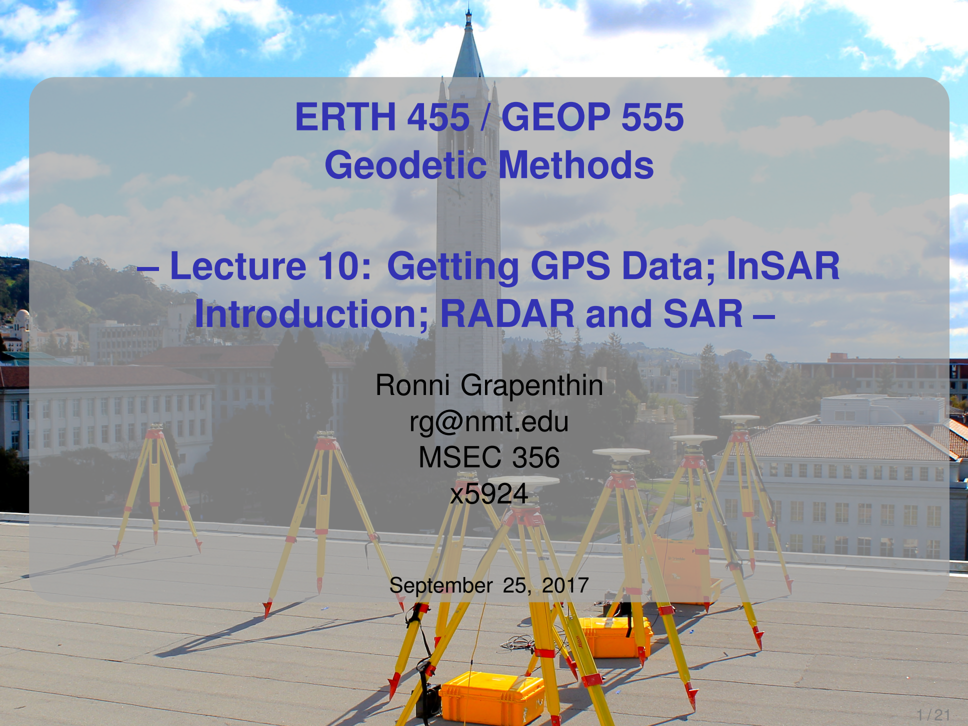

ERTH 455 / GEOP 555
Geodetic Methods

– Lecture 10: Getting GPS Data; InSAR Introduction; RADAR and SAR –

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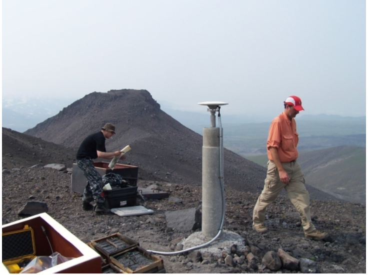
Getting Data. From where?

1) Your own campaigns: periodically go out and occupy benchmarks

Getting Data. From where?

2) build continuous sites ($10+ k)



Getting Data. From where?

3) data archives

- UNAVCO DAI `http://www.unavco.org/data/gps-gnss/data-access-methods/dai2/app/dai2.html`
- UNAVCO FTP `ftp://data-out.unavco.org/pub/`
- SOPAC `ftp://garner.ucsd.edu/pub/`, `http://sopac.ucsd.edu/dataBrowser.shtml`
- UNR (products) `http://geodesy.unr.edu/billhammond/gpsnetmap/GPSNetMap.html` (have ftp, too)
- regional networks, e.g. BARD: `http://seismo.berkeley.edu/bard/`

Getting Data. From where?

