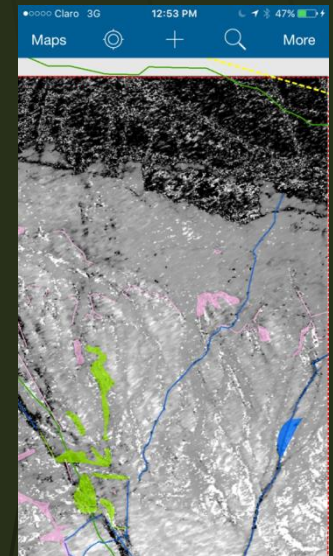
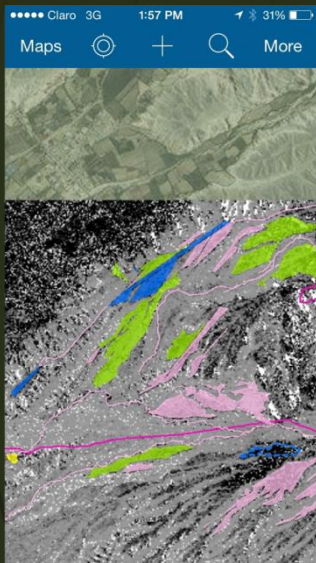




# Using NASA SAR Correlation Imagery to Preserve the Lines and Geoglyphs of Nasca and Pampas de Jumana World Heritage Site



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Governing Board Member, HIST

**13 September 2016**  
**2nd Huangshan Dialogue on UNESCO Sites**  
**Huangshan, China**



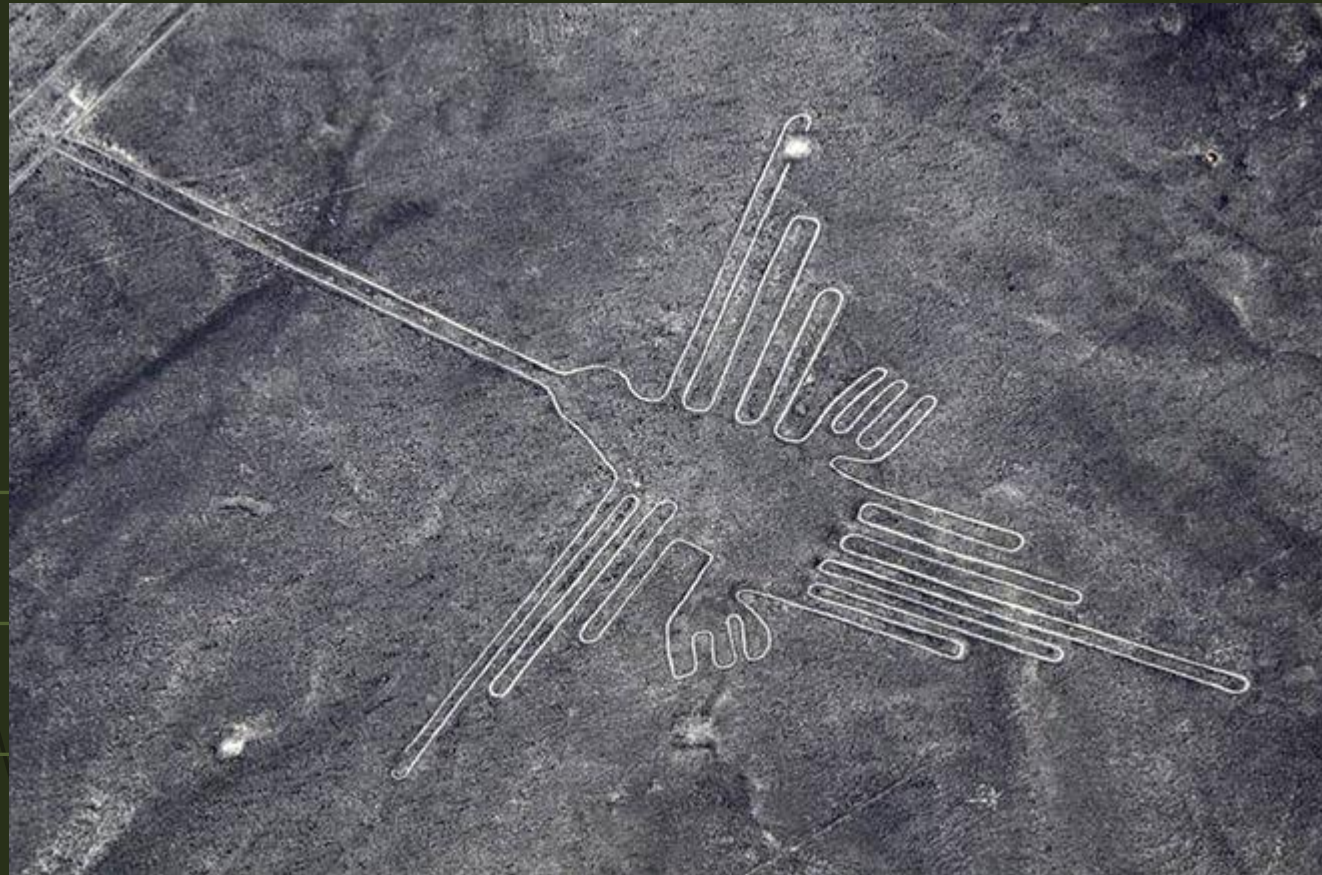
# Nasca Lines

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?

