Image Cross-Correlation Using COSI-Corr: A Versatile Technique to Monitor and Quantify Surface Deformation in Space and Time

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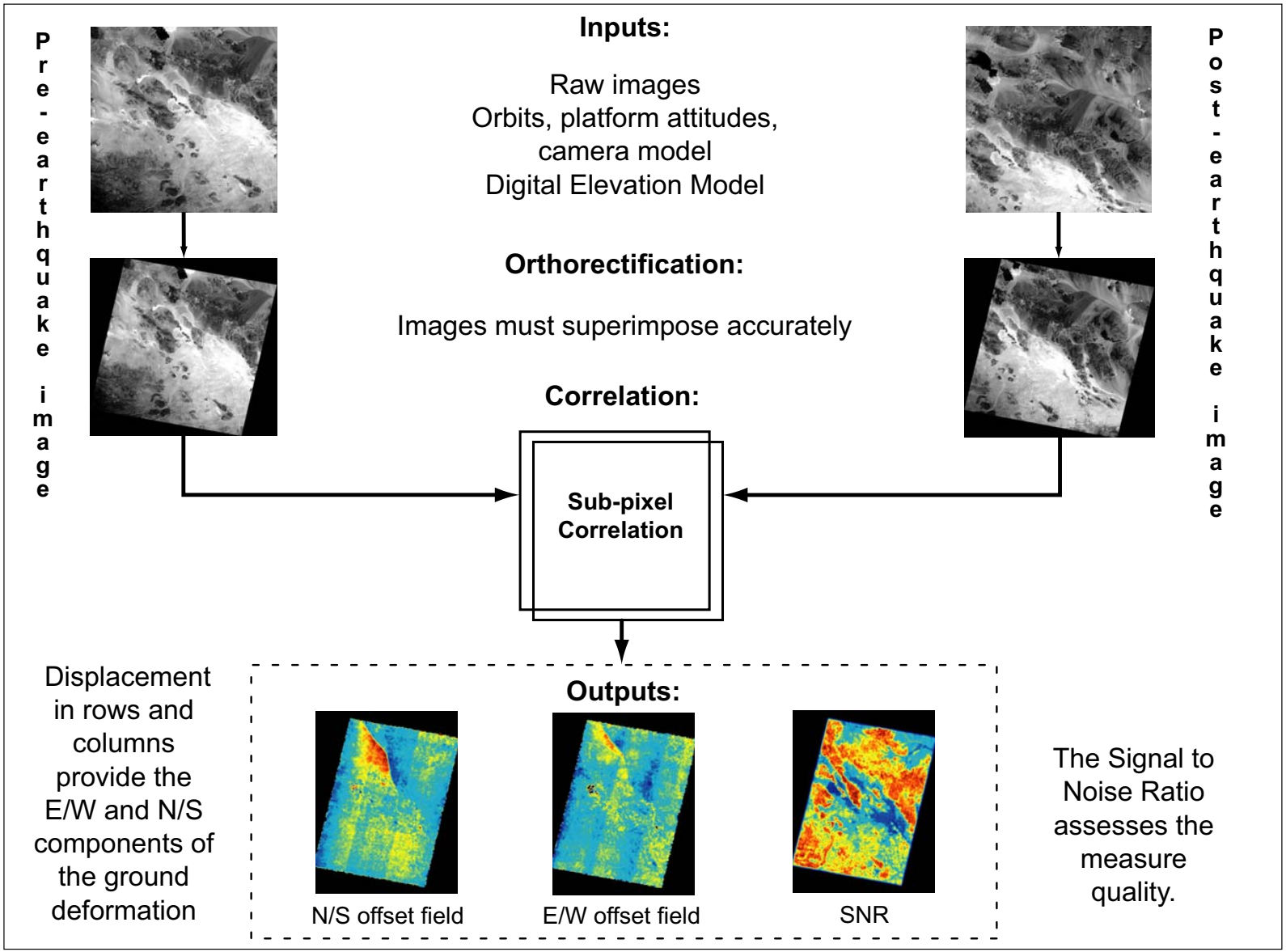
AGU 2011, Invited

COSI-Corr: Co-registration of Optically Sensed Images and Correlation



Leprince et al., 2007 - http://www.tectonics.caltech.edu/slip_history/spot_coseis/

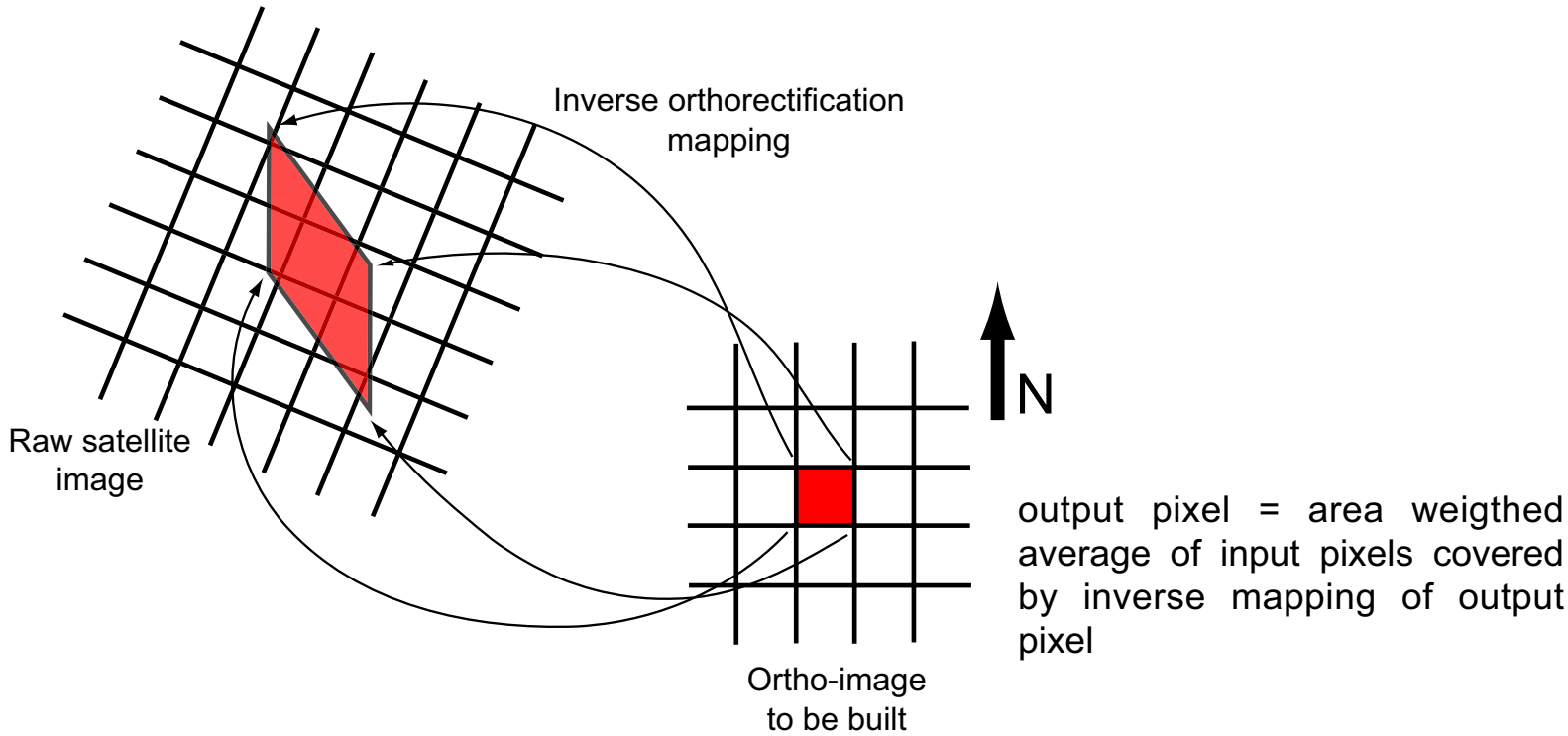
Comparing images acquired from different viewpoints

Can you find the moving piece?

Comparing images acquired from different viewpoints

Images must be projected and resampled in a common geometry to be compared

Image Resampling: principle



- Use approximated sinc kernels to preserve subpixel information and limit aliasing.

