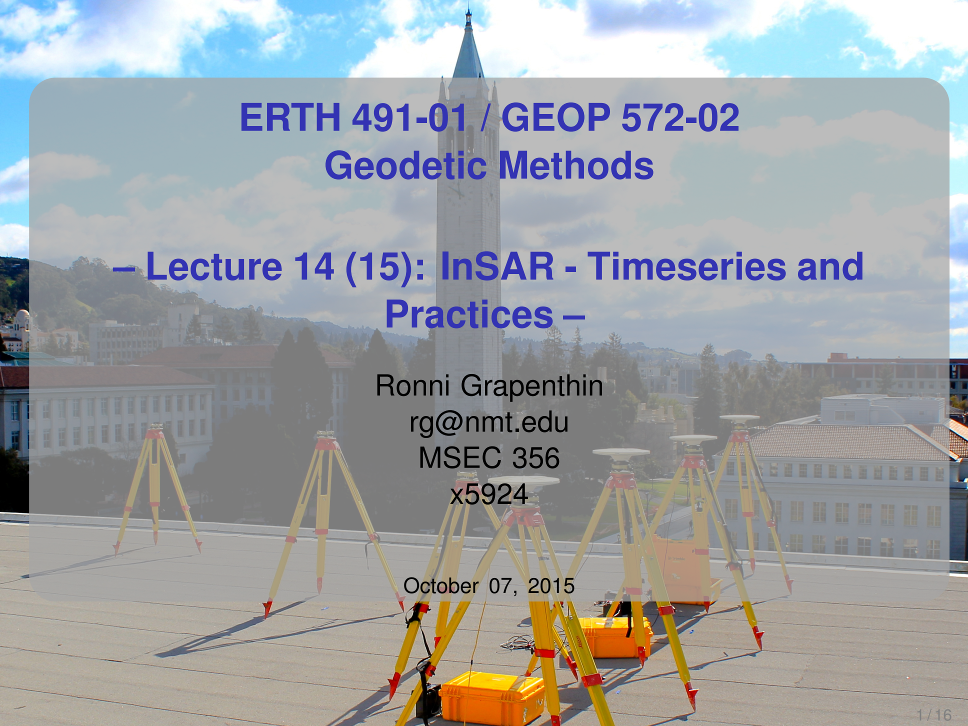

ERTH 491-01 / GEOP 572-02
Geodetic Methods

– Lecture 14 (15): InSAR - Timeseries and Practices –

Ronni Grapenthin
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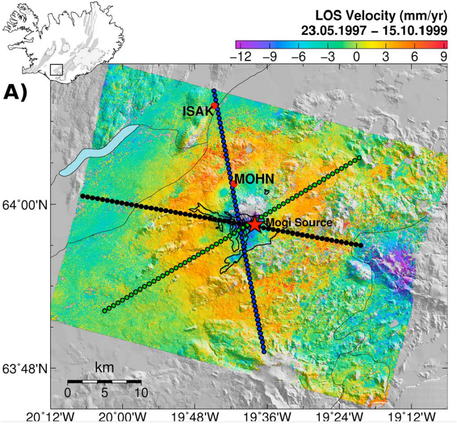
October 07, 2015

New Segment: "Guess the Process"



