Archaeological Site and Landscape Detection with Synthetic Aperture Radar (SAR)

Sites in Context from SAR Data

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San Clemente Island

AirSAR Flight Paths
San Clemente Island: April 7, 2002

AirSAR Flight Paths
- 54-1_hv_topsar_40mhz
- 144-1_hv_topsar_40mhz
- 144-2_hv_topsar_40mhz
- 144-3_hv_topsar_40mhz
- 144-4_hv_topsar_40mhz
- 324-1_hv_topsar_40mhz
- 324-2_hv_topsar_40mhz
- 324-3_hv_topsar_30mhz
Site Detection with SAR

- Typical San Clemente Island Site
- Dense grasses in middle
- Species of plants that ring center vary
### AirSAR and GeoSAR

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Frequency band</th>
<th>Bandwidth (MHz)</th>
<th>Band length (cm)</th>
<th>Single-look range resolution (m)</th>
<th>Polarization(s)</th>
<th>Interferometric</th>
<th>Pixel size in this study, after orthorectification and post-processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRSAR</td>
<td>P</td>
<td>20</td>
<td>68</td>
<td>7.5</td>
<td>HH, VV, HV, VH</td>
<td>No</td>
<td>5,5</td>
</tr>
<tr>
<td>AIRSAR</td>
<td>L</td>
<td>40, 80</td>
<td>25</td>
<td>3.7, 1.8</td>
<td>HH, VV, HV, VH</td>
<td>Yes</td>
<td>5,5</td>
</tr>
<tr>
<td>AIRSAR</td>
<td>C</td>
<td>40</td>
<td>5.7</td>
<td>3.7</td>
<td>HH, VV, HV, VH</td>
<td>Yes</td>
<td>5,5</td>
</tr>
<tr>
<td>GeoSAR</td>
<td>P</td>
<td>160 (max)</td>
<td>86</td>
<td>0.9</td>
<td>HH, HV or VV &amp; VH</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Too Notched</strong></td>
<td><strong>X</strong></td>
<td><strong>160</strong></td>
<td><strong>3</strong></td>
<td><strong>0.9</strong></td>
<td><strong>VV</strong></td>
<td><strong>Yes</strong></td>
<td><strong>3.3 DEM Image 5,5</strong></td>
</tr>
</tbody>
</table>

Ran tests of statistical association with archaeological sites for all bands and polarizations
PVV

75cm long, not affected by vegetation and small rocks

Organic soils, more moisture than surrounding soils
25cm long, not affected much by vertical vegetation structure, scattered by small rocks
5cm long, double-bounce from vertical grass structure
Testing the Null Hypothesis:

\[ H_0 : \bar{x}_1 = \bar{x}_2 \]

The null hypothesis is that the two sets of samples are drawn from the same universe of values. If so, the difference between the means of the two samples will be less than 1.96 standard deviations of the difference of the means. Or:

\[
\left( \frac{1}{n} \sum x_1 / n \right) - \left( \frac{1}{n} \sum x_2 / n \right) < 1.96 \sqrt{\frac{\sigma_1}{n} + \frac{\sigma_2}{n}}
\]
Model showing the number of datasets statistically associated with archaeological sites on San Clemente Island, and known archaeological sites. Datasets include PVV, CVV and LHH. Overlayed here are the locations of archaeological sites as determined by 100% survey of accessible land of the island.

Legend

- Known Archaeological Sites

Number of datasets statistically associated with site locations

6 Kilometers
## Extremely High Gain Statistic

<table>
<thead>
<tr>
<th>Number of associated SAR bands</th>
<th>% of area</th>
<th>% of sites</th>
<th>Gain statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>75.55375</td>
<td>16</td>
<td>−3.85252</td>
</tr>
<tr>
<td>1</td>
<td>20.92681</td>
<td>37</td>
<td>0.440908</td>
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<tr>
<td>2</td>
<td>3.329719</td>
<td>39</td>
<td>0.956286</td>
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<tr>
<td>3</td>
<td>0.189723</td>
<td>8.3</td>
<td>0.997753</td>
</tr>
</tbody>
</table>
Published in

Remote Sensing in Archaeology

Mapping Archaeological Landscapes from Space
Enhancements

- Machine learning
- Terrain-based archaeological predictive models
- Cross-validate
Enhancements

ROC curve:
Better test of model productivity
We want to run this on the SCI results
Intereferometric Analysis of C and X-Bands
Cost surface: energy expenditure increases from light yellow to red and then blue.

