
<td>44</td>
</tr>
<tr>
<td>1994</td>
<td>mission ended</td>
<td>SIR-C/X-SAR</td>
<td>USA/Germ./It.</td>
<td>life time: 7 months</td>
</tr>
<tr>
<td>1995</td>
<td>on orbit</td>
<td>RADARSAT-1</td>
<td>Canada</td>
<td>24</td>
</tr>
<tr>
<td>1995</td>
<td>on orbit</td>
<td>ERS-2</td>
<td>ESA</td>
<td>35</td>
</tr>
<tr>
<td>2000</td>
<td>mission ended</td>
<td>SRTM</td>
<td>USA/Germ./It.</td>
<td>life time: 11 days</td>
</tr>
<tr>
<td>2002</td>
<td>on orbit</td>
<td>ENVISAT</td>
<td>ESA</td>
<td>35</td>
</tr>
<tr>
<td>2006</td>
<td>on orbit</td>
<td>ALOS</td>
<td>Japan</td>
<td>46</td>
</tr>
<tr>
<td>2007</td>
<td>on orbit</td>
<td>TERRASAR-X</td>
<td>Germany</td>
<td>11</td>
</tr>
<tr>
<td>2007</td>
<td>on orbit</td>
<td>RADARSAT-2</td>
<td>Canada</td>
<td>24</td>
</tr>
<tr>
<td>2007</td>
<td>on orbit</td>
<td>COSMO-SKYMED-1 et 2</td>
<td>Italy</td>
<td>16 (~12h with 4 sat.)</td>
</tr>
<tr>
<td>2008</td>
<td>on orbit</td>
<td>TECSAR</td>
<td>Israel</td>
<td>?</td>
</tr>
<tr>
<td>2008</td>
<td>on orbit</td>
<td>COSMO-SKYMED-3</td>
<td>Italy</td>
<td>16 (~12h with 4 sat.)</td>
</tr>
<tr>
<td>2009</td>
<td>on orbit</td>
<td>RISAT</td>
<td>India</td>
<td>12</td>
</tr>
<tr>
<td>2009</td>
<td>in development</td>
<td>HJ-1C</td>
<td>China</td>
<td>31</td>
</tr>
<tr>
<td>2009</td>
<td>in development</td>
<td>TanDEM X</td>
<td>Germany</td>
<td>11</td>
</tr>
<tr>
<td>2009</td>
<td>in development</td>
<td>SMOTR 3 and 4</td>
<td>Russia</td>
<td>?</td>
</tr>
<tr>
<td>2010</td>
<td>in development</td>
<td>COSMO-SKYMED-4</td>
<td>Italy</td>
<td>16 (12h avec 4 sat.)</td>
</tr>
<tr>
<td>2010</td>
<td>in development</td>
<td>KOMPSAT-5</td>
<td>South Korea</td>
<td>?</td>
</tr>
<tr>
<td>2011</td>
<td>proposed</td>
<td>PAZ</td>
<td>Spain</td>
<td>?</td>
</tr>
<tr>
<td>2011</td>
<td>proposed</td>
<td>GMES/Sentinel-1</td>
<td>ESA</td>
<td>12</td>
</tr>
<tr>
<td>2012</td>
<td>proposed</td>
<td>TERRASAR-X2</td>
<td>Germany</td>
<td>11</td>
</tr>
<tr>
<td>2012</td>
<td>proposed</td>
<td>MAPSAR</td>
<td>Brazil/Germany</td>
<td>37</td>
</tr>
<tr>
<td>2012</td>
<td>proposed</td>
<td>RADARSAT-Constellation</td>
<td>Canada</td>
<td>?</td>
</tr>
<tr>
<td>2012</td>
<td>proposed</td>
<td>SAOCOM 1A</td>
<td>Argentina</td>
<td>16</td>
</tr>
<tr>
<td>2013</td>
<td>proposed</td>
<td>SAOCOM 1B</td>
<td>Argentina</td>
<td>16</td>
</tr>
<tr>
<td>?</td>
<td>proposed</td>
<td>TERRASAR-L</td>
<td>Germany/U.-K.</td>
<td>14</td>
</tr>
</tbody>
</table>
3. An overview on software

Several radar software exist, which one?