Grapenthin et al., 2010

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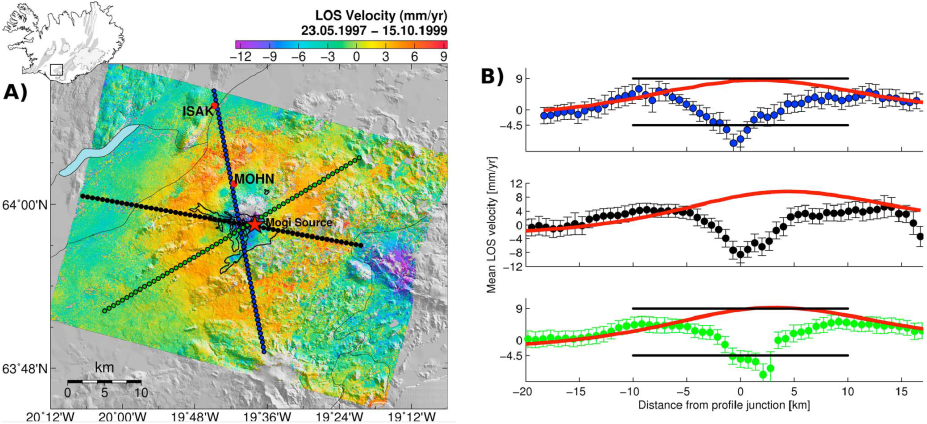


Grapenthin et al., 2010

InSAR - Processing Flow

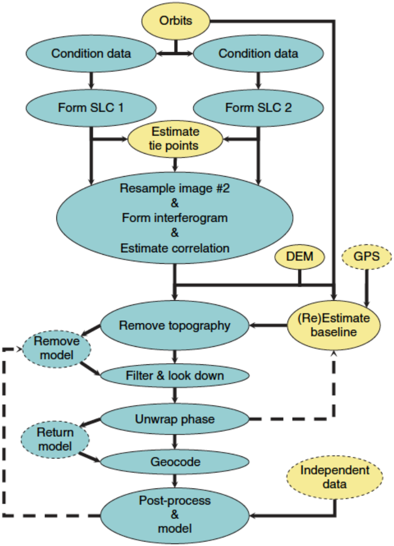
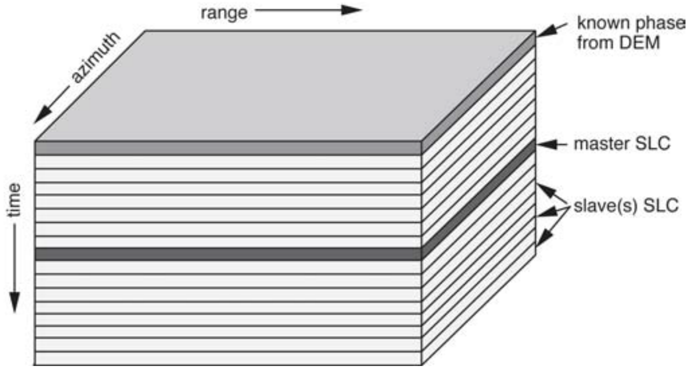


Figure 6 Representative differential InSAR processing flow diagram. Blue bubbles represent image output, yellow ellipses represent nonimage data. Flow is generally down the solid paths, with optional dashed paths indicating potential iteration steps. DEM, digital elevation model; SLC, single look complex image.

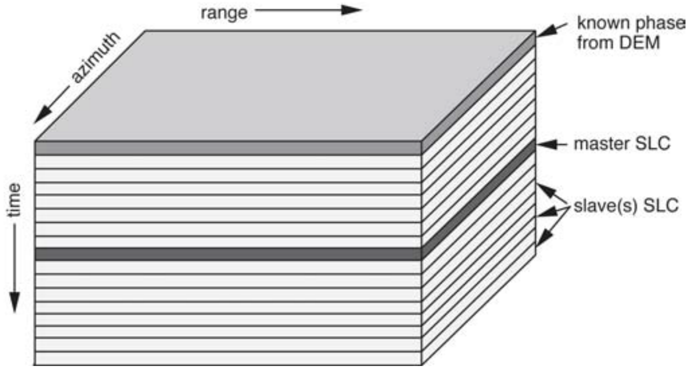
Simons and Rosen, 2007

InSAR - Timeseries: Stacking



Sandwell et al., 2011

InSAR - Timeseries: Stacking



Sandwell et al., 2011

What could be difficult about this?