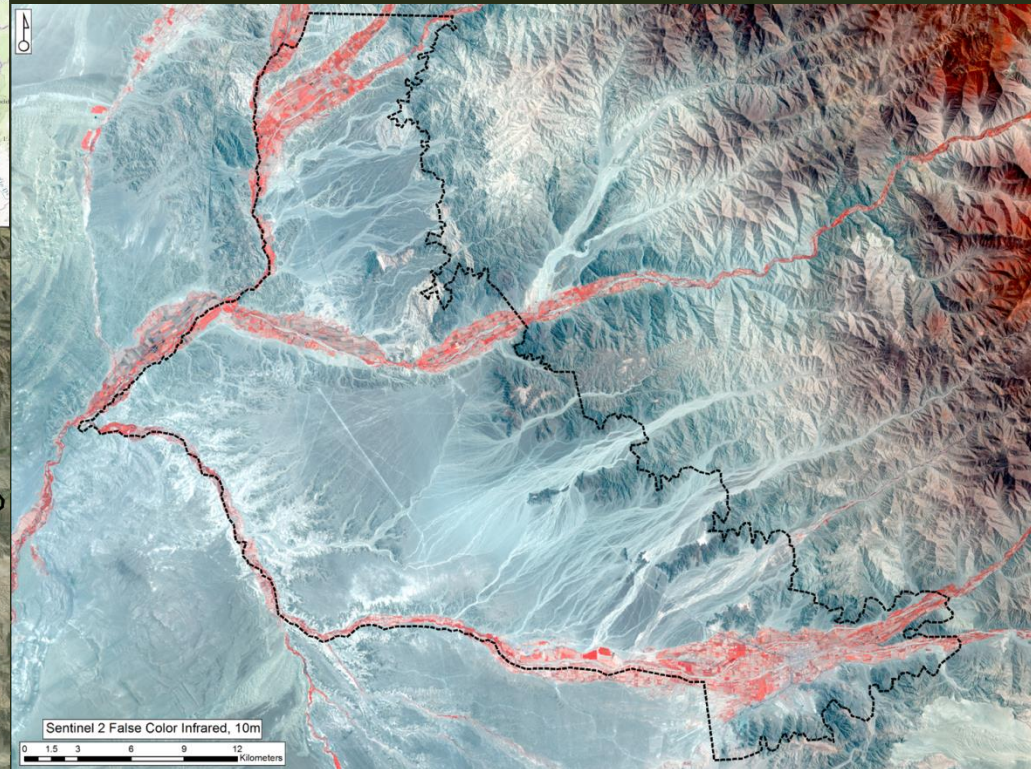
Whale, symbolizing importance of coastal environment





# 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

National Reserve of Paracas

San Fernando Bay National Reserve





# UAVSAR Platform and Flight line



Two flights: The first set of UAVSAR data was collected on 19 March 2013 and the second on 23 March 2015.



# UAVSAR correlation over Nasca

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

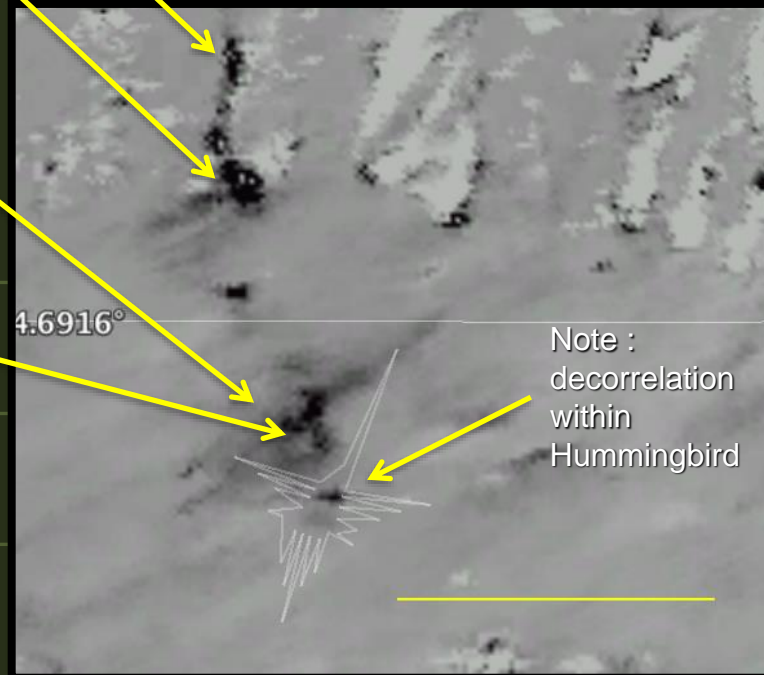
Area where the banner was placed is represented by the area of decorrelation near the hummingbird geoglyph.

Grey areas have correlation near 1.  
Black areas indicate lower values.