- free-of-charge / fees,
- hotline,
- update frequency,
- platform,
- ergonomics,
- documentation quality,
- access to the source codes → important to understand the methods and to allow an advanced parameter setting
- supported input satellite data format,
- output products,
- supported geocoding systems (same as the DEM).
Proposed terms in this particular context:

INSAR software packages (=INSAR processing suite) OR radar tools

Proprietary and commercial VERSUS Free-of-charge

Opensource or Freeware

(= source code available)

But in certain cases:

‘Use at no cost’ under restriction: private or scientific use only …
Proprietary and commercial INSAR software packages (in April 2009)

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Capabilities under interest</th>
<th>Supported SAR satellite sensors</th>
<th>Release</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARSCAPE</td>
<td>Sarmap</td>
<td>SAR focusing, INSAR, DINSAR, POLINSAR, PSINSAR</td>
<td>JERS1, RADARSAT1&amp;2, ERS1&amp;2, ENVISAT, ALOS, TSX¹, CSK²</td>
<td>4.0</td>
<td>Plug-in for ENVI or Arcview (Windows / Linux / Unix / MacOSX)</td>
</tr>
<tr>
<td>GAMMA</td>
<td>Gamma Remote Sensing</td>
<td>SAR focusing, INSAR, DINSAR, PSINSAR</td>
<td>SEASAT, SIRC, JERS1, RADARSAT1&amp;2, ERS1&amp;2, ENVISAT, ALOS, TSX, CSK</td>
<td>Not found</td>
<td>Linux / Windows / Unix / MacOSX</td>
</tr>
<tr>
<td>DIAPASON</td>
<td>CNES / Altamira Information</td>
<td>SAR focusing, INSAR, DINSAR</td>
<td>JERS1, RADARSAT1, ERS1&amp;2, ENVISAT, ALOS, TSX</td>
<td>4.3</td>
<td>Linux / Windows</td>
</tr>
<tr>
<td>IMAGINE</td>
<td>Geosystems</td>
<td>INSAR</td>
<td>JERS1, RADARSAT1&amp;2, ERS1&amp;2, ENVISAT, ALOS, TSX, CSK</td>
<td>9.3.2</td>
<td>Windows / Linux / Unix / MacOSX</td>
</tr>
<tr>
<td>EarthView</td>
<td>MDA</td>
<td>SAR focusing, INSAR, DINSAR, PSINSAR</td>
<td>JERS1, ERS1&amp;2, RADARSAT1&amp;2, ALOS, ENVISAT</td>
<td>Not found</td>
<td>Windows / Linux</td>
</tr>
</tbody>
</table>

¹Terrasar-X
²Cosmo-Skymed
1. Context and objectives
2. An overview on satellite sensors
3. An overview on software
4. A comparison between DORIS and SARSACE
5. Conclusions and current works
### Free-of-charge INSAR software packages (in April 2009)

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Capabilities under interest</th>
<th>Supported SAR satellite sensors</th>
<th>Release</th>
<th>Platform</th>
<th>Licence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROI_PAC</td>
<td>JPL / Caltech</td>
<td>SAR focusing, INSAR, DINSAR</td>
<td>JERS1, RADARSAT1&amp;2, ERS1&amp;2, ENVISAT, ALOS</td>
<td>3.0 (2007)</td>
<td>Unix / Linux</td>
<td>Open Channel Software/Caltech</td>
</tr>
<tr>
<td>DORIS</td>
<td>TU DELFT</td>
<td>INSAR, DINSAR, no unwrapping</td>
<td>JERS1, RADARSAT1, ERS1&amp;2, ENVISAT +ALOS, TSX</td>
<td>3.20 (2008)</td>
<td>Unix / Linux / MacOSX</td>
<td>GPL v2</td>
</tr>
<tr>
<td>RAT</td>
<td>Berlin Univ. of Technology</td>
<td>INSAR, POLINSAR, no geocoding</td>
<td>JERS1, RADARSAT1&amp;2, ERS1&amp;2, ENVISAT, ALOS, TSX</td>
<td>0.20 (2008)</td>
<td>IDL VM (Linux / Unix / Windows / MacOSX)</td>
<td>MPL 1.1</td>
</tr>
<tr>
<td>STAMPS</td>
<td>Stanford Univ.</td>
<td>PSINSAR</td>
<td>JERS1, ERS1&amp;2, RADARSAT1&amp;2, ENVISAT, ALOS</td>
<td>2.2 (2007)</td>
<td>Unix / Linux</td>
<td>None, source code available</td>
</tr>
</tbody>
</table>
DORIS
Conditions of use (DORIS)

The conditions of use are as follows.

