SAR interferometry – Status and future directions

Rüdiger Gens

Polarimetric InSAR

Polarimetric InSAR

- sensitivity to changes in surface scattering, even in the presence of significant volume scattering

Applications for Pol-InSAR

- tree height estimation
  - simple random volume over ground scattering model is adopted
  - interferometric coherence estimates from various polarizations are used to infer the forest height and ground topography
- biomass estimation

Long-term monitoring

Long-term monitoring

- permanent scatterer technique
  - focuses on the most stable scatterers in time
  - selected points minimally affected by temporal and geometric decorrelation
- short baseline time series approach
  - assumes that contiguous areas remain correlated over time
  - only excludes resolution cells with strong decorrelation

Permanent scatterers (PS)

- natural targets coherent over long periods of time
- targets of dimension smaller than resolution cell can be coherent in image pairs beyond the critical baseline
- PS targets highly accurate once atmospheric contribution are estimated and removed
  - sub-meter accuracy for DEMs
  - millimetric terrain motion detection

PS candidate (PSC) selection

- two main criteria
  - high selection reliability (not affected by decorrelation noise)
  - high detection probability
- optimization of coherence threshold and the dimension of the estimation window
  - tradeoff between false-alarm rate and detection probability (classical detection problem)

PS candidate (PSC) selection

- time series analysis of amplitude images (radiometrically corrected)
  - requires large number of images (>30)
  - looking for pixels with stable sequence of amplitude values
  - absolute values are almost insensitive to most of the phenomena that contribute to the phase values (APS, DEM errors, terrain deformation, orbit indeterminations etc.)

PS candidate (PSC) selection

- dispersion index D_A is a measure of phase stability (for high SNR values)
  - PSC can selected computing the dispersion index of the amplitude values relative to each pixel in the area of interest (only targets exhibiting values under a given threshold - typically 0.25)

PS candidate (PSC) selection

- additional PSs can be identified after APS removal by means of time series analysis of the phase values

Short baseline time series

- short baselines (typically < 200 m) reduce geometric decorrelation
- reduced sensitivity for DEM errors
- selection of usable resolution cells based on spatial coherence in certain windows
  - reduces resolution (typically > 80 m^2)
  - noise reduction
- linear trend or more detailed profile of deformation can be estimated

Stacking

- assumption of linear deformation pattern during certain time period
- number of interferograms covering parts of observation period can be added
  - weighted for individual time span
  - deformation is deviation by total time span
- atmospheric delayed is assumed to be averaged out
  - weighted averaging
  - use of overlapping interferograms in time

