Using NASA SAR Correlation Imagery to Preserve the Lines and Geoglyphs of Nasca and Pampas de Jumana World Heritage Site

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Nasca Lines

Lines, geometric shapes, figures outlining animals, plants, humans, and mythological figures. Some date to the earlier Paracas culture. These same designs are seen on Nasca pottery.

Trapezoid: ritual areas?

Whale, symbolizing importance of coastal environment
Nasca Lines: 
Role in Protecting the Environment

Rivers and stream begin in the high Andes, run through Nasca Lines WHS, and deliver water, nourishment, and pollutants to the coastal Pacific.
Coastal Protected Areas

- San Fernando Bay National Reserve
- National Reserve of Paracas
Two flights: The first set of UAVSAR data was collected on 19 March 2013 and the second on 23 March 2015.
Greenpeace disturbance area, December 2014.

A path taken to the *pampas* can be easily traced.

A large area where the equipment was left and the participants congregated is prominently decorrelated.

Area where the banner was placed is represented by the area of decorrelation near the hummingbird geoglyph.

Grey areas have correlation near 1. Black areas indicate lower values.
Filtered and Colorized Image of Hummingbird Disturbance
A Wilcoxon rank-sum test indicates, at a confidence level greater than 0.999, that the correlation values within and around the Hummingbird are lower than those of the general area.
Histogram Comparison

Pixel value comparison: hummingbird versus entire tile

Blue: hummingbird area
Red: entire SAR tile

More disturbance

Less disturbance

Red is entire correlation tile, blue is area around Hummingbird

Wilcoxon rank sum test with continuity correction

## data: testbirdvals and t
## W = 10872000, p-value < 2.2e-16

Statistical test of difference between the two sets of pixel values indicates that they are from different populations with virtual certainty.
Sentinel-1 Satellite Correlation

Returns (and patterns) are different for crops and natural vegetation.

Road used during 16-day window.

Water erosion during 16-day window.
Decorrelation in the Wider Landscape

- Colluvium activity
- Vegetation
- Paths
- Roads
- Low decorrelation
- Some decorrelation

Legend:
- High: 1
- Low: 0

Kilometers: 2 1 0 2
Current Project
Selected Sites

- **Palpa**
  - Contains the most significant disturbance

- **Pampa**
  - Contains best known glyphs

- **Cahuachi**
  - Capital, threatened by looting and development
Access to GIS Database
Ministerio, CSRM Foundation, JPL/NASA
Real-Time Data and Analysis Sharing Is In Place

Data sent to and from CSRM, Ministerio de Cultura, JPL/NASA

JPL/NASA develops correlation images

CSRM digitizes disturbance areas and conducts spatial and statistical analyses

Ministerio de Cultura verifies and identifies on the ground

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Extensive Looting
Cahuachi

A single disturbance area of the pyramid complex at Cahuachi, showing looting activity and excavated dirt piled up in the season streambed to the southwest of the complex.

Vegetation can be differentiated, crops vs. native

Road. Decorrelation indicates that it has been used. SAME CAN BE DONE EVERY 8 DAYS W SENTINEL 1 CORTRELATION
Interferogram of Mining Area

Mina Marcona, Peru
20150505_20150716

Sentinel 1A ARIA correlation image
Colors indicate amount of disturbance between observations (red – largest)

Sentinel 1A ARIA Interferogram
Colors indicate relative change in surface height
Applications

- Monitoring landscape disturbance in arid regions
- Monitoring vegetative change
- Monitoring mining and looting
- Used in conjunction with optical imagery, monitoring more specific effects of landscape disturbance
- Monitoring land slides, mudslides
- All done in a way that provides immediate and ongoing collaboration