Sub-Pixel Image Correlation: local rigid translations

- Fourier Shift Theorem

$$i_2(x,y) = i_1(x-\Delta_x, y-\Delta_y)$$
$$I_2(\omega_x,\omega_y) = I_1(\omega_x,\omega_y)e^{-j(\omega_x\Delta_x+\omega_y\Delta_y)}$$

- Normalized Cross-spectrum

$$C_{i_1 i_2}(\omega_x,\omega_y) = \frac{I_1(\omega_x,\omega_y)I_2^*(\omega_x,\omega_y)}{|I_1(\omega_x,\omega_y)I_2^*(\omega_x,\omega_y)|} = e^{j(\omega_x\Delta_x+\omega_y\Delta_y)}$$

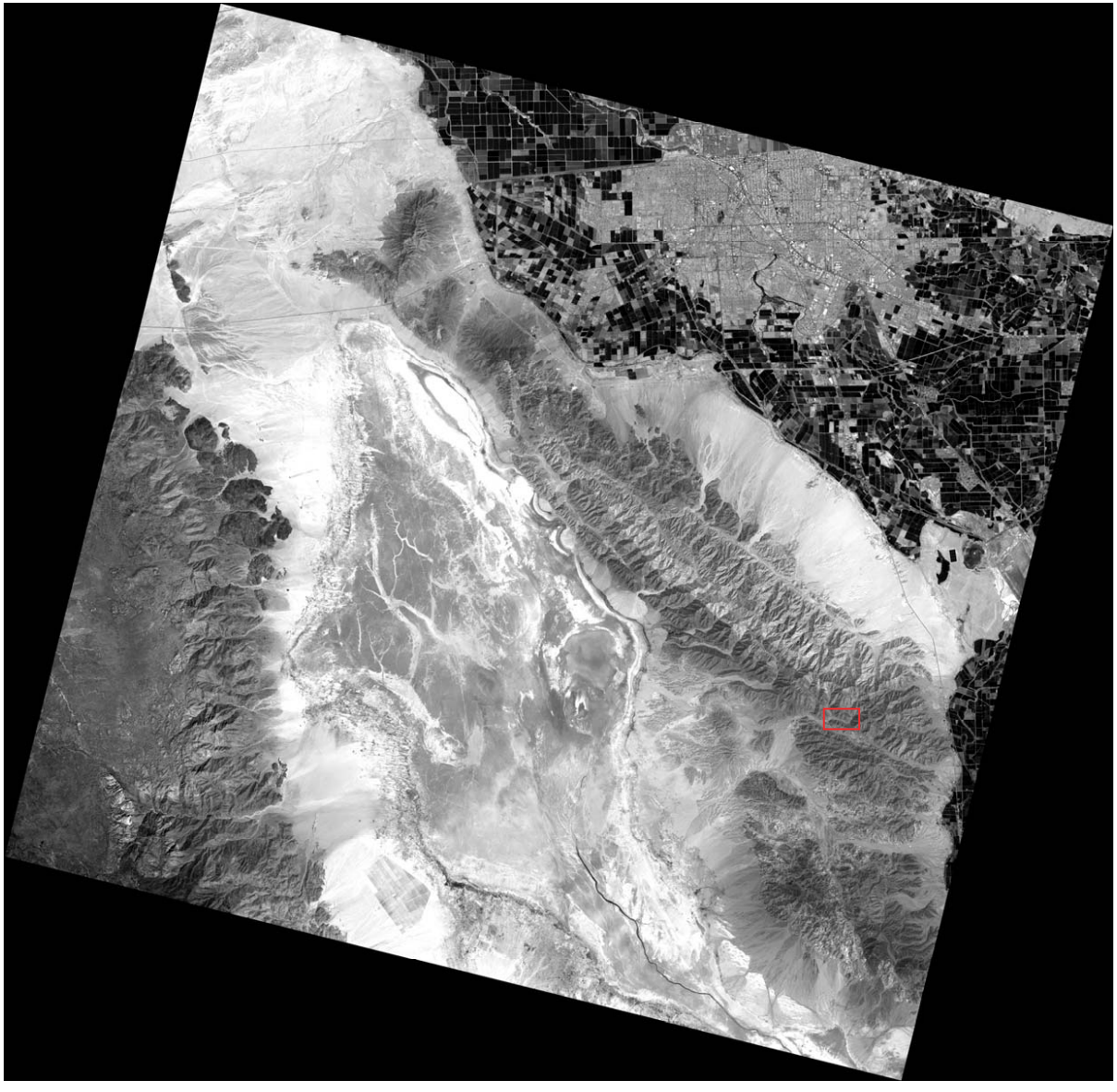
- Finding the relative displacement

$$\phi(\Delta_x,\Delta_y) = \sum_{\omega_x=-\pi}^{\pi}\sum_{\omega_y=-\pi}^{\pi} W(\omega_x,\omega_y)|C_{i_1 i_2}(\omega_x,\omega_y) - e^{j(\omega_x\Delta_x+\omega_y\Delta_y)}|^2$$

W weighting matrix. (Δ_x,Δ_y) such that ϕ minimum.

S. Leprince et al., IEEE TGRS, 2007

Retrieving horizontal deformation: using SPOT imagery



SPOT 5 images
2.5 m resolution

2009-05-26
2010-04-08

SPOT images provided via USGS:

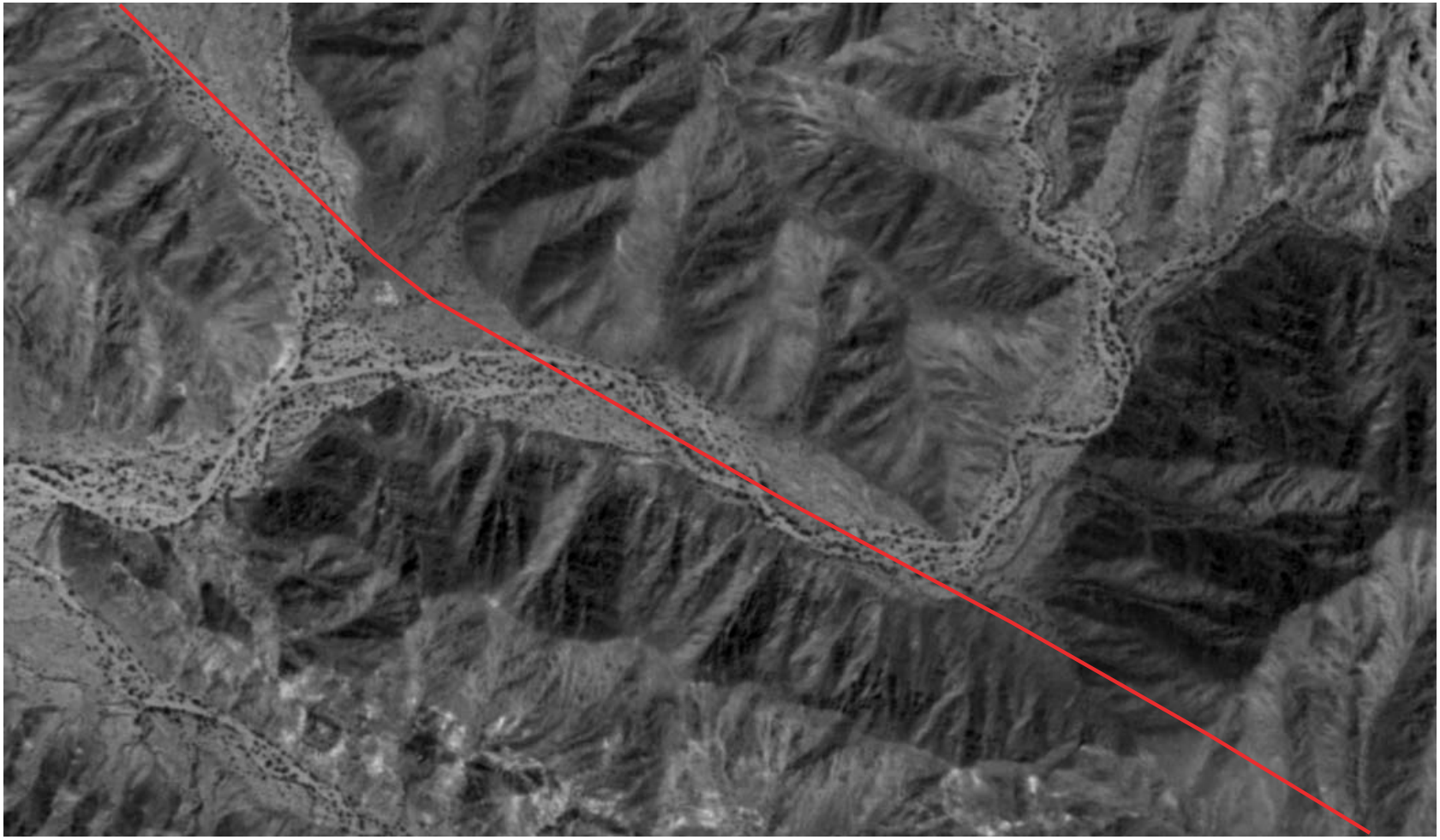
Rich Briggs
Ken Hudnut

USGS
science for a changing world

2010 Mw 7.2 El Mayor Earthquake - SPOT Imagery

- Can you see the ground motion?