Google Earth



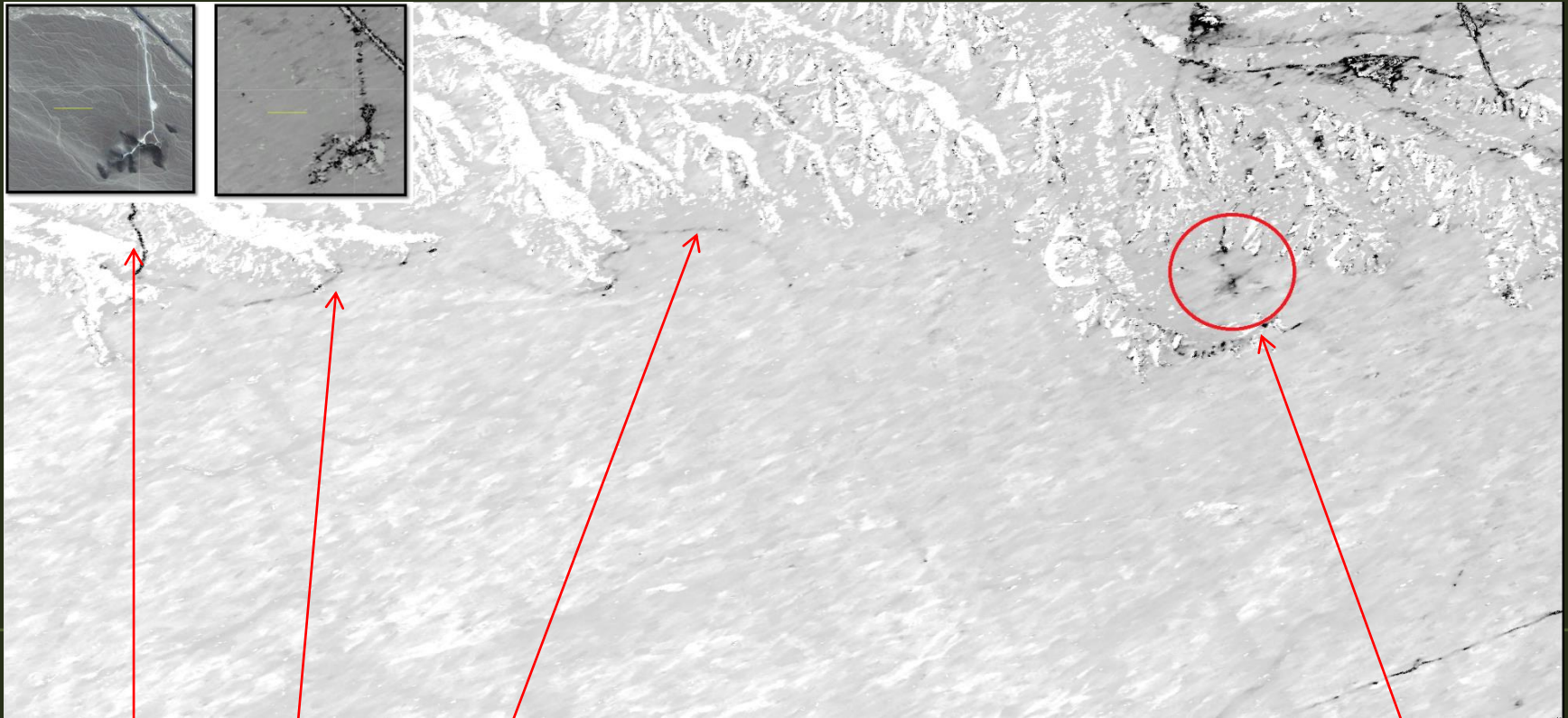
UAVSAR



Note :  
decorrelation  
within  
Hummingbird



# UAVSAR Correlation Image

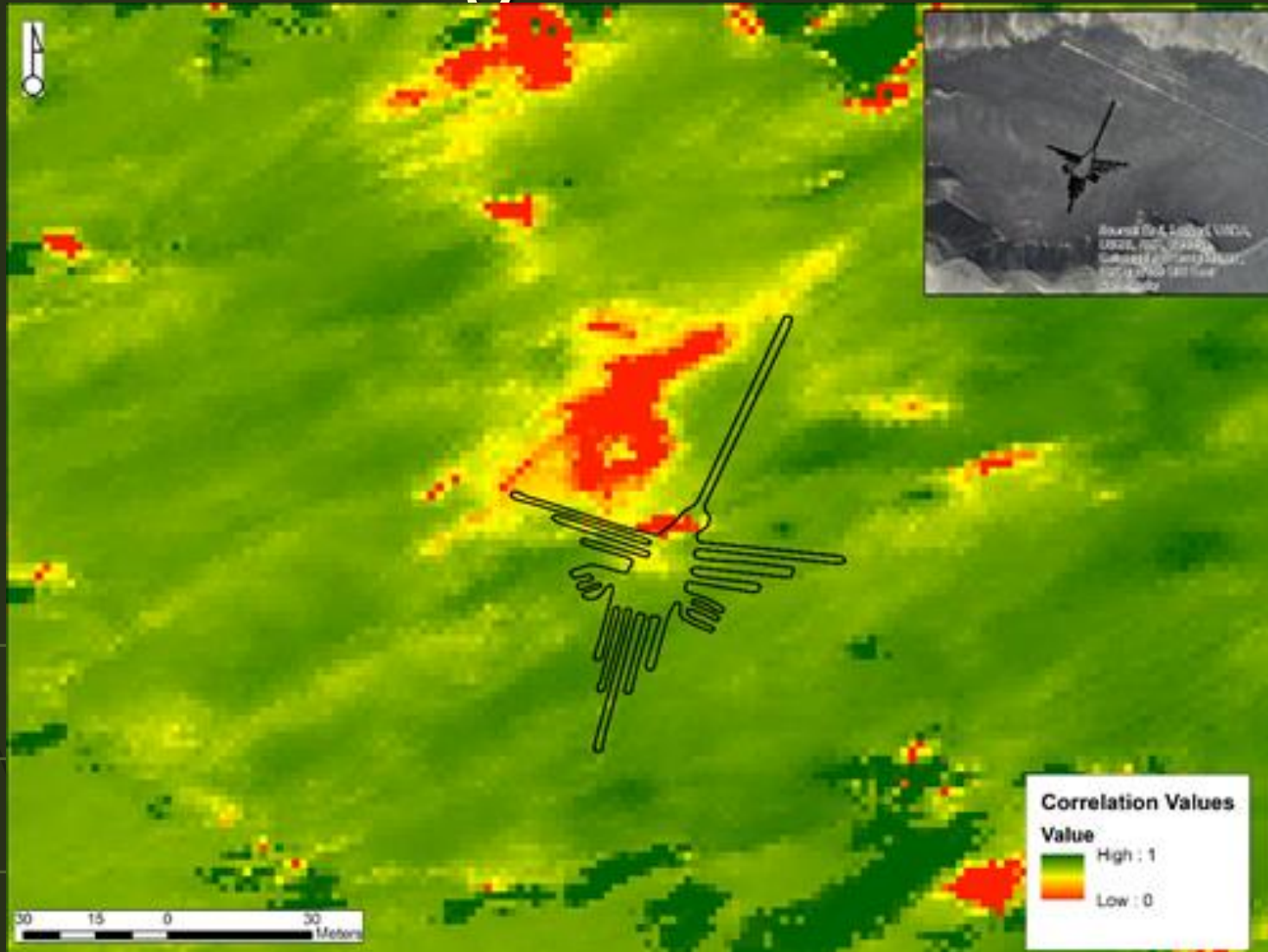


Road and pedestrian traffic

Hummingbird

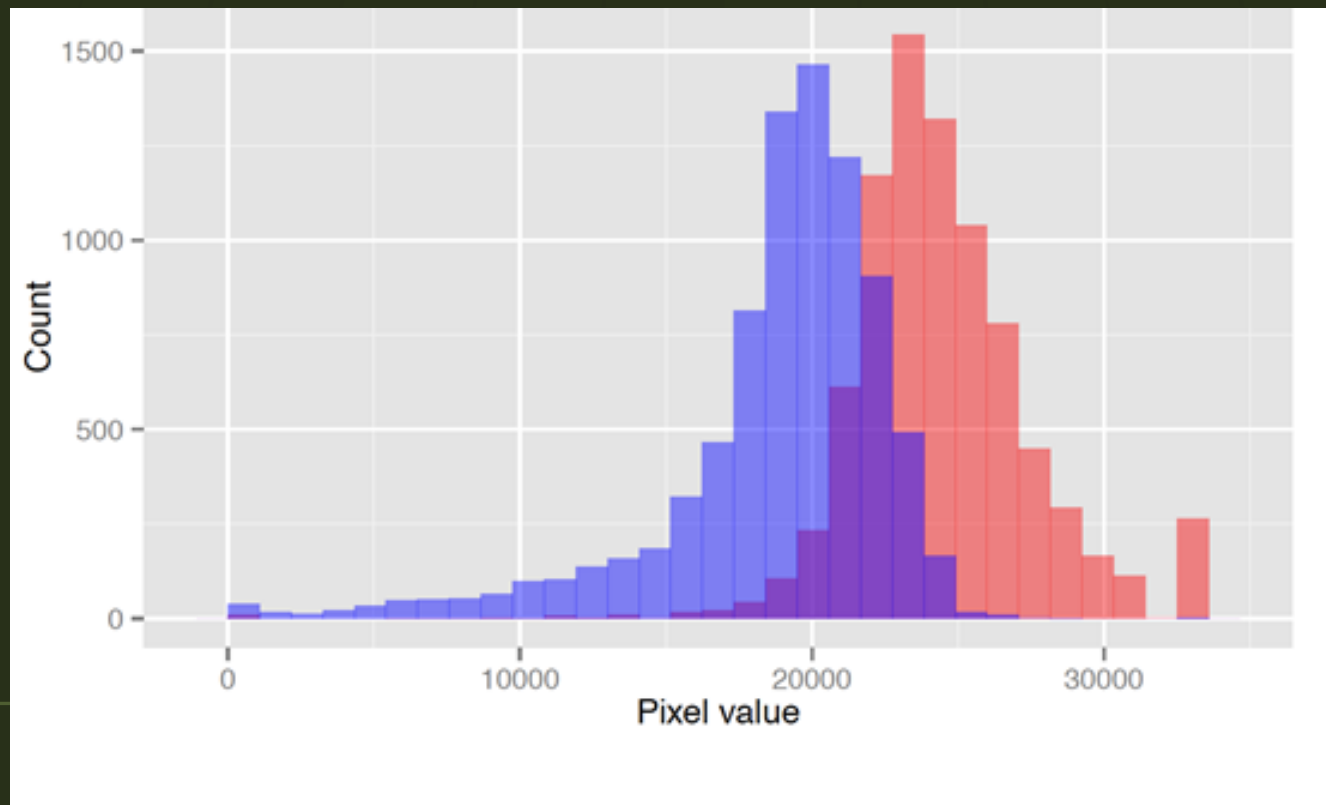


