SAR Interferometry opportunities with the European Space Agency

ERS-1, ERS-2, Envisat, Sentinel-1A, Sentinel-1B, ESA 3rd Party Missions (ALOS)

Prepared by ESA teams and ESA supporting companies
For the last 20 years, ESA has been constantly supporting the SAR Interferometry (InSAR) communities with:

- the provision of relevant InSAR data, through:
  - the development and operations of SAR satellites (ERS-1, ERS-2, Envisat)
  - a precise satellite orbital maintenance including InSAR tandem campaigns (ERS-1/ERS-2 tandem, ERS-2/Envisat tandem)
  - the development of a large and consistent InSAR data archive
  - a constant effort in facilitating access to SAR data

- the development of InSAR science and InSAR applications,

- bringing together the InSAR communities through the Fringe workshop.
ERS-2 has reached 14.5 years of operations

- ERS-2 was designed for 3 years nominal lifetime!

Satellite:

- no gyroscopes since 2001: gyro-less operations
- gyro-less data are being Doppler screened removing the attitude uncertainty
- SAR instrument works satisfactorily

Ground segment:

- Network of SAR data acquisition stations provides a good coverage

**ERS-2 mission should be operated until mid-2011 (16 years lifetime) followed by satellite decommissioning (de-orbiting)**
ERS-1 and ERS-2 missions

18 years of ERS-1/2 SAR data in the archive

ERS SAR Polarization: VV until mid 2009

The most complete and consistent SAR archive
Subsidence map 1992-2006: Permanent Scatterer InSAR
ERS SAR Tandem data allowed identifying the acceleration of Greenland glaciers flow (Rignot, 2006)

ERS SAR 1-day tandem: a unique dataset!

30 m < baseline < 100 m

100 m < baseline < 200 m
ERS-2 and Envisat can acquire SAR data over the same area with 30 minutes time interval. However the InSAR exploitation of ERS-2 and Envisat data is complicated by the difference of 31 MHz between the radar central frequencies and can be performed under certain geometry (baseline) conditions.

➔ to compensate for the frequencies difference, *ERS-2 orbit shall be shifted by about 2 km (perpendicular baseline of 2.1 km)*
Three ERS-2 / Envisat SAR Tandem campaigns:

1\textsuperscript{st} tandem: Sep. 07 to Feb. 08 \rightarrow Northern Hemisphere

2\textsuperscript{nd} tandem: Nov. 08 to Apr. 09 \rightarrow Northern Hemisphere

3\textsuperscript{rd} tandem: Feb. 10 to Apr. 10 \rightarrow Southern Hemisphere

\textbf{see poster ESOC (M. Martin Serrano)}
ERS-2 / Envisat Tandem
Franz-Josef Land, Arctic

No SRTM DEM at high latitudes

High coherence!

7 Dec. 2007
B_{perp} : 2066 m

⇒ see presentation Ice Session (U. Wegmuller)

Credits: Gamma Remote Sensing
ERS-2 / Envisat Tandem
New Orleans, USA

13 Sep. 2009
B_{perp} : 1440 m

see presentation DEMs Session (U. Wegmuller)

Credits: Gamma Remote Sensing
Envisat has reached 7.5 years of operations:

- Envisat was designed for 5 years nominal lifetime

Satellite:

- good overall status will platform and payload
- ASAR instrument works satisfactorily

Ground segment:

- about 270 min. of ASAR (high rate) data acquired every day, equivalent to 270 ScanSAR products or 1080 stripmap products per day
Envisat mission

A large archive dedicated to InSAR

ASAR archive: Image Mode, Swath 2, VV (i.e. ERS-like)
L’Aquila earthquake (April 2009)

Envisat ASAR data

see L’Aquila earthquake session on Tuesday afternoon
A large archive dedicated to InSAR

ASAR archive: Image Mode, Swath 2, HH
Envisat mission

A large archive dedicated to InSAR

ASAR archive: Image Mode, Swath 6, VV
Envisat mission

A large archive of ScanSAR data interesting for InSAR

ASAR archive: Wide Swath Mode, VV
Envisat mission

A large archive of ScanSAR data interesting for InSAR

ASAR archive: Wide Swath Mode, HH
ASAR Wide Swath Mode data used together with Image Mode data to analyse the Lazufre volcanic system (Central Andes)

Jan Anderssohn et al. (GFZ), in Remote Sensing of Environment, Volume 113, Issue 10, October 2009
Envisat satellite is in **good health** and with an expected reasonable evolution.

Efficient consumption of on-board hydrazine allows operating nominally Envisat until 2010. **But most of hydrazine will be consumed by 2010.**

*The Envisat 3-years extension requests a modification of the orbital parameters in 2010 to be able to operate the satellite with minimum hydrazine.*
Envisat operations should end in 2010, but Member States have agreed to fund a 3-year extension.

The new orbital parameters allow:
1. to keep current nominal mission until 2010,
2. to extend the mission beyond 2010,
3. to allow operations of all instruments with small or no degradation of their measurements, and minor impact on data quality, excepted for InSAR
4. to commit with the satellite disposal rules.

- Altitude change: -17.4 km
- Repeat cycle: 30 days / 431 orbits
- Orbit control: only altitude, inclination drift
- Mean Local Solar Time variation: +/- 10 min.
After Oct. 2010, Envisat orbit inclination will not be maintained:

- InSAR baselines will gradually increase with respect to their initial values.
- Some opportunities of better baseline values between successive acquisitions during (boreal) summer.