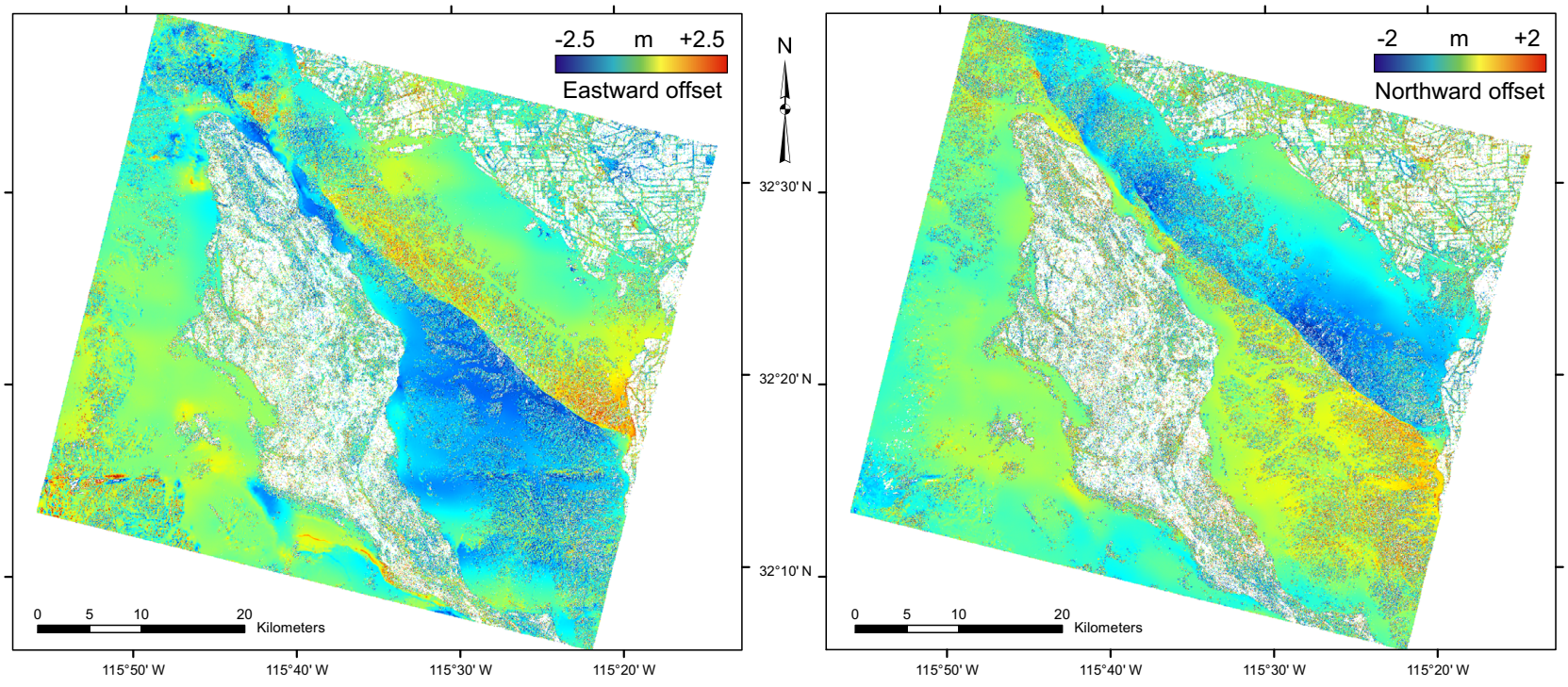
2010 Mw 7.2 El Mayor Earthquake - SPOT Imagery



- Can you see the ground motion?

The 2010 Mw 7.2 El Mayor-Cucapah Earthquake:

Horizontal offsets from SPOT imagery

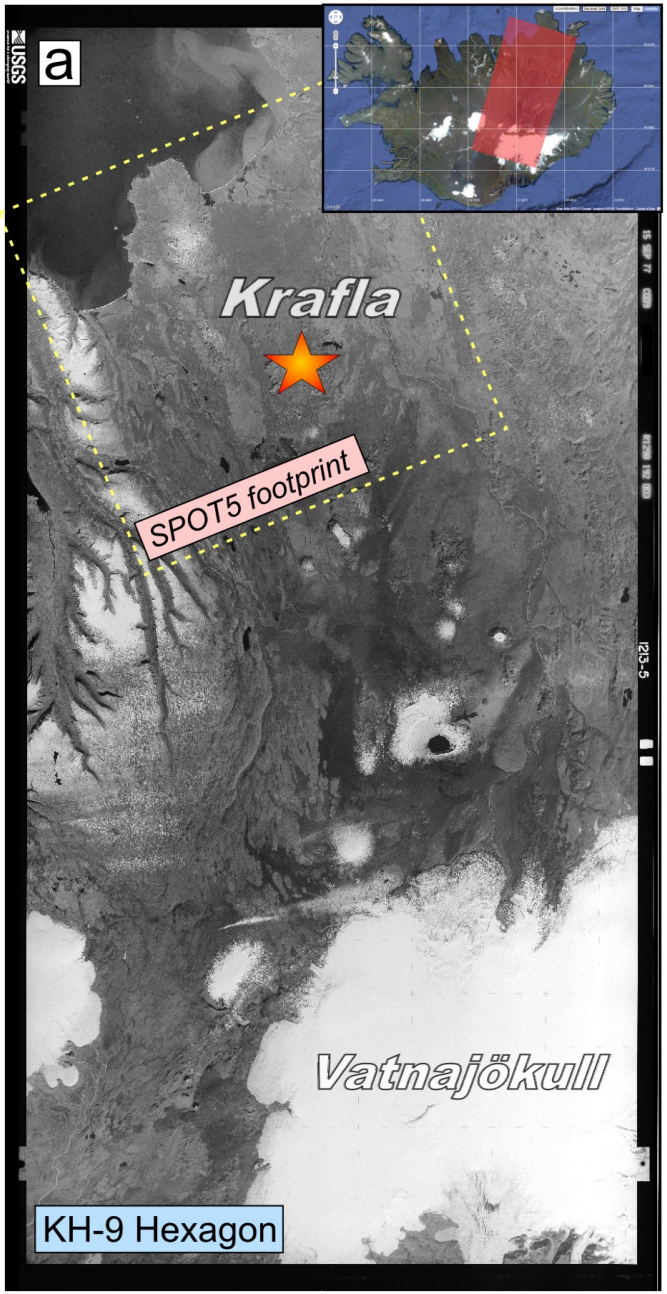


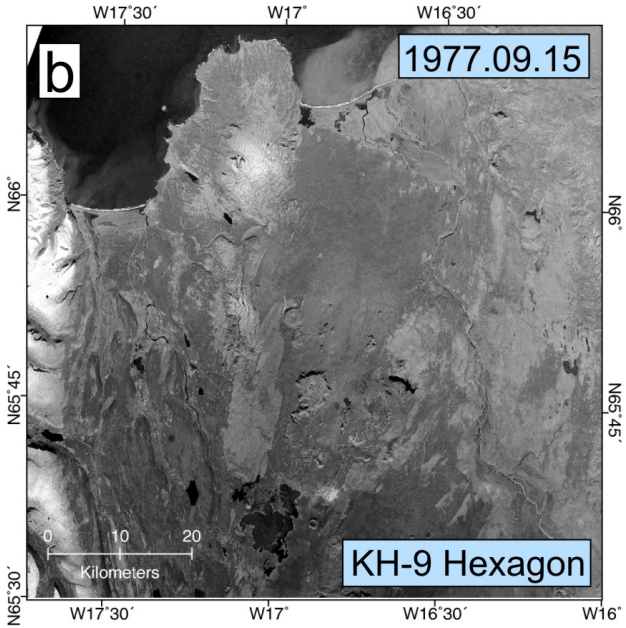
We measure slip variations for both lateral and normal components.

