DEM generation using ASAR (ENVISAT) for addressing hydrological characterization of Santa Cruz Island, Galapagos

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Aim & Methodology

- GIIWP GENERAL AIM: To understand the hydrological functioning of the Galapagos Islands
  - Fractured, insular environment undergoing increasing pressure on resource
- METHODOLOGY: To combine indirect & in-situ data acquisition
  - Lack of back ground data & difficulty of access to the field

- AIM OF DEM GENERATION:
  - To resolve lack of existing background data
    - Low accuracy 1:100,000 map (INERHI, PRONAREG, ORSTOM, 1987) then digitalized Souris, 2000 (DEM-IRD)
    - Low accuracy 90m SRTM DEM (2004)
    - No reference altitude points (Instituto Geografico Militar, Ecuador)
  - To obtain qualitative & quantitative data for hydrological modeling
Santa Cruz Island: Park land, agricultural zone & urbanization development

Total area: 986 km²
National Park area: 70%
The rest: Agricultural & urban zones

Generation of DEM – Choice of method

- **HYDROLOGICAL MODELLING REQUIREMENTS**
  - Topography 1:50,000

- **METHODS**
  - Optical stereoscopy - important cloud cover
  - SAR interferometry & radargrammetry
    - Tested and validated techniques – ERS & Radarsat
    - New potential with Envisat
    - Regular data acquisition over Galapagos - background mission
Interferometry

- No ERS1-ERS2 tandem pairs
- ASAR 35 to 70 days repeat
  - 3 asc. pairs
  - 2 desc. pairs
- Baselines 220 to 280 m
- Earthview InSar (Atlantis Sci.)
- External DEM for phase unwrap

Problems
- Noise and atmospheric artefacts
- Low coherence in vegetated zones
Radargrammetry

- **ASAR multiple incidence capacity**
  - 3 asc. images IS2 – IS3 – IS5
  - 3 desc. images IS2 – IS4 – IS6

- **Processing carried out by Gamma Remote Sensing**
  radargrammetry and space triangulation - Wegmüller et al., 2003

- **Integration of SRTM 90 m DEM**

- **Resulting DEM** – combination of different B/h and SRTM
Santa Cruz DEMs: 2000, 2004 and this study

Souris-IRD

Interferometric

SRTM – 90 m

Radargrammetric
Validation

- 2 databases of Ground Control Points generated

Field acquisition of GPS points

+ Digitized GCPs, road survey map

GCPs from GPS field acquisition

BLUE: GPS track
BLACK: GCPs from paper map

GPS along road tracking
Comparison of profiles:

1. **Sours Altitude Validation by Ground Control Points**
   - $y = 0.961x - 1.4544$, $R^2 = 0.98$

2. **SRTM Altitude Validation by Ground Control Points**
   - $y = 1.007x + 1.0976$, $R^2 = 0.9973$

3. **Interferometry Altitude Validation by Ground Control Points**
   - $y = 0.9136x - 14.514$, $R^2 = 0.9718$

4. **Radargrammetric Altitude Validation by Ground Control Points**
   - $y = 1.0081x - 0.3363$, $R^2 = 0.9975$
## Summary of DEMs

<table>
<thead>
<tr>
<th>DEM</th>
<th>Theodolite</th>
<th>min/max</th>
<th>GPS</th>
<th>min/max</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Souris-IRD (50 m)</td>
<td>21</td>
<td>1 m/50 m</td>
<td>31</td>
<td>0 m/113 m</td>
<td></td>
</tr>
<tr>
<td>SRTM (90 m)</td>
<td>9</td>
<td>0 m/35 m</td>
<td>12</td>
<td>0 m/48 m</td>
<td></td>
</tr>
<tr>
<td>Interferometric (20.4 m)</td>
<td>25</td>
<td>4 m/55 m</td>
<td>43</td>
<td>2 m/63 m</td>
<td>missing data</td>
</tr>
<tr>
<td>Radargrammetric (20 m)</td>
<td>9</td>
<td>0 m/35 m</td>
<td>11</td>
<td>0 m/49 m</td>
<td></td>
</tr>
</tbody>
</table>
River network

Extracted from SRTM (1) & radargrammetry (2) DEMs
this study

Mapped in 1986
INGALA/IRD/PRONAREG
SRTM & Radargrammetry comparison

1: SRTM river network
2: radargrammetric river network
3: SRTM watershed boundaries
4: radargrammetric watershed boundaries
Local scale validation

Map of fractures extracted from a GoogleEarth mosaic shown on the bottom right show a clear relationship with the drainage network and watershed boundaries. Oblique aerial view of a large open fractures is shown.
Pelican Bay Watershed & Water Management issues

Protected Galapagos National Park Area
Endemic bird nesting areas
Important runoff generation

Agricultural zone
Greatest need for water all year round
To ensure quality production

Known inundation zone during El Nino years

Deep well providing brackish water
Important risks of contamination

Actual limited surface runoff
Zone highly influenced by fractures

Known inundation zone during El Nino years

Exploited brackish water contaminated “grietas”
Conclusions

- SRTM 90 m good reference but with insufficient resolution
- Combining SRTM & radargrammetric/interferometric gives better results
- ASAR - ENVISAT represent a good potential for DEM generation
- Data error estimation & field data acquisition is a necessity

- Qualitative data
  - Theoretical river network & fracture distribution
  - Physical characteristics of watersheds

- Decision tool
  - Hydrological monitoring network of the system
  - Water resource management