# Filtered and Colorized Image of Hummingbird Disturbance





# Histogram: Inside and Out of Hummingbird Area



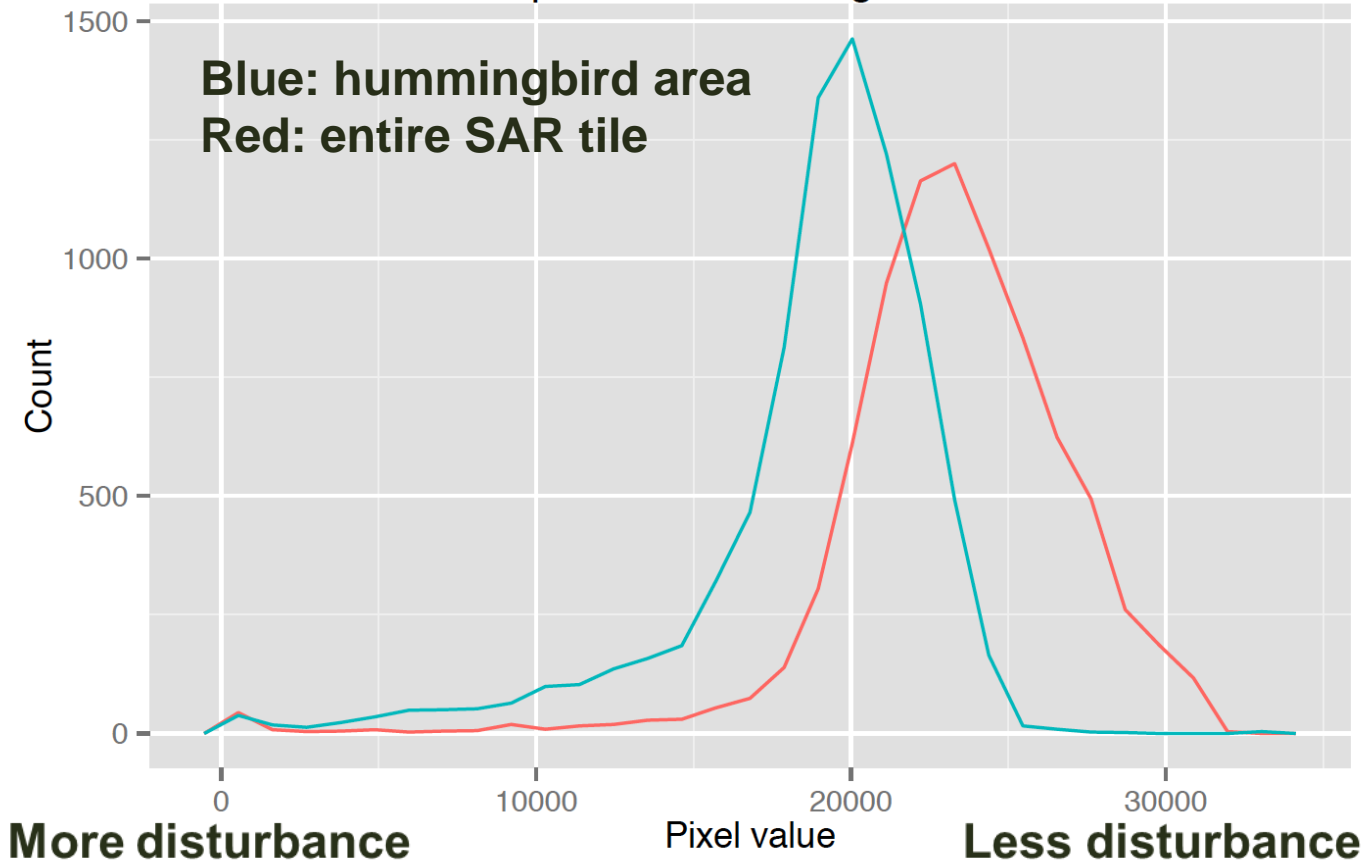
A Wilcoxon rank-sum test indicates, at a confidence level greater than 0.999, that the correlation values within and around the Hummingbird are lower than those of the general area.