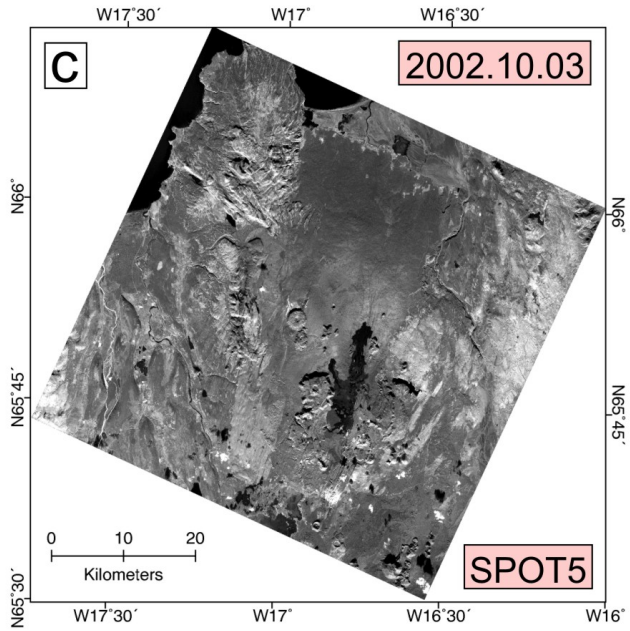
Accuracy better than 1/10 pixel.

Wei et al., Nature Geoscience, July 2011

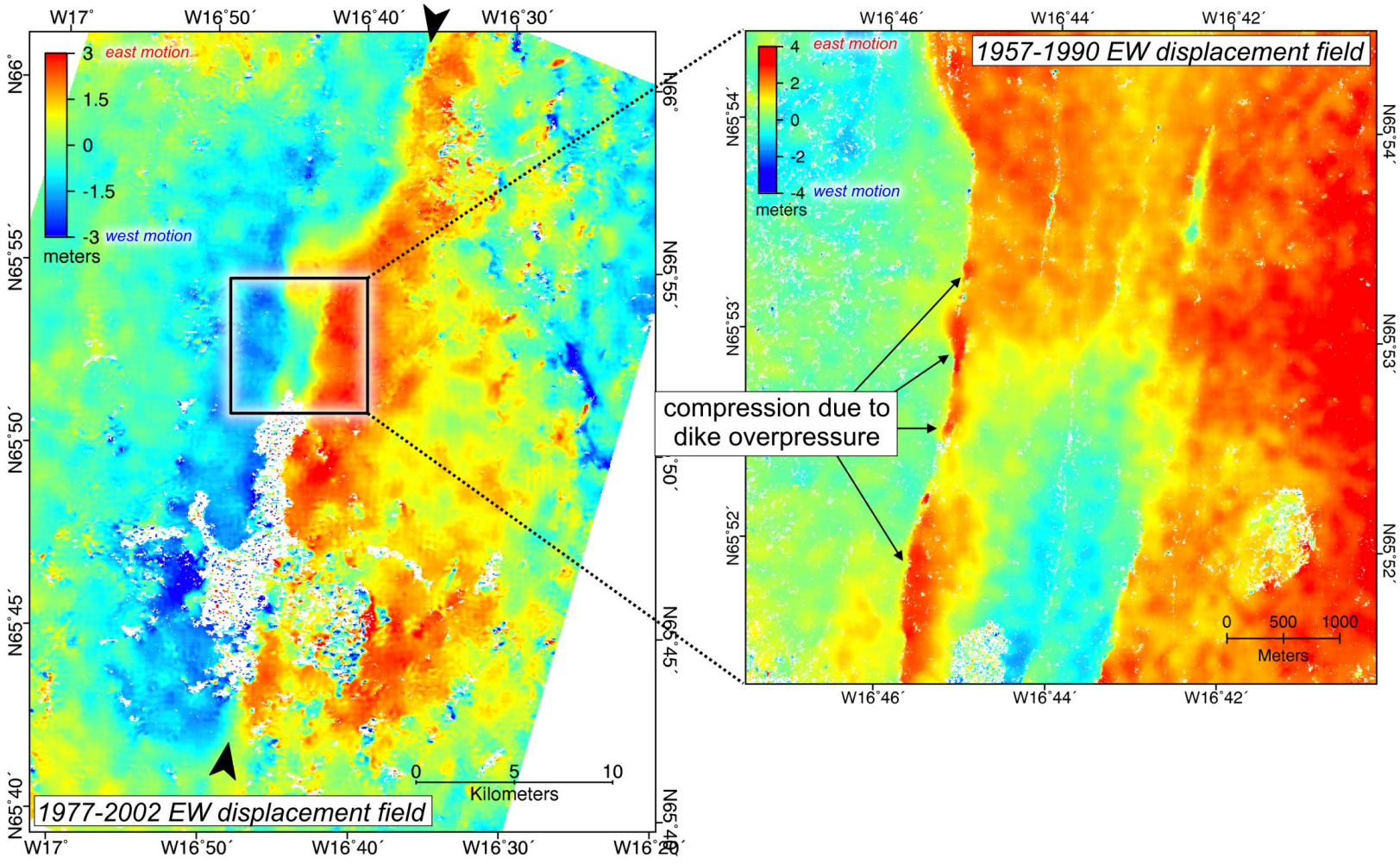
Iceland Krafla crisis 1975-1984: declassified spy images







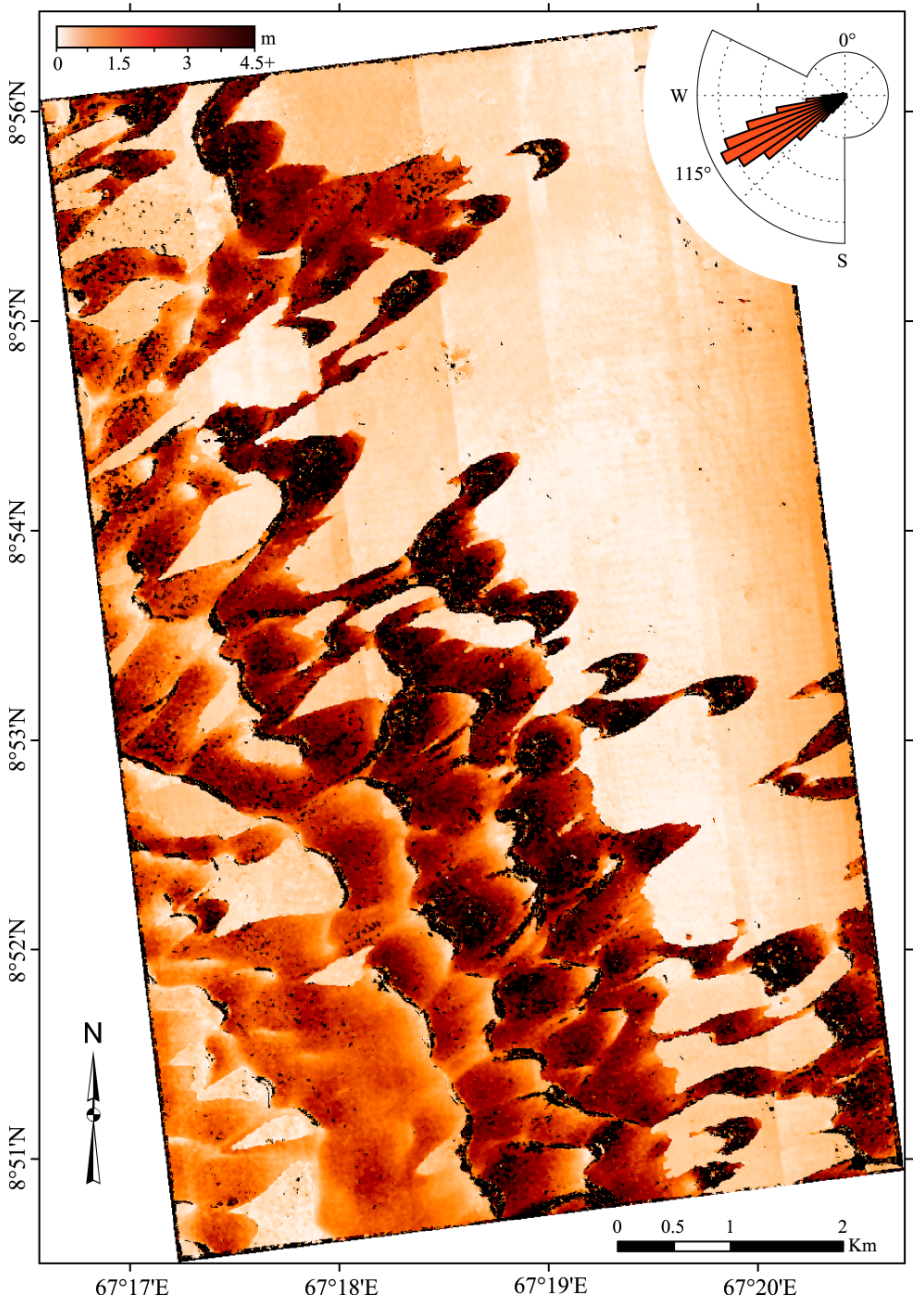
Iceland Krafla crisis 1975-1984: declassified spy images