1. Doris is a **scientific-purpose software** and cannot be commercialized, nor can parts or products of it be commercialized. **Parties interested in using Doris or its products for any commercial purposes are requested to contact Dr. Ramon Hanssen** of DEOS (r.f.hanssen@tudelft.nl)

2. Our version of the software is the only official one. Please **do not distribute** the Doris software to third parties, instead refer to the Doris home page. This in order **to guarantee uniformity** in the distribution of updates and information.

3. Delft University of Technology is not responsible for any damage caused by errors in the software or the documentation.

4. Users are very **welcome to extend the capabilities** of the Doris software by implementing new algorithms or improving the existing ones. It is intended that if new software is developed based on Doris, that this also is **made available for free** to the other users (through us).

5. We would appreciate if any addition or modification of the software would be announced first to us, so that it can be included in the official (next) version of the software.

6. Publications that contain results produced by the Doris software should contain an **acknowledgment**. […]
1. Context and objectives
2. An overview on satellite sensors
3. An overview on software
4. A comparison between DORIS and SARSCAPE
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Free-of-charge radar tools (in April 2009)

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Capabilities under interest</th>
<th>Supported SAR satellite sensors</th>
<th>Release</th>
<th>Platform</th>
<th>Licence type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVIVIEW</td>
<td>ESA</td>
<td>Basic tools for SAR data handling</td>
<td>ERS1&amp;2, ENVISAT</td>
<td>-</td>
<td>Unix / Linux / Windows / Solaris / AIX / HP-UX</td>
<td>Freeware</td>
</tr>
<tr>
<td>NEST (following BEST)</td>
<td>ESA</td>
<td>Basic tools for SAR data handling</td>
<td>JERS1, RADARSAT1, ERS1&amp;2, ENVISAT, ALOS, TSX</td>
<td>2C-1.2 (06/2009)</td>
<td>Windows / Linux / MacOSX</td>
<td>GPL</td>
</tr>
<tr>
<td>SNAPHU</td>
<td>Stanford Univ.</td>
<td>Unwrapping software</td>
<td>-</td>
<td>1.4.2 (2003)</td>
<td>Unix / Linux</td>
<td>Copyright</td>
</tr>
<tr>
<td>Getorb</td>
<td>TU DELFT</td>
<td>Precise orbit retrieval</td>
<td>ERS1&amp;2, ENVISAT</td>
<td>2.3.2 (2008)</td>
<td>Unix / Linux</td>
<td>None, source code available</td>
</tr>
<tr>
<td>POLSARPRO</td>
<td>ESA / Rennes-1 Univ.</td>
<td>Polarimetric tools among which POLINSAR</td>
<td>SIRC, RADARSAT2, ENVISAT, ALOS, TSX</td>
<td>4.0 (2009)</td>
<td>Windows / Unix / Linux</td>
<td>GPL v2</td>
</tr>
<tr>
<td>ASF SAR tools</td>
<td>ASF</td>
<td>In particular SAR Processor</td>
<td>Not found</td>
<td>1.1.10 (2009)</td>
<td>Windows / Linux</td>
<td>Not found</td>
</tr>
<tr>
<td>IDIOT</td>
<td>Berlin Univ. of Technology</td>
<td>DINSAR, no unwrapping, no geocoding</td>
<td>ENVISAT</td>
<td>1.3 (2008)</td>
<td>IDL VM (Linux / Windows / Unix / MacOSX)</td>
<td>Freeware</td>
</tr>
</tbody>
</table>
Copyright (SNAPHU)
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3. An overview on software
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5. Conclusions and current works

IDIOT:

![IDIOT - InSAR Deformation Inspection and Observation Tool](image)

**PROJECT FILE SELECTION:**

- **Master Track:** Choose your master track file name
- **Slave Track:** Choose your slave track file name
- **Output Directory:** Choose your working directory
- **SRTH-3 Directory:** Choose your SRTM directory