InSAR - Timeseries: Stacking

- often most challenging: geometrical alignment of large stack of images, align with topographic phase
- alignment problematic: temporal and geometric decorrelation
- subpixel alignment can fail due to lack of correlated areas

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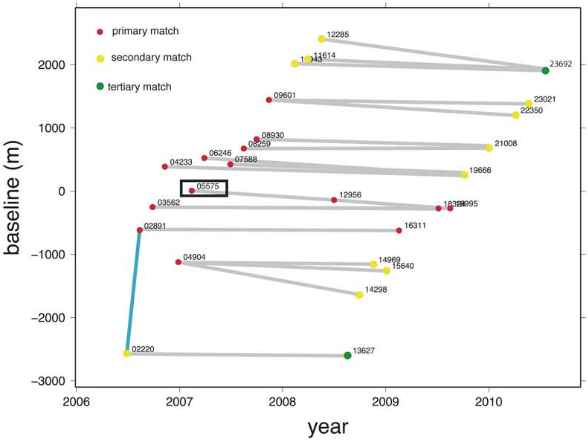

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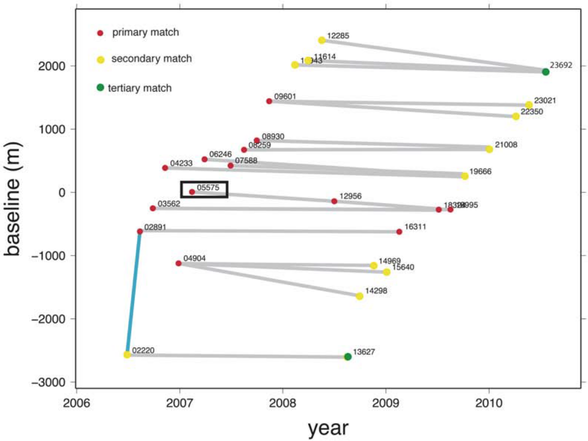
InSAR - Timeseries: Stacking



Sandwell et al., 2011

- ALOS stack, track 213, frame 0660, Coachella Valley, California
- temporal decorrelation not as problematic: desert
- geometry: 5 km perpendicular baseline change over 2 years

InSAR - Timeseries: Stacking

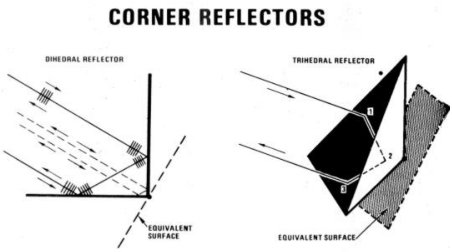
gmtSAR processing:

1. preprocess all images independently
2. use `pre_proc_batch.csh` – creates the baseline plot above
3. select master image in middle of baseline vs. time plot
   - alignment to overall $<$ 2-pixel precision
   - multi-step approach
   - *primary match* – images near master in baseline vs time plot aligned directly to master
   - *secondary match* – each primary match slave is surrogate master to its neighbors
   - *tertiary match* – possible to define for images very far from master
4. use `align_batch.csh` – to run alignment (time consuming!)
5. generate/retrieve a DEM
6. use `intf_batch.csh` – to make set of interferograms

InSAR - Timeseries: Permanent Scatterers

- in addition to temporal/geometric decorrelation: errors due to temporal & spatial variations of atmosphere, ionosphere (random)
- corner reflectors: continuously reliable coherent scatterers
- identify consistent reflectors in series of images,

http://uavsar.jpl.nasa.gov/technology/calibration/cr2.html



http://www.geog.ucsb.edu/~jeff/115a/remote_sensing/radar/radar2.html

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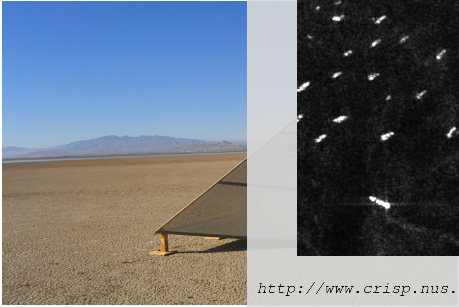