- Corona-Hexagon KH-9 correlated with SPOT images
- High resolution archived air-photos

Study by J. Hollingsworth, Caltech

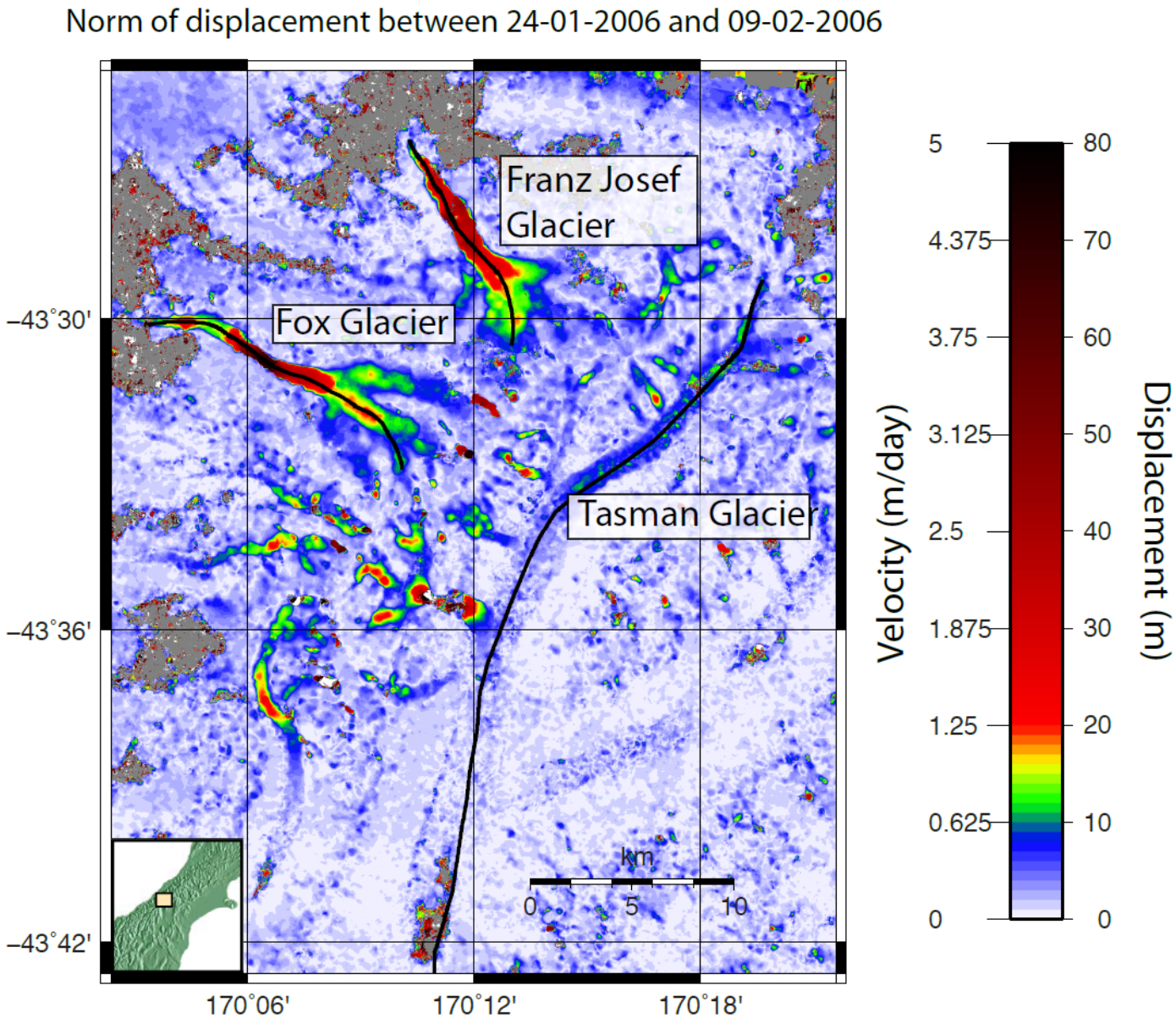
Tracking Sand Dunes on Mars, Nili Patera



Sand ripples displacement over 3 months retrieved from NASA HiRISE instrument orbiting Mars

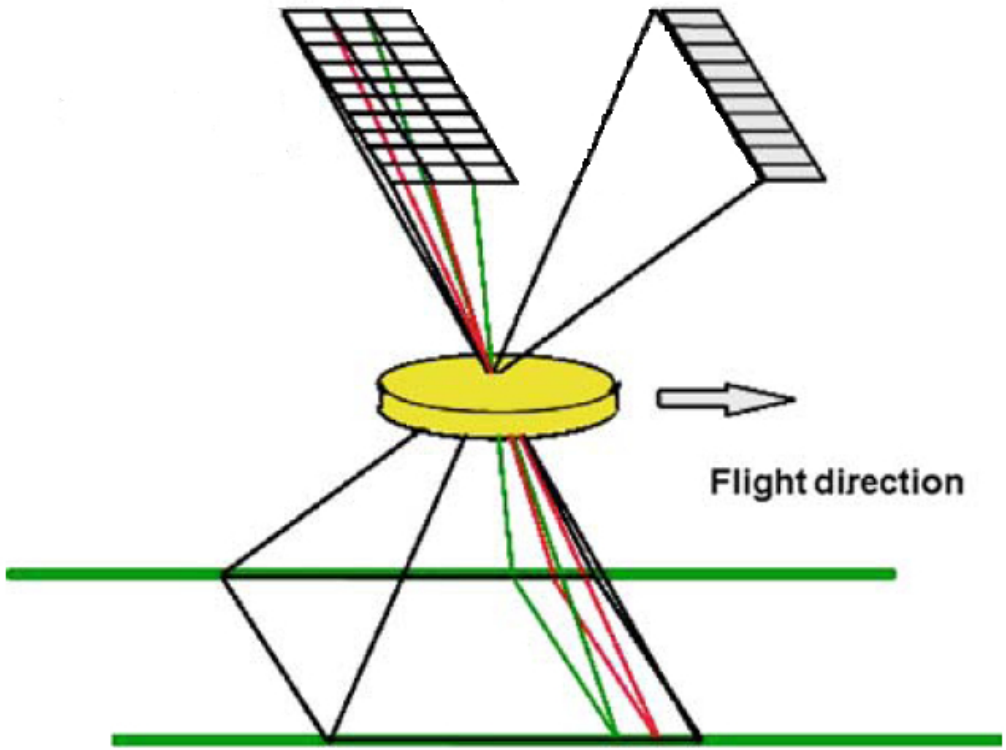
Study by F. Ayoub, Caltech

Tasman Glacier, New-Zealand (ASTER images, 15 m)