# Histogram Comparison

Pixel value comparison: hummingbird versus entire tile

**Blue:** hummingbird area  
**Red:** entire SAR tile



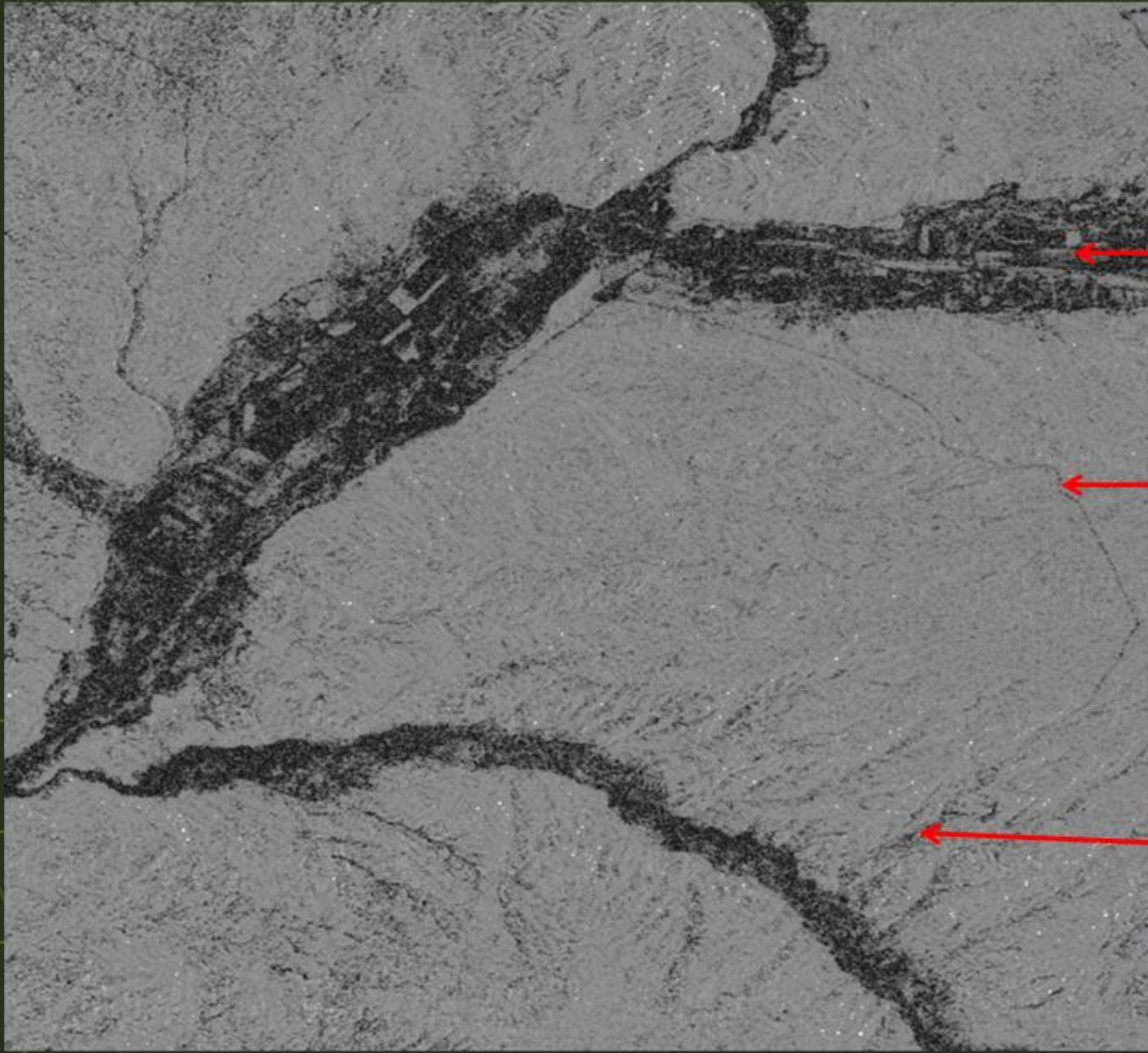
## Wilcoxon rank  
sum test with continuity  
correction  
##  
## data: testbirdvals  
and t  
## W = 10872000, p-value  
< 2.2e-16

Statistical test of  
difference  
between the two  
sets of pixel  
values indicates  
that they are from  
different  
populations with  
virtual certainty

Red is entire correlation tile, blue is area around Hummingbird



# Sentinel-1 Satellite Correlation



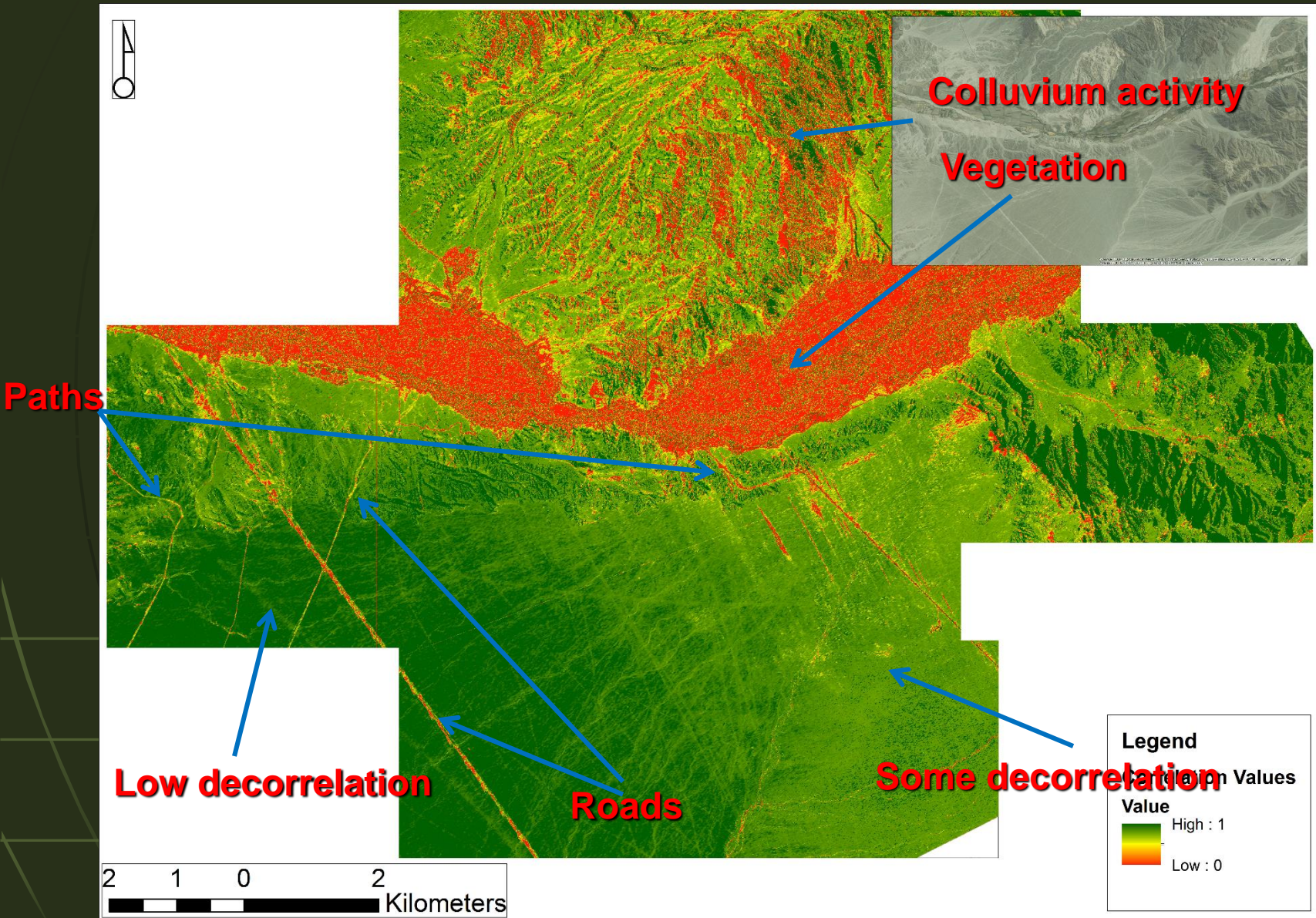
Returns (and patterns) are different for crops and natural vegetation