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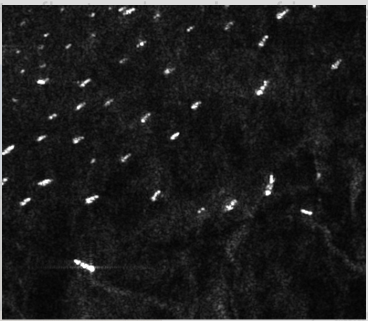
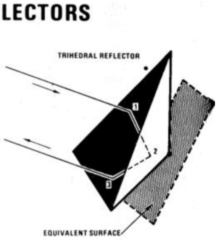


http://www.crisp.nus.edu.sg/~research/tutorial/sar_int.htm



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InSAR - Timeseries: Permanent Scatterers

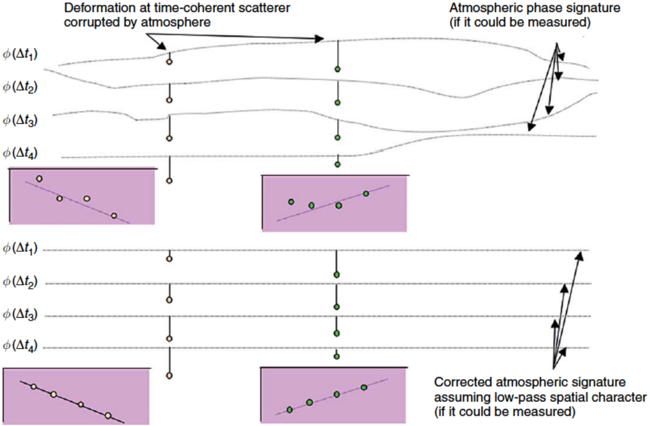

Figure 14 The 'permanent scatterer' technique identifies time-coherent scatterers by estimating the contributions of topography, deformation, and atmospheric delay to the phase under model constraints through correlation maximization. Topography is assumed to be static (with the interferometric phase proportional to baseline), deformation is assumed to follow some functional form (e.g., linear or sinusoidal with time), and atmospheric delay is assumed to vary randomly in time and with long spatial wavelength.

Simons and Rosen, 2007

InSAR - Baseline Errors

InSAR - Baseline Errors

- orbit errors can induce long-wavelength phase ramps (incorrect topo removal)
- long perpendicular baseline can induce short-wavelength error in rough topography
- can deal with this by ramp removal or use GPS constraints on geometry

InSAR - Propagation Delays

InSAR - Propagation Delays

- due to atmosphere and ionosphere, inhomogeneous over space and time
- more severe in repeat-track than along track observations
- GPS can be used to estimate correction, however: point-based
- might miss or focus on regional variations
- statistical approaches deal with interpolations of wet-delay
- high-resolution weather models promise help
- merging weather models with GPS / radiosonde observations may bring improvement

InSAR - Image Stacking

InSAR - Image Stacking

- target is event that occurred quickly (in between 2 measurements) or process w/ constant rate
- could increase signal to noise ration by stacking/averaging multiple **interferograms**
- reduces effect due to tropospheric delay (uncorrelated on these time scales)
- discover small signals
- reduce number of observations
- work in radar or geocoded coordinates

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Methods:

- brute force: average all interferograms together
  - regions of decorrelation are union of decorrelation in individual pictures
  - e.g, co-seismic displacements for smaller earthquakes
- use weighted average, weight is inverse of covariance matrix
- more formal: pose as least-squares problem (may include model parameters)