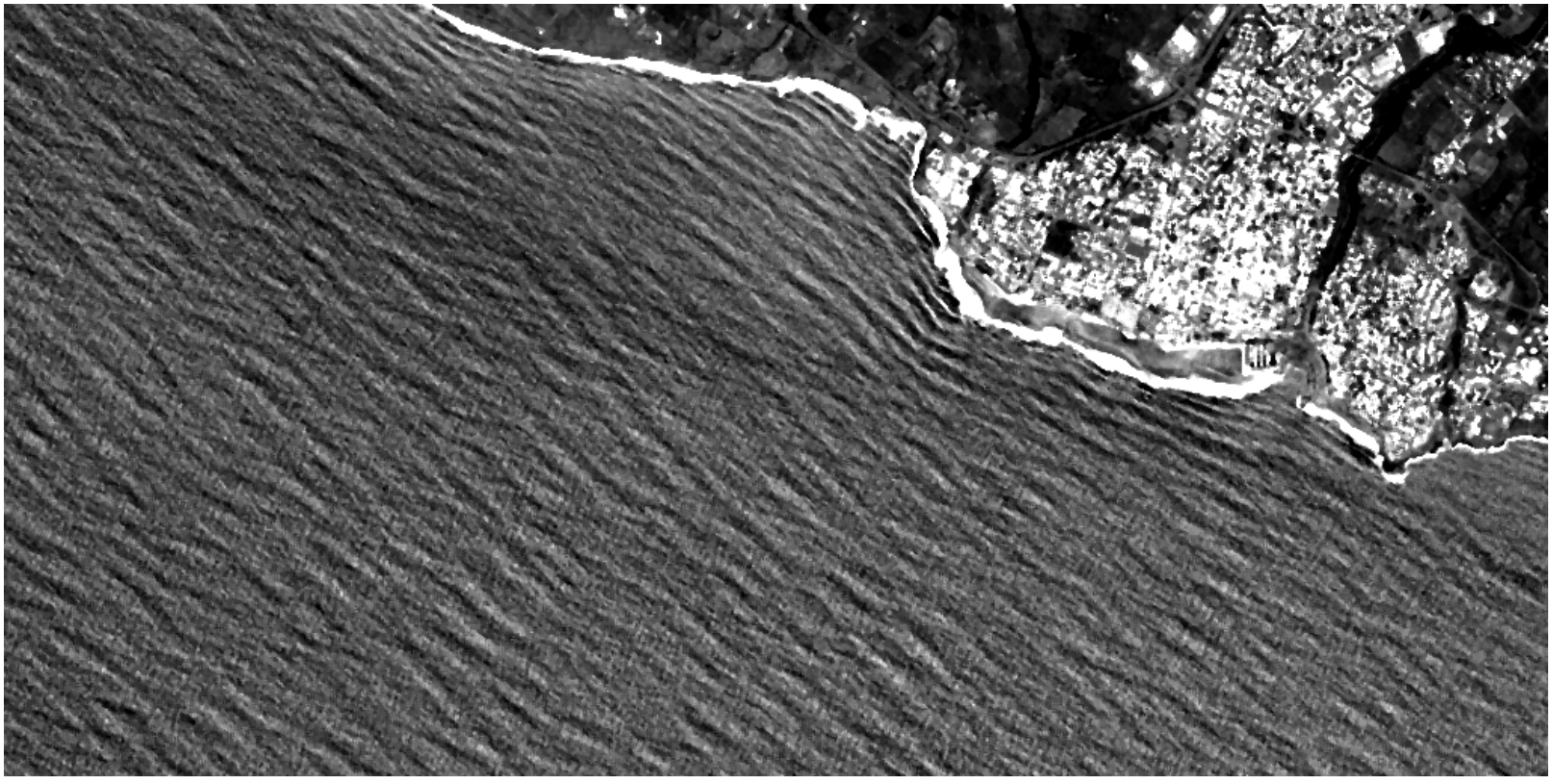
F. Herman, et al., J. Glacology, 2011

Taking Advantage of Panchromatic and Multi-Spectral Pusbroom Sensors



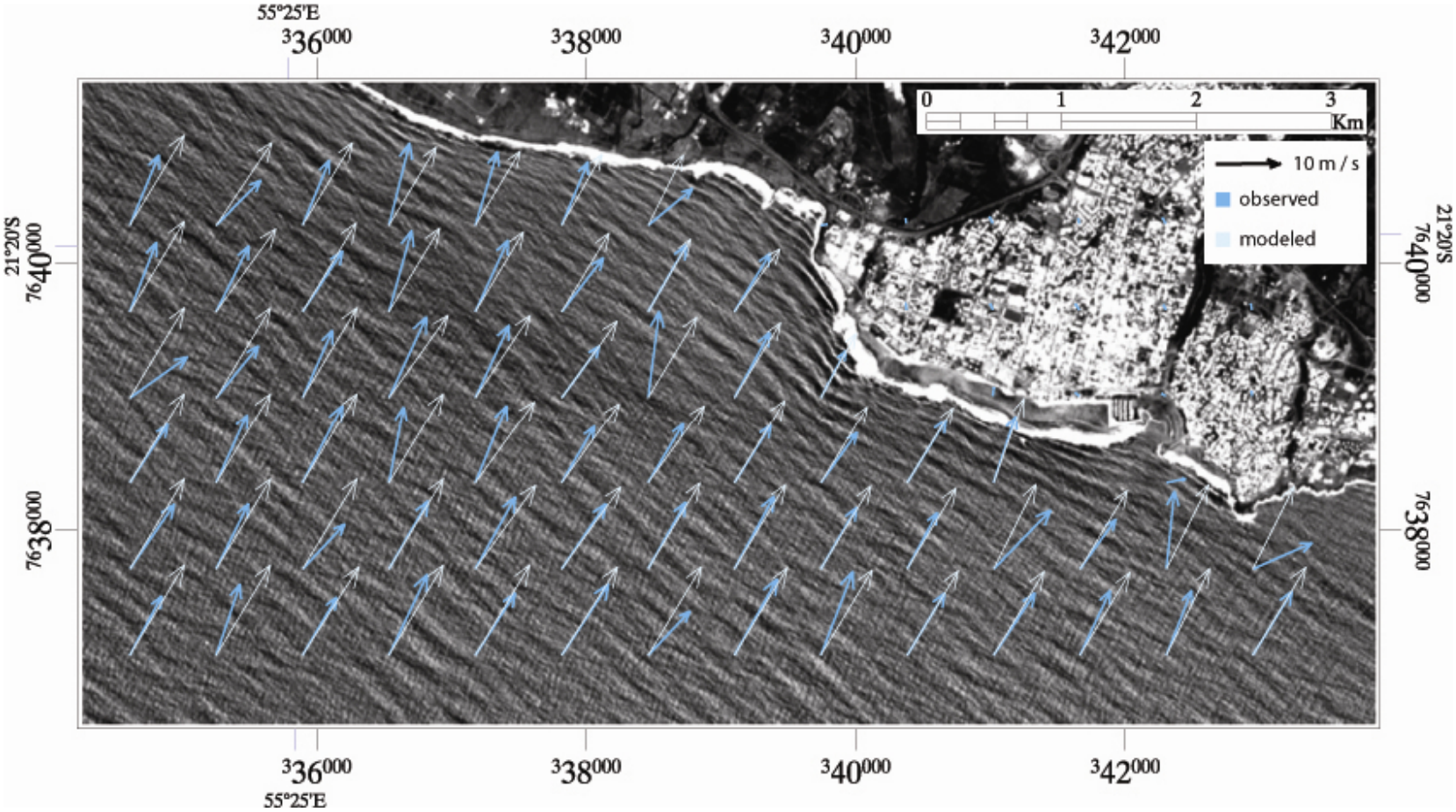
Time delay between Pan and MSI acquisition is around 2.5-3 s on SPOT satellites