Road used during 16-day window

Water erosion during 16-day window



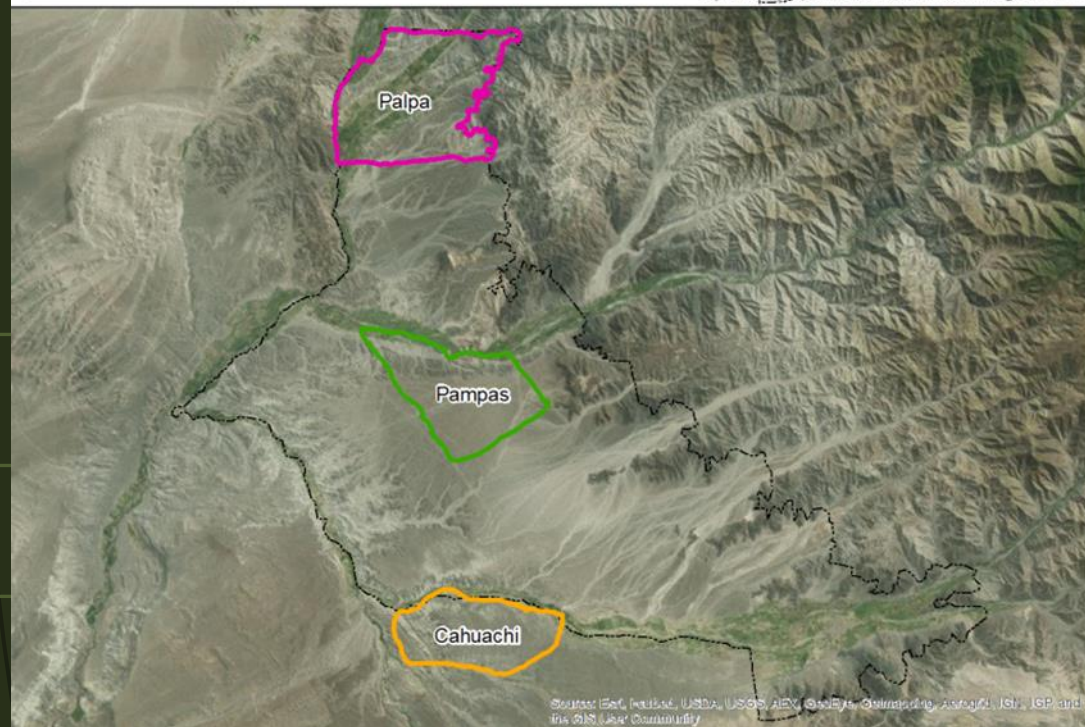
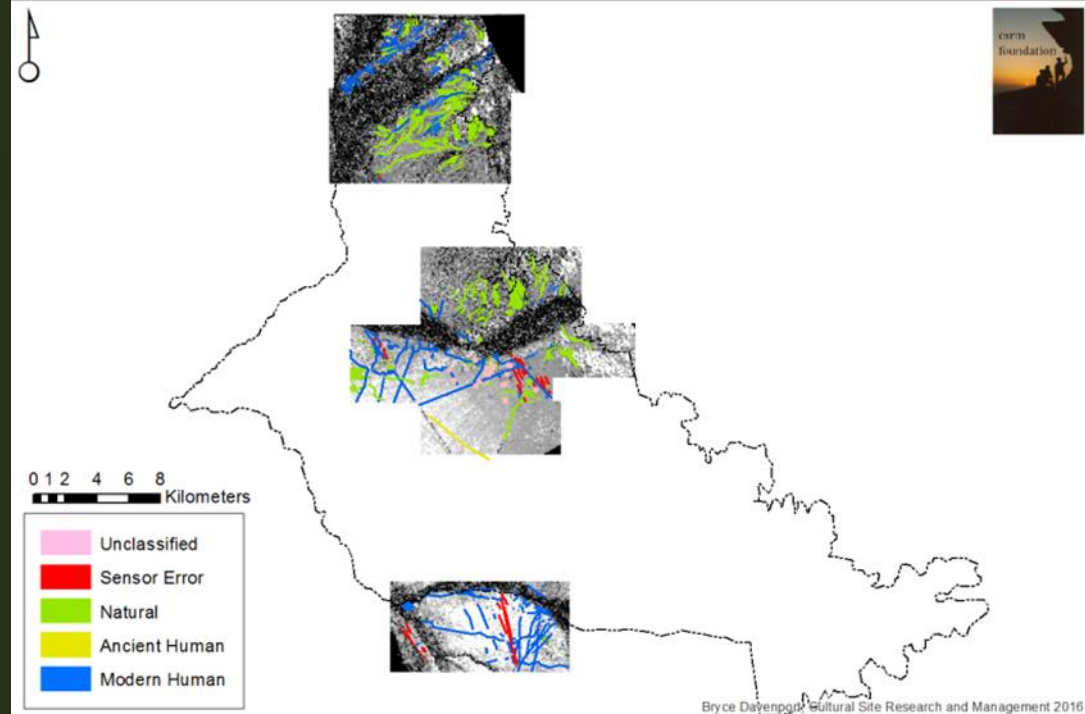
# Decorrelation in the Wider Landscape