**DELFIT PRECISE ORBITS:**

- **START PROCESSING**
- **QUIT (DO NOTHING)**
- **About**
Our choice: **DORIS**

→ **Advantages:**
  → free-of-charge for non-commercial use (GPL)
  → Mailing list
  → Recently updated
  → Linux or Cygwin for Windows
  → Easy to use
  → Well documented
  → Access to source code
  → Allowing the complete INSAR processing
  → Used by STAMPS for the advanced PS processing

→ **Inconvenients:**
  → No graphical interface
  → Irregular updates
  → All satellite format not supported, no aerial sensor
  → Use other libraries (LAPACK, FFTW) and software (SNAPHU, PROJ.4, GetOrb, GMT)
4. A comparison between DORIS and SARSCAPE

**DORIS v3.20 flowchart**

- Master SAR data
- Slave SAR data
- DEM
- Precise orbit files
- Interferogram generation, including slave coregistration and spectral shift filterings
- Interferogram
- Reference topographic phase
- Interferogram flattening and phase filtering
- Differential interferogram
- Unwrapped differential interferogram
- Unwrapping (Snaphu)
- GCP
- Radar-to-ground geocoding tables
- Table of unwrapped geocoded measurements
- Interpolation tools (GMT advised)
- Unwrapped geocoded DINSAR map

---

**FFTW**

**Lapack**

**GETORB**

**Proj.4**

**SNAPHU**

**GMT**

**Kampes, B. M., Usai, S.,**

# Differences between DORIS and SARSCAPE

<table>
<thead>
<tr>
<th>SARSCAPE v4.0</th>
<th>DORIS v3.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Free-of-charge (in non-commercial context)</td>
</tr>
<tr>
<td>Hotline</td>
<td>Mailing list</td>
</tr>
<tr>
<td>Regular updates</td>
<td>Irregular updates</td>
</tr>
<tr>
<td>Graphical interface</td>
<td>Command line software</td>
</tr>
<tr>
<td></td>
<td><strong>well documented</strong></td>
</tr>
<tr>
<td></td>
<td><strong>easy to use</strong></td>
</tr>
<tr>
<td>Proprietary</td>
<td>Open source (in non commercial context)</td>
</tr>
<tr>
<td>Easy to install</td>
<td>Compilations could take time…</td>
</tr>
<tr>
<td>Many supported satellite and aerial data format</td>
<td>Less supported data format</td>
</tr>
<tr>
<td>Many supported geocoding systems</td>
<td>Working in WGS84</td>
</tr>
</tbody>
</table>

*two different strategies for the orbital parameters refinement*
Experiments using DORIS and SARSCAPE with the same dataset

SAR data

- 2 ASAR data from the BAM ENVISAT ASAR dataset package (ESA):

  track 120, frame 3024, IS2, descending mode
  Orbit numbers 9192 (03/12/2003, master)
  10194 (11/02/2004, slave)

Earthquake
26/12/2003
Amplitude radar image (in radar sensor geometry)

Bam

Nord

Est

Ouest

Sud

~100 km

~100 km

26
DEM

SRTM3 DEM (NASA)

Shaded SRTM3 DEM covering the same area as the ASAR data
DORIS radar-coded differential interferogram

SARSCAPE radar-coded differential interferogram
1. Context and objectives
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**DORIS unwrapped radar-coded diff. Interferogram using SNAPHU**

**SARSCAPE unwrapped radar-coded diff. Interferogram using SNAPHU**

-45 rad
-20 cm

62 rad
+28 cm

*(relative measurements)*
Image of the difference between these two last results

5.6cm along 140km

Mean=-2.3 rad (-1cm) Sigma=1.8 rad (0.8 cm)
Dissimilarities due to different residual orbital errors in DORIS and in SARSCAPE.

Classical quadratic residual trend in two-pass DINSAR results.

Current solutions:
- compensation of a quadratic global trend
- PS INSAR

Need of Ground Control Points to assess the accuracy of each result.

Coherent obtained results: validation of our use of DORIS
5. Conclusions and current works

→ Several radar sensors and INSAR software (« proprietary and commercial » / « free-of-charge »)

→ Need for a dataset including the final result and in situ measurements for training an interested user.

→ Validation of our choice of DORIS software for two-pass DINSAR for our current works:

   studies on urban sites using A-DINSAR (stack-DINSAR and PSINSAR)