Taking Advantage of Panchromatic and Multi-Spectral Pusbroom Sensors



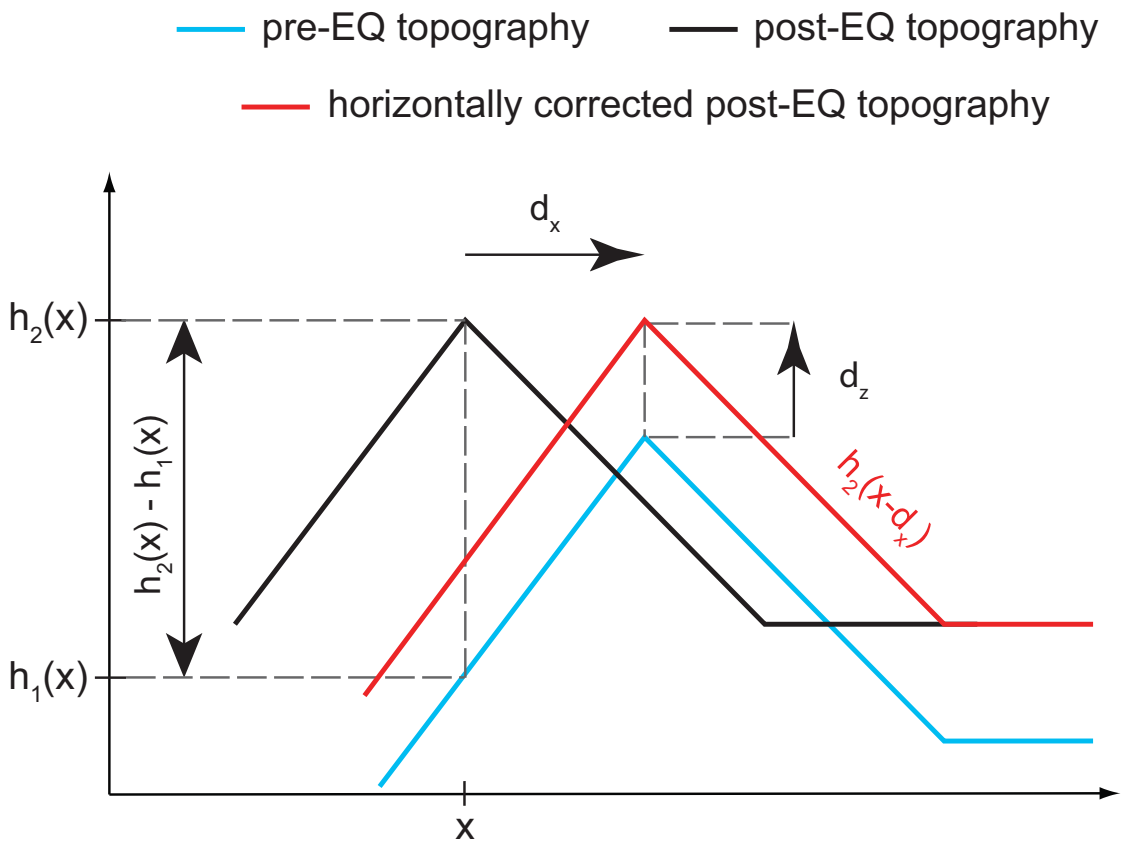
Correlating panchromatic and green bands to derive oceanic wave velocity

Taking Advantage of Panchromatic and Multi-Spectral Pusbroom Sensors



Study with Marcello De Michele, BRGM, France. In press RSE, 2011.

Retrieving vertical offset from pre- post-LiDAR differencing



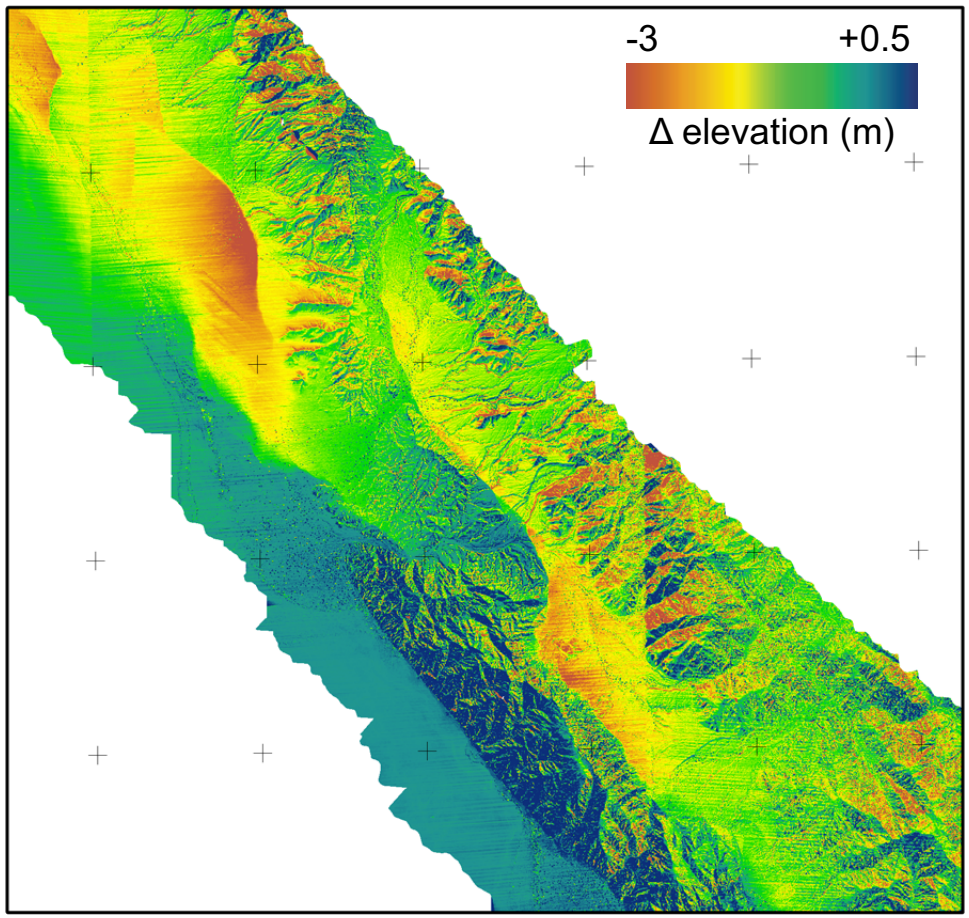
$$h_2(x) - h_1(x) = h_1'(x)d_x + d_z$$

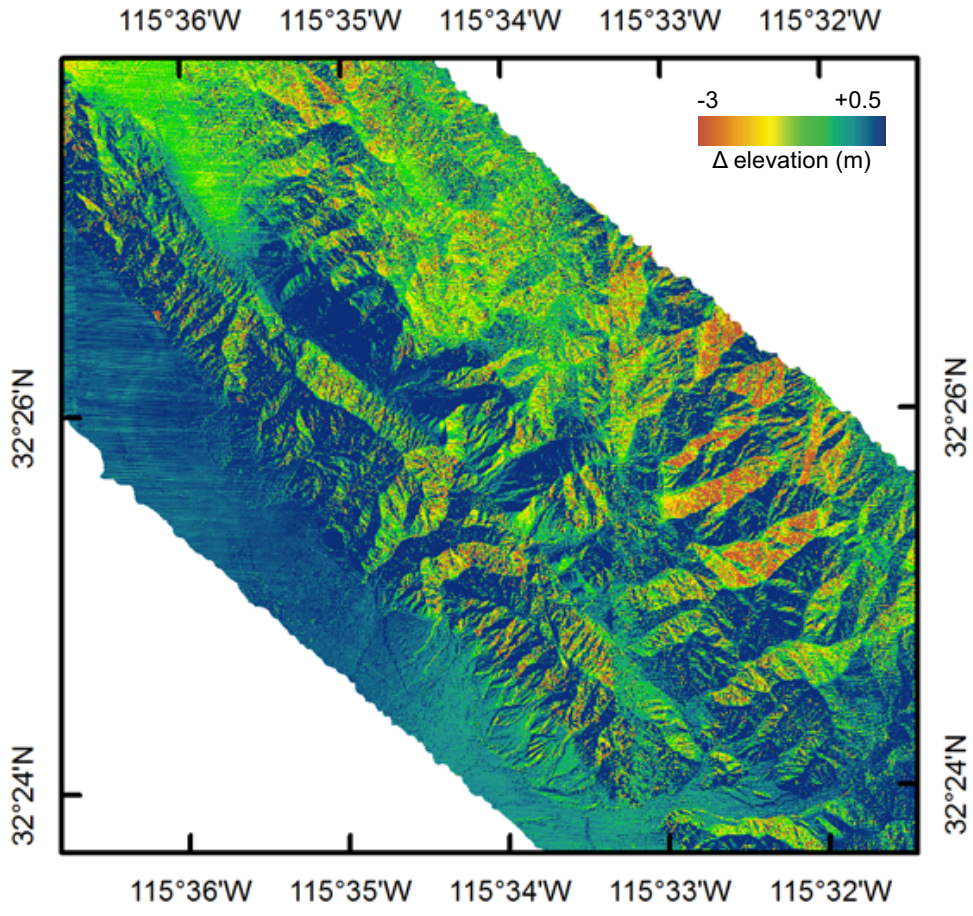
$$h_2(x - d_x) - h_1(x) = d_z$$

- We use COSI-Corr to estimate and compensate the horizontal displacement between pre- and post-EQ LiDAR