3) data archives (continued)

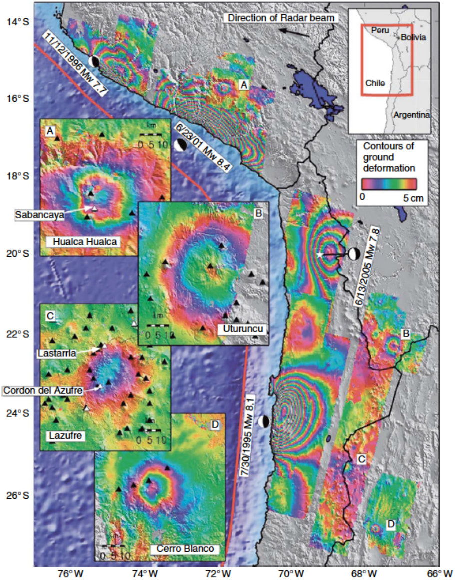
- Japan GEONET: open, but need to register `http://datahouse1.gsi.go.jp/terras/terras_english.html`
- New Zealand GEONET: `ftp://ftp.geonet.org.nz/gps/`, 1Hz: `ftp://ftp.geonet.org.nz/rtgps/rinex1Hz/PositioNZ/`
- NSF funded research required to make data available publicly, not all research in US NSF funded, though
- Other countries may not have open data sharing policy - contact potential collaborators!
- Be sure to acknowledge the archive, and the site PI (use DOIs where available).

The First InSAR Applications

- 1992 M_w=7.3 Landers Earthquake
- before that (1987 onwards):
- ocean currents, ice motion, soil swelling in Imperial Valley

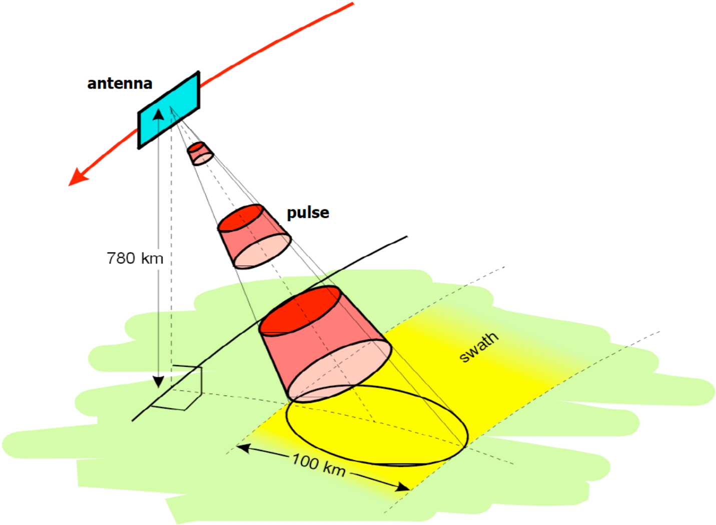
Massonnet et al., 1993

Now: "Fishing Trips"