# Current Project Selected Sites

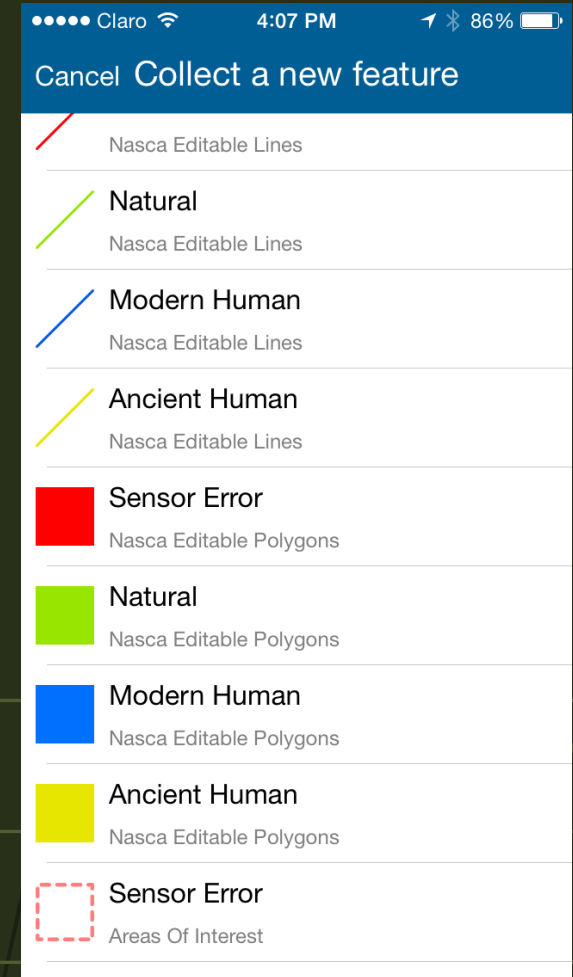
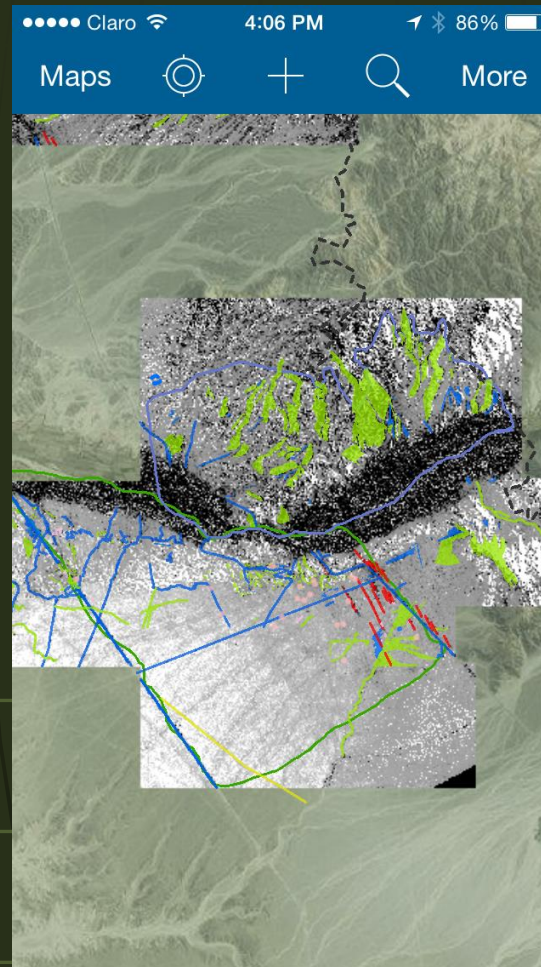
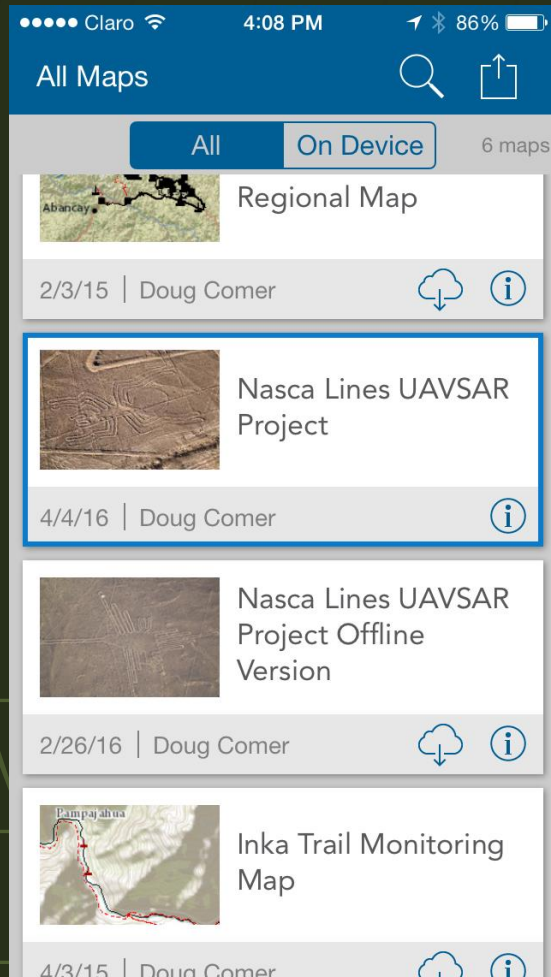
- Palpa
  - Contains the most significant disturbance
- Pampa
  - Contains best known glyphs
- Cahuachi
  - Capital, threatened by looting and development





