Extraction of Subsurface Features from InSAR-derived Digital Elevation Models

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Outline

• Context
  – Radar penetration & Subsurface mapping
  – Global DEMs (Digital Elevation Models)
• Materials and Methods
• Results
  – Extraction of subsurface features
  – Comparisons of different DEMs
• Conclusions
Introduction – Radar penetration & subsurface mapping

• radar penetration:
  – roughness of surface relative to wavelength: homogeneous, fine-grained thin (1-2 m thick) cover materials.
  – dielectric property: moisture content is less than about 1.0%.

• subsurface mapping:
  – a low-loss thin sand layer enhances the capability to image the subsurface sand-bedrock interface.
  – the skin depth ranges from 1.5 to 6 m at L-band, the SIR-A frequency shown by laboratory experiment.
  – field observations showed that the sand layer thickness ranges from 0.8 to 2 m.

  Courtesy P. Paillou et al.
Introduction – Global DEMs

• Global DEMs up to 30 m are available for public use
  – SRTM-C and –X DEM
  – ASTER GDEM
  – ICESat Elevation dataset

• InSAR-derived DEM for specific requirement
  – ALOS-PALSAR
  – TanDEM-X

• Problems of application to hyperarid areas
  – DSM (Digital Surface Model) or DSSM (Digital SubSurface Model) in hyperarid area?
  – Detect subsurface features? Bedrock height Mapping?
    Or surface lowered due to deep channels
Study Sites

• Eastern Sahara
  – Kufrah River
    • southeast Libya, 23°N-24°N, 23°E-24°E
    • a tributary of a paleodrainage system passing from south to north till Sarir Dalmah in Libya.

• Ténéré Desert
  • northeast Mali and northwest Chad
  • 15°N-20°N, 10°E-20°E

– Gilf Kebir Plateau
  • southwest Egypt, 23°N-24°N, 26°E-28°E
  • 1,300 crater-like features over 4,000 km² (Paillou, P., Schuster, M., Tooth, S., et al., 2009)
Several global DEM datasets are used to investigate their penetration depth, which is a key characteristic in terms of subsurface features detection and bedrock mapping.

<table>
<thead>
<tr>
<th></th>
<th>ASTER GDEM</th>
<th>SRTM-C DEM</th>
<th>SRTM-X DEM</th>
<th>ICESat /GLA14</th>
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<td>TOPEX/</td>
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<tr>
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<td>±15 m (rel.)</td>
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<td>Vertical accuracy</td>
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<td>±16 m (abs.)</td>
<td>cm scale</td>
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<td>±10 m (rel.)</td>
<td>±6 m (rel.)</td>
<td>±6 m (rel.)</td>
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Materials and Methods

- ALOS-PALSAR 25 m Forest and non-Forest (FNF) map was used to delineate paleo-channels.
  - Japan Aerospace Exploration Agency (JAXA), has produced the 4 year, 25m spacing global PALSAR mosaics from 2007 to 2010 using the accurate SAR processing.
  - PALSAR HH, HV backscatter is slope corrected and ortho-rectified using the SRTM, and the radiometrically calibrated.

Courtesy M. Schimada et al., JAXA
A paleoriver is delineated on PALSAR HH backscatter image and overlaid on Gaussian-filtered and hill-shaded SRTM-C DEM.
Results - Extraction of subsurface features

Eastern Sahara

A paleoriver is delineated on PALSAR HH backscatter image and overlaid on Gaussian-filtered and hill-shaded SRTM-C DEM.
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Results - Extraction of subsurface features

Ténéré Desert – Part A
Results - Extraction of subsurface features
Ténéré Desert – Part A
Results - Extraction of subsurface features

Ténéré Desert – Part A

PALSAR doesn’t show this linear features due to affluence by low backscatter from background.

Delineated from PALSAR HH backscatter
Results - Extraction of subsurface features

Ténéré Desert – Part A

PALSAR doesn’t show this linear features due to affluence by low backscatter from background.

Delineated from PALSAR HH backscatter

fractures or faults?
Results - Extraction of subsurface features

Ténéré Desert – Part A

None of the linear and circular features are shown in Landsat image, whereas most recognisable in PALSAR HH backscatter image.

Most circular features are shown in SRTM-C DEM, but less apparent in PALSAR images.
Results - Extraction of subsurface features

Ténéré Desert – Part B

Optical image: only shows outcrop rock.

SRTM-C DEM: rock with elevation different from background, also show different forms of sand cover.

ALOS-PALSAR image: bedrock under thin sand layer.

only outcrop rock can be seen

Landsat image

SRTM-C DEM

ALOS/PALSAR
Optical image: only shows outcrop rock.

SRTM-C DEM: rock with elevation different from background, also show different forms of sand cover.

ALOS-PALSAR image: bedrock under thin sand layer.
DEM appearance to show surface expression of buried paleorivers.
In this study area, ASTER GDEM is very noisy.

SRTM-C DEM agrees closely with ICESat/GLA14.

However, SRTM-X DEM has a large bias with ICESat/GLA14 and SRTM-C DEM, which appears to be caused by phase adjustment difficulties (Marschalk, U and Roth, A et al., 2004).
Results - Comparisons of different DEMs

Gilf Kebir Plateau

**GT1**

<table>
<thead>
<tr>
<th>DEM-difference</th>
<th>Mean</th>
<th>Std</th>
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<tbody>
<tr>
<td>ASTER - ICESat</td>
<td>1.90</td>
<td>15.52</td>
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<tr>
<td>SRTM-C - ICESat</td>
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<td>2.41</td>
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**GT2**

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**GT3**

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<td>SRTM-C - ICESat</td>
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<td>SRTM-X - ICESat</td>
<td>-5.37</td>
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**GT4**

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<td>14.11</td>
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<tr>
<td>SRTM-C - ICESat</td>
<td>3.00</td>
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<tr>
<td>SRTM-X - ICESat</td>
<td>-1.56</td>
<td>3.71</td>
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</table>
ASTER GDEM is also very noisy.

SRTM-C DEM agrees closely with ICESat/GLA14, but 2-3 m bias within steep slope area.

SRTM-X DEM has a negative bias of ≈2~5 m from ICESat/GLA14.
R: SRTM-C DEM, G:PALSAR-HH, B:ASTER GDEM

- ASTER GDEM acts the worst to show the profile of paleoriver.
- SRTM-C DEM shows lower elevations across paleoriver bed, while PALSAR-HH image displays lower backscatter.
Results - Comparisons of different DEMs

Detail investigation of eastern Sahara

Topographic features analysing

- More information shown by combining both SRTM-C DEM and ALOS-PALSAR backscatter.
- Both SRTM-C DEM and PALSAR backscatter image show the crater-like feature.

R: SRTM-C DEM, G: PALSAR-HH, B: ASTER GDEM

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1. SRTM-C DEM agrees closely with ICESat elevation and are superior to ASTER GDEM and SRTM-X DEM, but is of insufficient accuracy in terms of heighting expressions of subsurface features ability over hyperarid regions.

2. Comparing with SRTM DEM, ALOS/PALSAR image shows more detailed subsurface features, but is easily affected by similar backscatterers from background.

3. Combining subsurface features extraction results of SRTM-C DEM and PALSAR image, the study shows a great potential to map the bedrock elevation by using InSAR of lower frequency and longer baseline, such as ALOS-2/PALSAR-2 datasets.
Thank you for your attention!
Questions & Suggestions please!