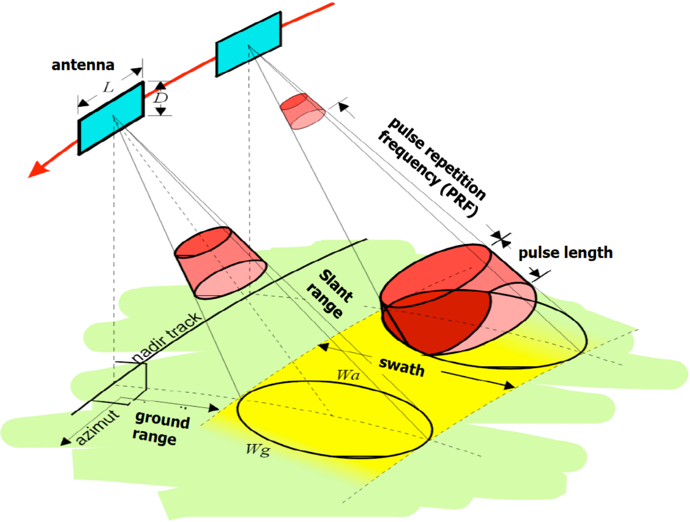
Simons and Rosen, 2007

InSAR - General Concept



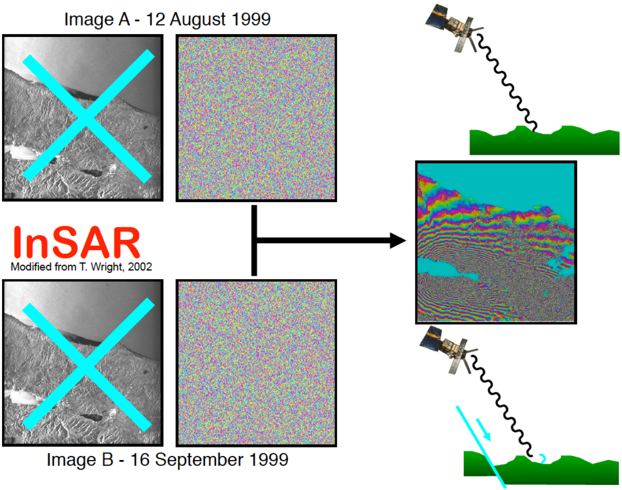
loaned from *J. Freymueller*

InSAR - General Concept



loaned from *J. Freymueller*

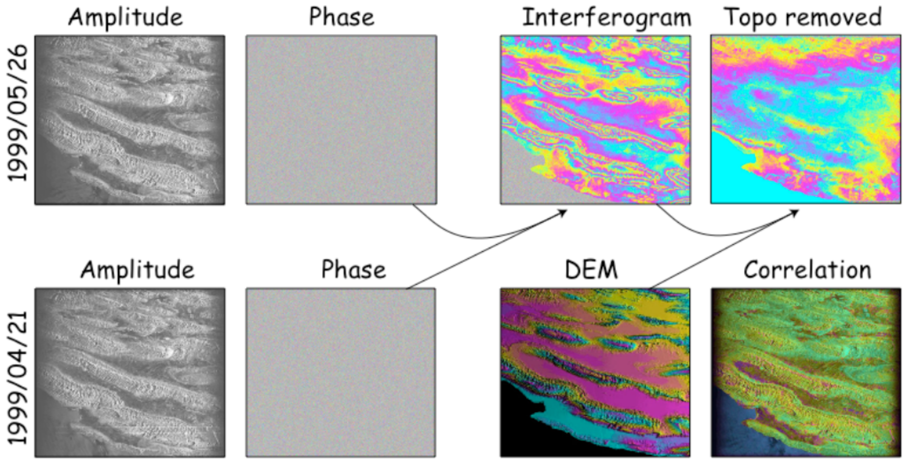
InSAR - General Concept



loaned from *R. Bürgmann*

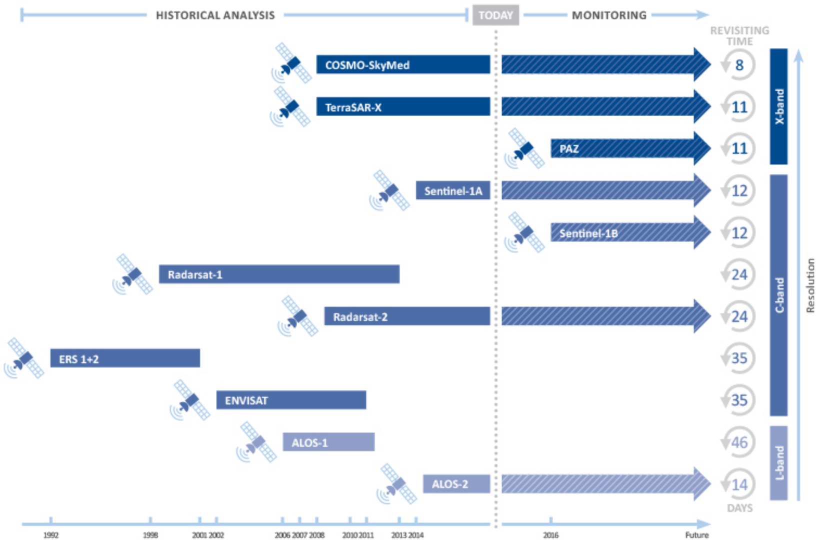
complex values radar signal contains information on amplitude $a = \sqrt{Im^2 + Re^2}$, and phase $\phi = arctan\frac{Im}{Re}$

InSAR - General Concept



loaned from *J. Freymueller*

InSAR - Mission Overview



from `http://treuropa.com/newsletter/15-years-expertise-advanced-insar-technology/`

