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Overview

- Exupéry - mobile Volcano Fast Response System (VFRS)
- Challenge and Difficulties
- Test Site & TS-X acquisitions
- Coherence analysis
- Atmospheric corrections in troposphere
- PSI results
- Multi-Stack fusion
The majority of the active and dangerous volcanoes are located around the pacific ring of fire.
- Half of them are located in **third world countries**.
- Develop mobile **VFRS** (volcano fast response system) to **support those countries** in case of a volcanic crisis.

**WP2 Satellite based observations:**
- SAR interferometry, SO2 from GOME-2, InfraRed imaging
Exupéry - mobile Volcano Fast Response System (VFRS)

**Challenge and Difficulties**

- Test Site & TS-X acquisitions
- Coherence analysis
- Atmospheric corrections in troposphere
- PSI results
- Multi-Stack fusion
- Difficulties and error sources
  - Temporal decorrelation
  - Lack of accurate elevation information
  - Geometric problems
  - Atmospheric delay
Exupéry - mobile Volcano Fast Response System (VFRS)
Challenge and Difficulties
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Multi-Stack fusion
Test Site: Fogo Volcano

- **Fogo Volcano (São Miguel, Portugal)**
  - Whole island 63.5 km (NW-SE), 15.6 km (width)
  - Maximum altitude ~947 m
  - Seismic unrest since 2002, maximum in 2005; seismic inactive since 2007
  - High density of vegetation

- **Acquisition plan**

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Acquisition Duration</th>
<th>Scene No.</th>
<th>Acquisition Mode</th>
<th>Cross Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS-X</td>
<td>12.2007 - 10.2010</td>
<td>47</td>
<td>Stripmap</td>
<td>ascending</td>
</tr>
<tr>
<td>TS-X</td>
<td>01.2008 - 10.2010</td>
<td>43</td>
<td>Stripmap</td>
<td>descending</td>
</tr>
<tr>
<td>ALOS</td>
<td>06.2007 - 12.2008</td>
<td>9</td>
<td>Polarimetry</td>
<td>ascending</td>
</tr>
<tr>
<td>ERS1</td>
<td>1995/2005</td>
<td>2</td>
<td>ERS1/2</td>
<td>descending</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>1995/6/27</td>
<td>2</td>
<td>ASAR</td>
<td>descending</td>
</tr>
</tbody>
</table>
Test Site: Stromboli Volcano

- **Stromboli Volcano (Italy)**
  - Surface ca. 12.4 km²
  - Maximum altitude ~924 m
  - Less density of vegetation
  - Active volcano
    - Repeated large-scale lateral collapses in Sciara del Fucco

[A. Bosman, et al. 2009]
Test Site: Stromboli Volcano

- **Stromboli Volcano (Italy)**
  - Surface ca. 12.4 km²
  - Maximum altitude ~924 m
  - Less density of vegetation
  - Active volcano
    - Repeated large-scale lateral collapses in Sciara del Fuclo

- **Multi-geometrical acquisition plan**
  - TerraSAR-X High Resolution Spotlight
  - Duration: 2008-01 to 2008-10
  - 69 TS-X HSL, ~17 TS-X per geometry
  - 3-4 days one acquisition
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Coherence Comparison: X- and L-band

(Top) 11-days TS-X interferogram with master: 2009-04-30, slave: 2009-05-11, baseline 12.5m, height ambiguity -640.6 [m/cycle] and its coherence image as well as the coherence histogram.

(Bottom) 46 days ALOS/PALSAR interferogram master: 2007-06-24; slave: 2007-08-09, baseline 9.42m, height ambiguity 19834.59 [m/cycle] and the coherence image.
Temporal Decorrelation

- Temporal decorrelation model.

\[ \gamma(t) = (\gamma_0 - \gamma_n) e^{-t/\tau} + \gamma_n \]

[A. Parizzi, et al., 2009]

- Example of descending stack (master selected in the middle of the stack)

- More stability in city area
- Stable rocks could be detected due to better spatial resolution in vegetated area
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- PSI results
- Multi-Stack PS-DEM
Atmospheric delay in troposphere

- Zenith excess path in line of sight (LoS) direction

\[ L_{LOS} = \frac{10^{-6}}{\cos \theta} \left[ \frac{k_1 R_d}{g_m} P(z_0) + \int_{z_0}^{\infty} \left( k_2 - \frac{R_d}{R_v} k_1 \right) \left( e + k_3 \frac{e}{T^2} \right) dz \right] \]

[R. Hanssen, 2006]

- Water vapor pressure & temperature

- 2008-01-28
- 2008-08-02
Atmospheric delay

- Zenith excess path in line of sight (LoS) direction

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- Atmospheric delay in repeat-pass interferogram

\[ \partial L_{LOS}(z) = L_{LOS}^S(z) - L_{LOS}^M(z) \]

\[ \varphi_{atmo} = \frac{-4\pi}{\lambda} \cdot \partial L_{LOS}(z) \]

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Wavelength</th>
<th>Delay (12.5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS-X</td>
<td>3.017 cm</td>
<td>25.3 rad</td>
</tr>
<tr>
<td>ALOS</td>
<td>23.62 cm</td>
<td>3.3 rad</td>
</tr>
</tbody>
</table>

M: 2008-01-28 S: 2008-08-02
Atmospheric corrections

- Integration of atmospheric path with weather data from European Centre for Medium-Range Weather Forecasts (ECMWF)

- Input: pressure level data of temperature and specific humidity
  - 37 pressure level data from 1 hPa to 1000 hPa

- Average delay/elevation ration $k_s^m$

$$k_s^m = S_s - S_m$$

with

$$S_m = \frac{\partial L_{LOS}^m(z_{\text{max}}) - \partial L_{LOS}^m(z_{\text{min}})}{z_{\text{max}} - z_{\text{min}}}$$

$$S_s = \frac{\partial L_{LOS}^s(z_{\text{max}}) - \partial L_{LOS}^s(z_{\text{min}})}{z_{\text{max}} - z_{\text{min}}}$$
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PS Deformation Map

- 43 TS-X SM scenes, descending
- 18 TS-X HSL scenes, descending
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Challenge and Difficulties

Test Site & TS-X acquisitions

Coherence analysis

Atmospheric corrections in troposphere

PSI results

Multi-Stack fusion
- Elevation offset $\Delta s$

Diagram:
- Orbit$_1$
- True height $h$
- Range
- $\Delta h_1$
- $\Delta s_1$
- $P_1$ (UTM$_1$)
Elevation offset $\Delta s$ with cross-heading tracks

- $\Delta h_1$
- $\Delta s_1$
- $\Delta s_2$
- $\Delta h_2$
- Elevation offset $\Delta s$ with cross-heading tracks

- Estimation of elevation offset with Iterative Closest Points (ICP) algorithm
  - Working with ‘similar’ shape
  - No need of correspondence points
• Density ca. 1144 PSs/Km\(^2\) → 4766 PSs/Km\(^2\)
- Assumption: only vertical deformation
Conclusion

- Successful application of PSI method with rocky volcano
- Multi-stack fusion possibility with different geometries
- Atmospheric delay not neglected due to large height difference
- Fast decorrelation of X-band in vegetated area (Fogo volcano)
- Future mission Tandem-L with larger wavelength and better temporal resolution
Thank you for your attention