Why are clusters of habitation sites and a cluster of ritual sites located away from sources of food, materials, and water?
Viewshed

- Ability to see wide areas of ocean
  - Exploit windows of opportunity as pods of sea mammals, logs, and whales pass by
- Ability to coordinate with those who must mobilize quickly to exploit resources
Faroe Islands Whale Hunting

“This photo was taken from land, while the boats were hunting a group of pilot whales into a fjord. The whales were killed a few minutes later, after swimming on to the beach or near to the beach, where men were waiting. “

“The hunting is not planned, boats don’t go out searching for the whales, it happens when a boat or perhaps a ferry happens to finds a group of pilot whales near land, and then they pass the message on and other boats sail out to chase them into the nearest bay or fjord. “


Photos by Eileen Sanda, shared under Creative Commons license

Such opportunistic hunting of sea mammals is still practiced today; it is probably similar to practice at SCI. It requires communication and coordination
Relationships Among Southern Channel Island Sites

Large Ritual Sites
Seen as Bright Red Areas

Line from Ledge Site to Lemon Tank Site (seen below, photo taken looking north) extends to Two Harbors area of Santa Catalina Island, site of largest settlement there.
SAR Penetration of Dry Soils

PALSAR image of riverbeds and tributaries now covered by desert sand in Kufrah Basin, Libya.
Mojave Buried Shorelines

- As glaciers receded, huge lakes formed in the Mojave
- The lakes attracted mega fauna, now extinct
- These in turn attracted some of the human groups that first entered the New World
- We see remnants of these lakes as playa
Clovis Culture

Entered New World over the Bering Land Bridge, then moved south when ice-free corridor formed

Used finely made, specialized tools

Megafauna extinct about 1,000 years after human entry, c. 13,000 B.P.

Clovis tools no longer used
Western Stemmed and Clovis

Also known as Western Pluvial, San Dieguito, etc.: 14,300 -8,000 B.P

Fluted points, 13,500-10,000 B.P. (includes Folsum)

Were these used by the first humans to enter the New World?
Interestingly, early dates for human occupation on San Clemente and all other Channel Islands

in *Quaternary Science Reviews*, however, is evidence in the form of pollen and charcoal from soil cores in deep water within three lakes on Sanak Island in the Aleutians, which suggests that Sanak (and perhaps the corridor into the American continents) was ice free by 17,000 years ago.

Stone tools found in Paisley Cave, Oregon, with a very reliable date of 14,300 before the present.
UAVSAR Data Search

You can search by flight ID, line ID, line sitename, line description, and date of acquisition (in YMD or YMDDD format). Only flight IDs can be searched as a range (e.g., "200001-020003"). To search multiple criteria using OR, separate your search with commas (e.g., "San Andreas, 26532").
To search multiple criteria using AND, separate your search with period (e.g., "Hab1 11042")
To search multiple criteria using NOT, separate your search with exclamation mark (e.g., "Hab1! 11042").

In the map, click on the download icons to download the data.
The data fusion method used in this study is the Principal Component (PC) spectral sharpening algorithm (Welch and Ahlers, 1987). It is a popular data fusion method and normally used to sharpen a low resolution multi-band image with a high resolution panchromatic band. The optical WorldView-2 multi-band data acquired on October 14, 2010 was fused with the ALOS/PALSAR L-band image acquired in HH mode on September 17, 2008. Before fusing the data sets, the PALSAR data were filtered using the refined Lee filter method with a $3 \times 3$ window size. The data were also interpolated from the original 12.5 m spatial resolution to 0.5 m and co-registered to the WorldView-2 panchromatic data. A color composite of the fused SAR/WorldView-2 bands 7, 4, 3 displayed as RGB rendered the best color contrast, as shown in Fig. 4.
Fig. 4. (a) & (c) are the WorldView-2 panchromatic and multi-band (7, 4, 3) data, respectively, (b) is the resampled ALOS/PALSAR data and (d) is the hybrid WorldView-2/PALSAR.

Ahmed Gaber, Magaly Koch, M. Helmi Griesh, Motoyuki Sato, Farouk El-Baz

Near-surface imaging of a buried foundation in the Western Desert, Egypt, using space-borne and ground penetrating radar


http://dx.doi.org/10.1016/j.jas.2012.12.019
Archaeology = Material in Context

Archaeologists analyze uncontaminated material in context.

Residue analysis to reveal ancient diet.

Stratigraphic integrity.

Total carbon in a specimen.

C¹⁴ (Amount becomes less with time).

Living, Moment of Death, Old, Older, "Infinite Age".

No measurable radiation.
Thank You

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