InSAR - Processing Flow

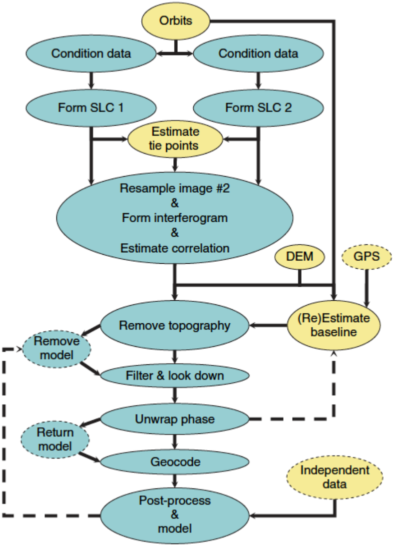


Figure 6 Representative differential InSAR processing flow diagram. Blue bubbles represent image output, yellow ellipses represent nonimage data. Flow is generally down the solid paths, with optional dashed paths indicating potential iteration steps. DEM, digital elevation model; SLC, single look complex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

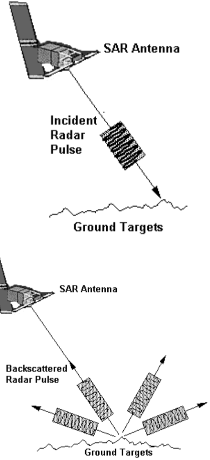
Simons and Rosen, 2007

Need to talk about:

- Radar (today)
- Synthetic Aperture (today)
- Interferometry (Wednesday)
- phase unwrapping, noise sources (next Monday)
- timeseries, stacking, permanent scatterers (next Wednesday)

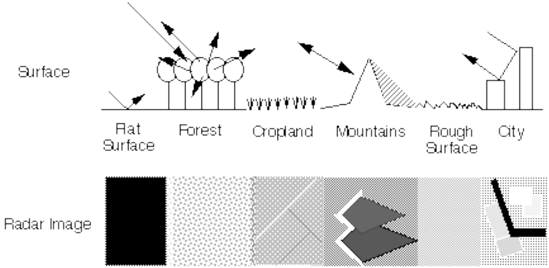
Radar

- Radio Detection and Ranging
- active system uses EM waves
- reflection, refraction, polarization, interference with one another
- principle:
  - send pulse of oscillating EM energy
  - frequency f, duration τ
  - scatter - some energy returns to radar
  - $\lambda = c/f$
  - $R = ct/2$



from: `http://southport.jpl.nasa.gov/desc/imagingradarv3.html`

Radar Scattering



from: `http://southport.jpl.nasa.gov/desc/imagingradarv3.html`

Rules of Thumb for Surfaces in Radar Images:

- Smooth (calm water surface) - black
- Rough (water in windy day) - white
- hills, other large scale surface variations - bright on one side, dim on the other
- human made objects - bright spots (corner reflectors)

Radar Resolution

It’s an issue - it’s low!

Need Synthetic Aperture because angular resolution is governed by ratio of λ to aperture (size of antenna).

Coherent radiation passes through 1D aperture (follow Sandwell et al., 2011):

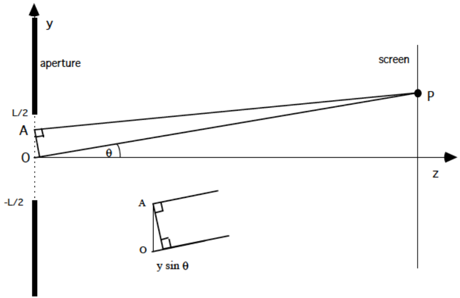


Figure A1 Diagram for the projection of coherent microwaves on a screen that is far from the aperture of length L.