# Access to GIS Database

## Ministerio, CSRM Foundation, JPL/NASA





# Real-Time Data and Analysis Sharing Is In Place





# Extensive Looting



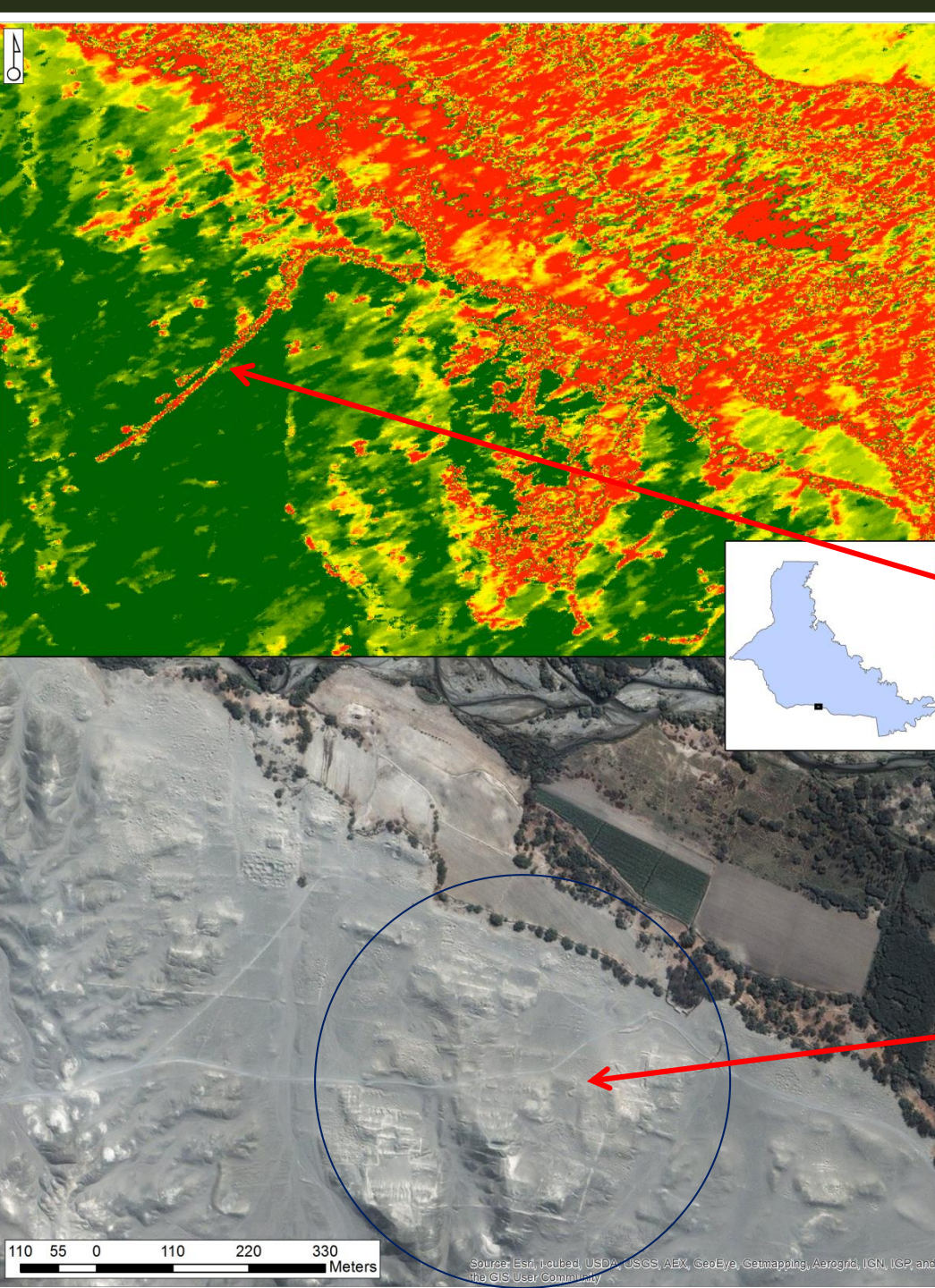


# Cahuachi

Vegetation can  
be differentiated,  
crops vs. native

Road. Decorrelation  
indicates that it has been  
used. SAME CAN BE DONE  
EVERY 8 DAYS W  
SENTINAL 1  
CORTRELATION

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





# Interferogram of Mining Area

Mina Marcona, Peru

20150505\_20150716

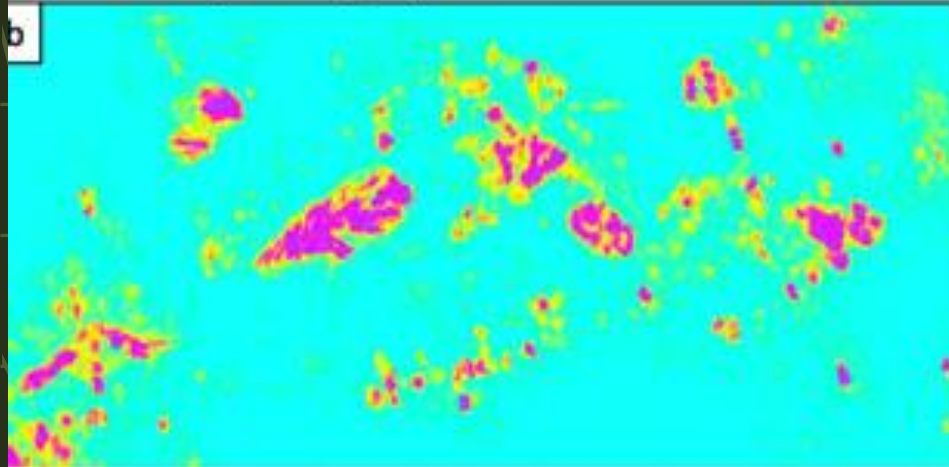
Google Earth

a



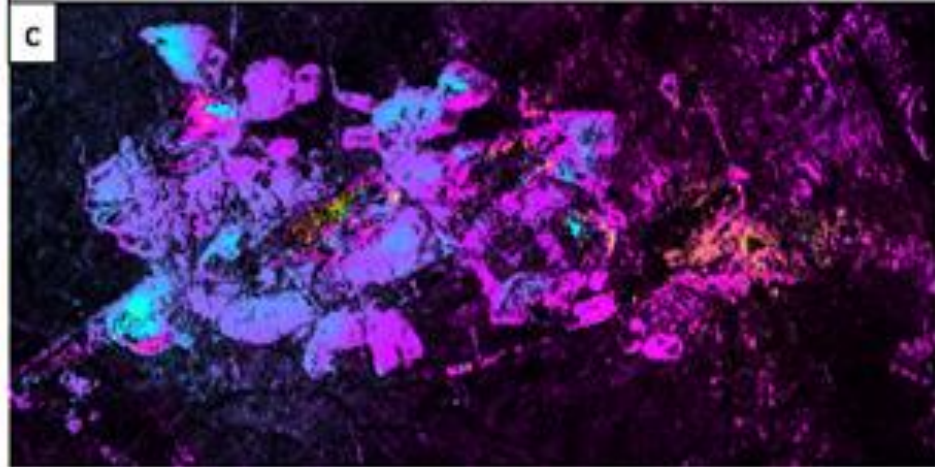
Sentinel 1A ARIA correlation image  
Colors indicate amount of disturbance between  
observations (red – largest)

b



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

c





# 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