Estimating the age of arid-zone alluvial fan surfaces using roughness measurements from spaceborne radar backscatter

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Background - Alluvial fan surfaces respond to geologic and climate changes as they record the deposition and erosion processes that govern their evolution. The goal of this research is to establish a new and widely applicable dating technique for desert alluvial surfaces that builds on surface roughness as a calibrated proxy for surface age and on our ability to measure surface roughness from orbital radar backscatter data.

Study area - Two alluvial chronosequences located in southern Israel within the Dead Sea rift valley (fig 1) are examined. The region is hyper-arid with a mean annual rainfall of 30 mm. The studied chronosequences of Shehoret and Raham consist of Holocene to late Pleistocene surfaces that have been previously dated with OSL (Porat et al., 2010). The older late Pleistocene surfaces (~87 ka) are characterized by a well-developed desert pavement. Both chronosequences are comprised of ~90% Phanerozoic carbonate clasts ~5-10% Pre-Cambrian magmatics and trace amounts of Phanerozoic sands and gravels. Vegetation cover on the studied alluvial surfaces is sparse (< 5%).

Results –

- All radar backscatter configurations analyzed display a general correlation between dB values and surface age (Fig. 5).
- Separation in all cases was achieved between the younger (Qa3 & Qa4) and older (Qa1a & Qa1b) age groups.
- HH-polarized image with 38° incidence angle and 6.25 m resolution yielded the best separation between all surfaces (fig Sb).
- Comparison between the different radar imaging configurations indicates that both spatial resolution and incidence angle play an important role in determining the achieved separation between terraces.
- A radar image with the optimal imaging configuration identified above was analyzed for the Raham fan and compared to field-based geomorphic mapping conducted by Crouvi et al. (2004) for this fan (Fig. 6). The radar-constrained ages are consistent with the previous (Crouvi et al., 2004) geomorphic age estimates for these surfaces (based on soil profile development).

Conclusions

- Radar backscatter in the studied desert alluvial fans serves as a feasible proxy for constraining surface age of Holocene – late Pleistocene terraces.
- HH polarization, high incidence angle (38°) and high spatial resolution (6.25 m) produced the best results for ALOS PalsAR data.
- Ongoing research is focused on determining lithological effects on radar backscatter.

Methods

1. Geomorphic field mapping.
2. Ground-based Surface Roughness (SR) measurements (ground-based LiDAR).
3. Age vs. SR calibration curves.
4. Radar backscatter from orbital data. ALOS-PALSAR L-Band, different polarizations (e.g., HH, HV), different incidence angles (e.g., 24°, 38°) and different resolutions (e.g., 6.25m, 12m).
5. Age vs. radar backscatter calibration curves (using the data from stages 1-4).
6. Testing at a different locations.

Figure 1. The main terraces of the Shehoret chronosequence capturing the monotonous reduction of surface roughness over time.

Table 1. Characteristic parameters of ALOS PalsAR images.

<table>
<thead>
<tr>
<th>Date</th>
<th>Band</th>
<th>Wavelength</th>
<th>Polarization</th>
<th>Incidence angle (center)</th>
<th>Ground-range resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>L-band</td>
<td>23 cm</td>
<td>HH</td>
<td>24°</td>
<td>6.25 m</td>
</tr>
<tr>
<td>2010</td>
<td>L-band</td>
<td>23 cm</td>
<td>HV</td>
<td>24°</td>
<td>6.25 m</td>
</tr>
<tr>
<td>2010</td>
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<td>30 cm</td>
<td>HH</td>
<td>24°</td>
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</tr>
</tbody>
</table>

Figure 2. Surface scanning by LiDAR. 50-100 m² representative areas were scanned for each of the surfaces. Scan resolution was 3 mm, with 3-4 views per site. Radar backscatter vs. surface age for Nahal Shehoret (e.g., Crouvi et al., 2004) for these terraces are in blue.

Figure 3. Radar backscatter vs. surface age for Nahal Shehoret (black square) and Nahal Raham (red points). Shaded red boxes mark the radar-constrained surface ages. Surface ages from Crouvi et al. (2004) for these terraces are in blue.

Figure 4. Age vs. RMS height in the Shehoret chronosequence. Surface age is inversely proportional to surface roughness. The rate of RMS reduction appears to decrease with time.

Figure 5. Statistical behavior of radar backscatter (db) vs. the surface age.

Figure 6. Radar backscatter vs. surface age for Nahal Shehoret (black square) and Nahal Raham (red points). Shaded red boxes mark the radar-constrained surface ages. Surface ages from Crouvi et al. (2004) for these terraces are in blue.