Sandwell et al., 2011, GMTSAR documentation

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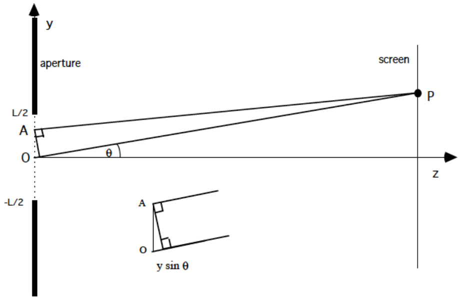

Figure A1 Diagram for the projection of coherent microwaves on a screen that is far from the aperture of length L.

Sandwell et al., 2011, GMTSAR documentation

- point sources of radiation between -L/2, L/2
- screen far away: $AP || OP$; so $AP - y sin(\theta) = OP$
- solve for illumination pattern on screen as function of θ

Fraunhofer diffraction 2/3

Amplitude of illumination at P is integral of all sources along aperture multiplied by their complex phase value:

$$P(\theta) \;\; = \;\; \int_{-L/2}^{L/2} A(y) e^{-i2\pi y k sin(\theta)} dy$$

with $k = 1/\lambda$; $P(\theta)$ is *Fraunhofer diffraction integral*

Fraunhofer diffraction 2/3

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Illumination across aperture is uniform, so $A(y) = 1$

Substitute $s = 2\,\pi\,y\,k\,sin(\theta)$ for easy evaluation of integral:

$$\begin{aligned} P(\theta) &= \int_{-L/2}^{L/2} e^{-i\,s\,y} dy = \frac{e^{-i\,s\frac{L}{2}} - e^{i\,s\frac{L}{2}}}{-i\,s} \\ &= \frac{2}{s} sin(s\frac{L}{2}) = L\,sinc(s\frac{L}{2}) \\ &= L\,sinc(\frac{L\,\pi\,sin(\theta)}{\lambda}) \end{aligned}$$

Fraunhofer diffraction 3/3

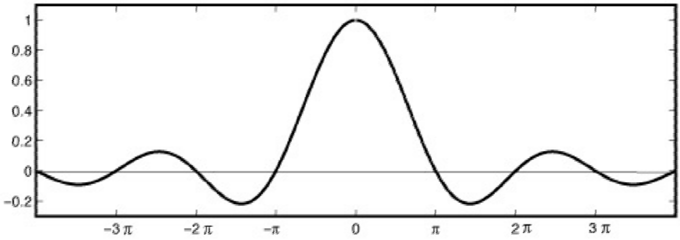

Figure A2. Sinc function illumination pattern for the aperture shown in Figure A1.

Sandwell et al., 2011, GMTSAR documentation

Fraunhofer diffraction 3/3

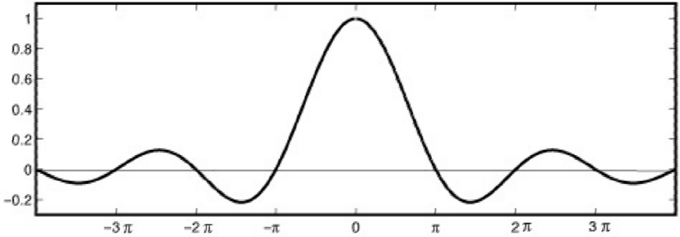

Figure A2. Sinc function illumination pattern for the aperture shown in Figure A1.

Sandwell et al., 2011, GMTSAR documentation

- first zero crossing, angular resolution θ_r, at π
- $\frac{L\pi\, sin(\theta)}{\lambda} = \pi$ for $sin(\theta_r) = \frac{\lambda}{L}$
- for small angles $\theta_r \approx \frac{\lambda}{L}$ and $tan(\theta_r) \approx sin(\theta_r)$
- here we have it! angular resolution, θ_r, is governed by ratio of λ to aperture (size of antenna).

Examples

- GEOSAT orbits Earth at 800 km,
- 1 m parabolic dish operates in Ku-band (13.5 GHz, $\lambda = 0.022$ m)
- footprint diameter about 43 km
- ERS: along track footprint = 8.5 km; range-direction footprint about 85 km
- optical system with 1 m aperture, but wavelength $\lambda = 5 \times 10^{-7}$ m has footprint diameter of 0.97 m

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Lesson:

Need major increase in antenna length for microwave system to get high angular resolution!

Synthetic Aperture!