Estimated linear trend of -3.76 mdeg/cycle
Values of the (normal) baselines for Swath #2 as a function of the latitude, for different temporal distances from cycle #2 (Nov. 2010) to cycle #40 (Dec. 2013)

\[ \text{closer to the Equator, better will be the baselines} \]
Envisat mission extension

<table>
<thead>
<tr>
<th>Swath</th>
<th>Latitude bounds after 11 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS1</td>
<td>± 4.5°</td>
</tr>
<tr>
<td>IS2</td>
<td>± 5.5°</td>
</tr>
<tr>
<td>IS3</td>
<td>± 8°</td>
</tr>
<tr>
<td>IS4</td>
<td>± 10.5°</td>
</tr>
<tr>
<td>IS5</td>
<td>± 13°</td>
</tr>
<tr>
<td>IS6</td>
<td>± 15.5°</td>
</tr>
<tr>
<td>IS7</td>
<td>± 18.5°</td>
</tr>
</tbody>
</table>

*Maximum latitude where the normal baseline is lower than 50% of the critical baseline (for flat terrain), after about 1 year i.e. at end 2011*
ESA 3rd party mission: ALOS

- ESA operates the ALOS Data European Node (ADEN) and provides data to European/African/Middle-East users.
- ALOS satellite is currently in post-routine operations after its 3 years nominal lifetime.
- JAXA estimates to be able operating ALOS until 2013/14 (propellant for 5 years from now).
ALOS mission

Wenchuan earthquake, China, 12 May 2008

“Slip maxima at fault junctions and rupturing of barriers during the 2008 Wenchuan earthquake”,
Zheng-Kang Shen, Jianbao Sun et al.  

Work done as part of the ESA-MOST Dragon-2 Programme
GMES and Sentinel-1 missions

GMES Space Component – led by ESA:

- **Sentinel missions**: developed specifically for GMES
- **Contributing missions**: EO missions built for purposes other than GMES but offering part of their capacity to GMES (EU/ESA Member States, EUMETSAT, commercial, international)

+ national SAR missions (Radarsat, TerraSAR-X, COSMO, ...)
Sentinel-1 main characteristics:

- **Sun synchronous orbit, MLST**: 18:00 h at ascending node
- **7 years design lifetime, consumables for 12 years**
- **12 days repeat cycle, 175 orbits/cycle**

- **Duty cycle**: up to 25 min/orbit in high rate acquisition modes
- **Communication link rate**: ~600 Mbps
Sentinel-1 acquisition modes

4 acquisition modes

Single Look Resolution:
(Azimuth x Ground Range)

- Stripmap Mode: 5 x 5 m
- Interferometric WideSwath Mode: 20 x 5 m
- Extra WideSwath Mode: 40 x 20 m
- Wave Mode: 5 x 5 m
Key operational concept:

- **Pre-defined stable observation plan**, to support operational activities (e.g. land surface motion monitoring, sea ice monitoring, maritime surveillance)

- **On-request satellite tasking**, processing and dissemination capability to support Emergency & Security GMES Services

- **Systematic processing and dissemination** of all acquired data within 24 h

- **Systematic NRT data access** capability (less than 3 h after data sensing)

- **Downlink** (direct and on-board recorder) to Core ground stations + direct downlink to Collaborative local ground stations (e.g. for support to specific NRT operations)

- **On line data access** to fresh and past data (no media usage foreseen)

- **Stable and traceable product quality** meeting the quality requirements and accurate product calibration

⇒ *see presentations on Friday morning (E. Attema, B. Rosich)*
The principles of the Sentinel data policy are jointly established by EC and ESA.

The principles of the Sentinel Data Policy are based on a **full and open access** to the data:

- anybody can access acquired Sentinel data; in particular, no difference is made between public, commercial and scientific use and in between European or non-European users (on a best effort basis, taking into consideration technical and financial constraints);

- the licenses for the Sentinel data itself are **free of charge**;

- the Sentinel data will be made available to the users via a "generic" online access mode, free of charge. "Generic" online access is subject to a **user registration** process and to the acceptance of generic terms and conditions;

- additional access modes and the delivery of additional products will be tailored to specific user needs, and therefore subject to tailored conditions;

- in the event security restrictions apply to specific Sentinel data affecting data availability or timeliness, specific operational procedures will be activated.

ESA Member States approved those principles in September 2009.
A constant objective:

→ ease access to Earth Observation data

- Common objective for all missions data handled by ESA:
  Envisat, ERS, Earth Explorers, and Third Party Missions

- Revised ESA EO data policy in preparation:
  → open and free of charge for most data (user registration)
  → some restrictions for SAR data and some 3rd Party Missions

- Development of alternative ways to provide data (e.g. processing on demand, toolboxes)

- Maintain effort in improving quality of products (algorithms, validation)

- Maintain effort in exploiting data (e.g. ESA Supersite Initiative)
  
  → see following presentation (W. Lengert)
NEST SAR Toolbox

Provides both basic and advanced tools for the SAR user community

**Example:**
Orthorectified image using rigorous SAR simulation

**NEST status:**
- 1800 registered users worldwide
- basic InSAR functionality (NEST-DORIS) being implemented

➔ see presentations later today:
- 10:45-11:00:
  *NEST: the ESA toolbox for scientific exploitation of SAR data*
- 11:30-11:45:
  *NEST-DORIS, InSAR extension for NEST*
As for the last 20 years, ESA is committed to continue its support to the InSAR user communities:

- maintaining the effort in facilitating access to SAR data,
- strengthening the exploitation of its large InSAR archive,
- developing and operating the Sentinel-1 missions (2 satellites),
- seeking reinforced partnerships with other SAR operators (e.g. Canadian Space Agency, Japanese Space Agency).