InSAR - Time Series

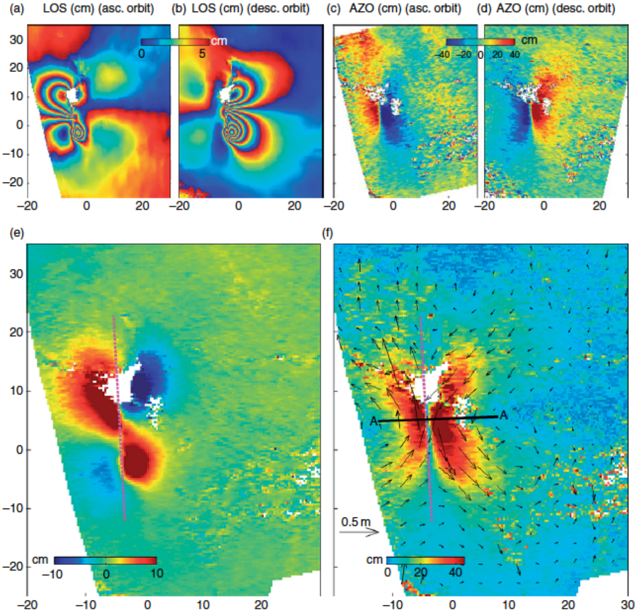
InSAR - Time Series

Improve by removing models for:

- seasonal deformation (snow, atmosphere, . . .)
- co-seismic steps
- post-seismic exponential decays
- similar to (and maybe informed by) GPS timeseries ‘cleaning’ based on physical models

InSAR - 3D Deformation

- better constrain physical models (volcano, earthquake)
- earthquake in LOS only: tradeoff amplitude / rake of slip
- worse if we don't know location of small events well
- don't assuming purely vertical/horizontal deformation



Fialko et al., Nature, 2005

InSAR - 3D Deformation

For example (*Fialko et al., GRL, 2001*):

- ascending and descending LOS displacement
- ascending and descending azimuthal displacements (cross-correlate radar amplitude pixels along satellite track)

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LOS-displacements, d_{los} are projection of vector displacement field U_i onto look vector:

$$d_{los} = [U_n\, sin(\phi) - U_e\, cos(\phi)]\, sin(\lambda) + U_u\, cos(\lambda) + \epsilon_{los}$$

with ϕ: azimuth of satellite heading (clockwise from North)
λ: radar incidence angle
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InSAR - 3D Deformation

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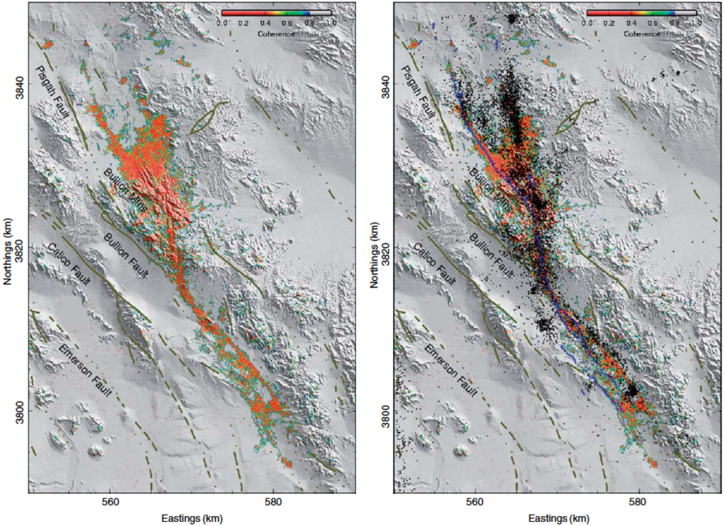
with ϕ: azimuth of satellite heading (clockwise from North)
λ: radar incidence angle
ϵ: measurement error
Azimuthal offset, d_{azo} is projection of horizontal displacement onto satellite heading:

$$d_{azo} = U_n \, cos(\phi) - U_e \, sin(\phi) + \epsilon_{azo}$$

InSAR - Decorrelation as Signal



Simons and Rosen, 2007