Vertical offsets: Borrego and Puerta Accomodation Fault zones

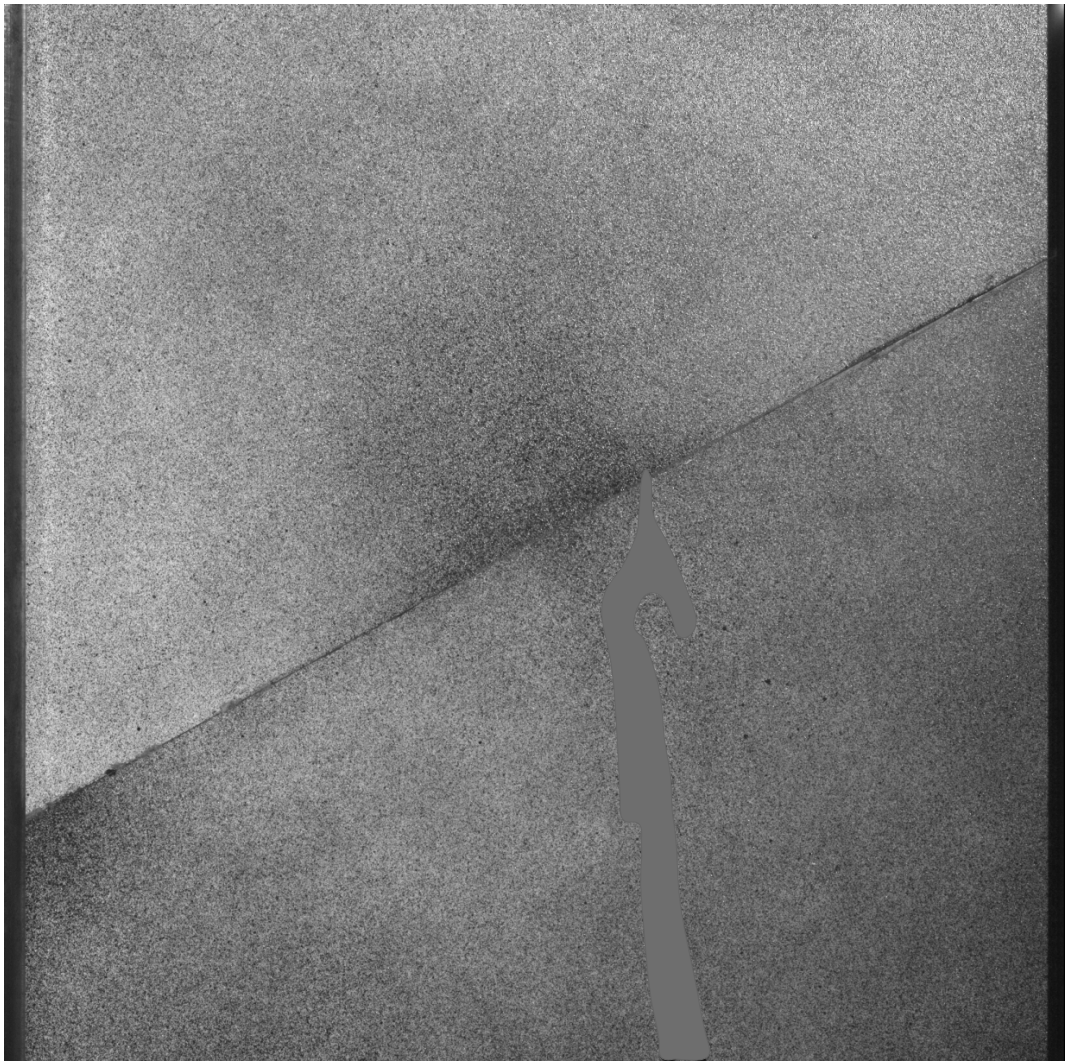
- LiDAR differencing before and after horizontal compensation

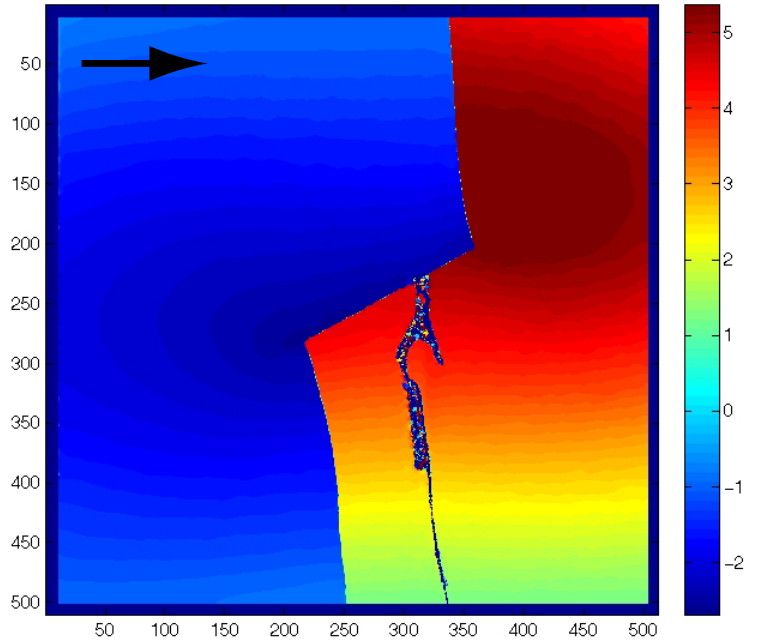


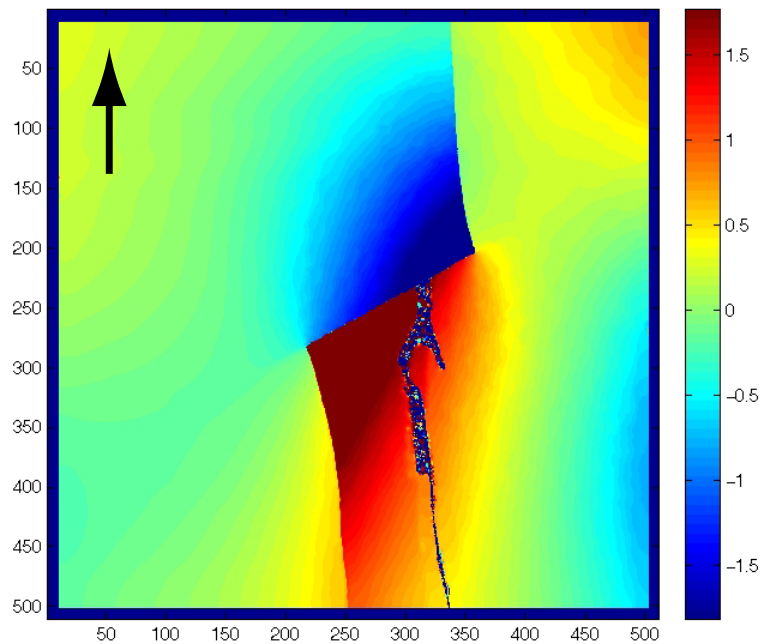


with **S. Akciz, K. W. Hudnut, A. Hinojosa Corona, and J. M. Fletcher**

Crack Experiments in the Lab: Earthquake Simulations







Work with **Vito Rubino and Ares Rosakis, Caltech**

Conclusions:

- **Sub-pixel** image registration and correlation are versatile tools to monitor time changes,
- **High resolution, high accuracy offset maps** in 2D or 3D, ideally 4D with time-series,
- Clear goal of achieving a **continuous and high resolution monitoring of our environment** to better understand climate evolution, water resources, geomorphology, seismotectonics, etc.
- COSI-Corr technology is being transfered to **Imagin'Labs Corporation, a Caltech spin-off**, to propose routine processing of large data sets and expert processing services.

imagin' LABS

www.imaginlabs.com