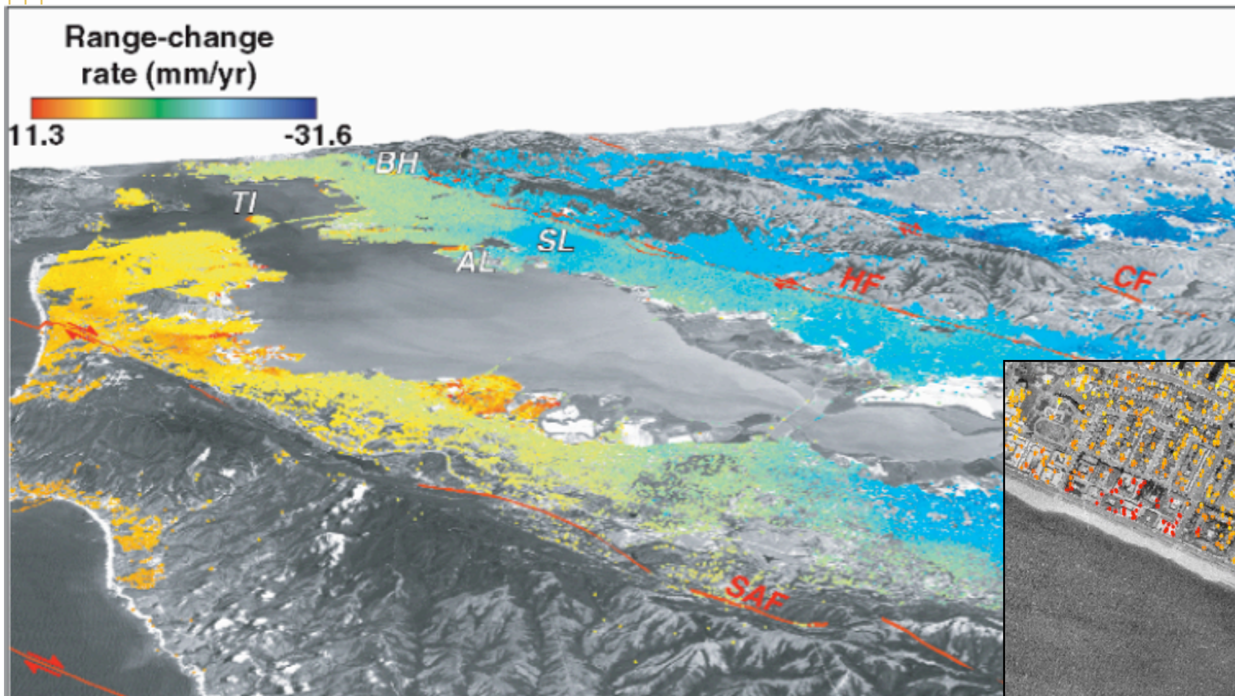
Stacking

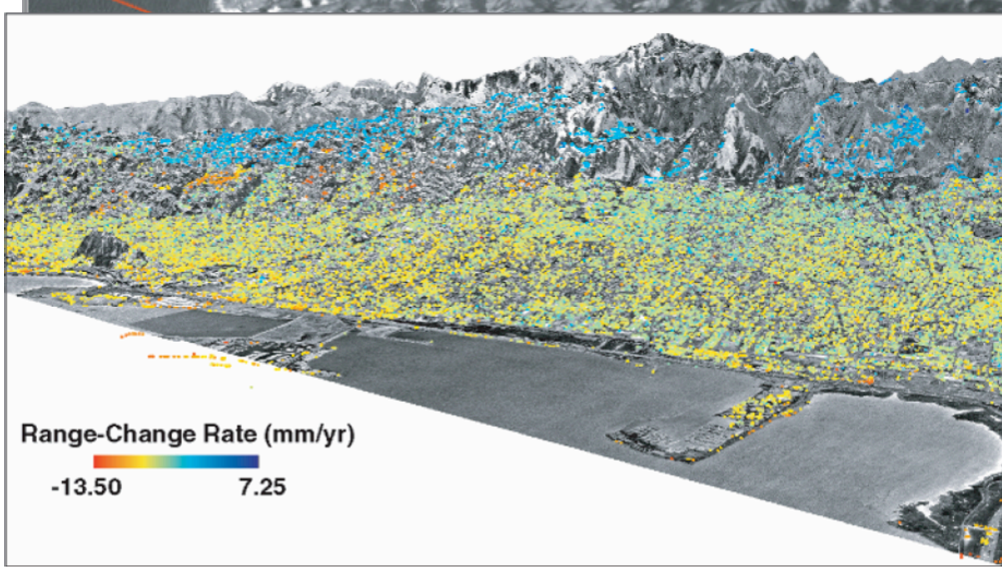
- unwrapped phase required
  - stacking of interferograms from independent acquisition pairs
  - interferogram with common acquisitions
- no phase unwrapping required for applying gradient approach (Sandwell and Price, 1998)
  - gradients between neighboring resolution cells are stacked
- comparison of results with geodetic techniques require unwrapping in any case

Permanent scatterer examples

Courtesy: Richard Carande, NevaRidge

San Francisco Area PS Measurements



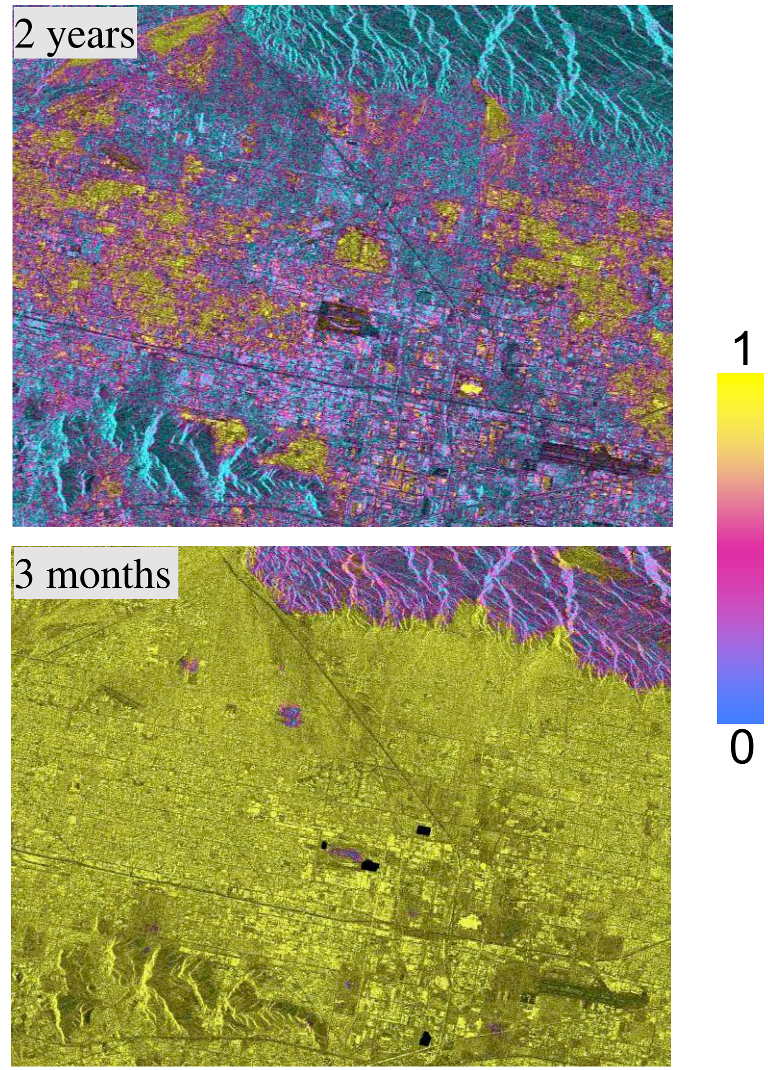


Results from: Feretti, et al.,
EOS V85, No. 34, Aug 2004

ITSA - Temporal Stacking

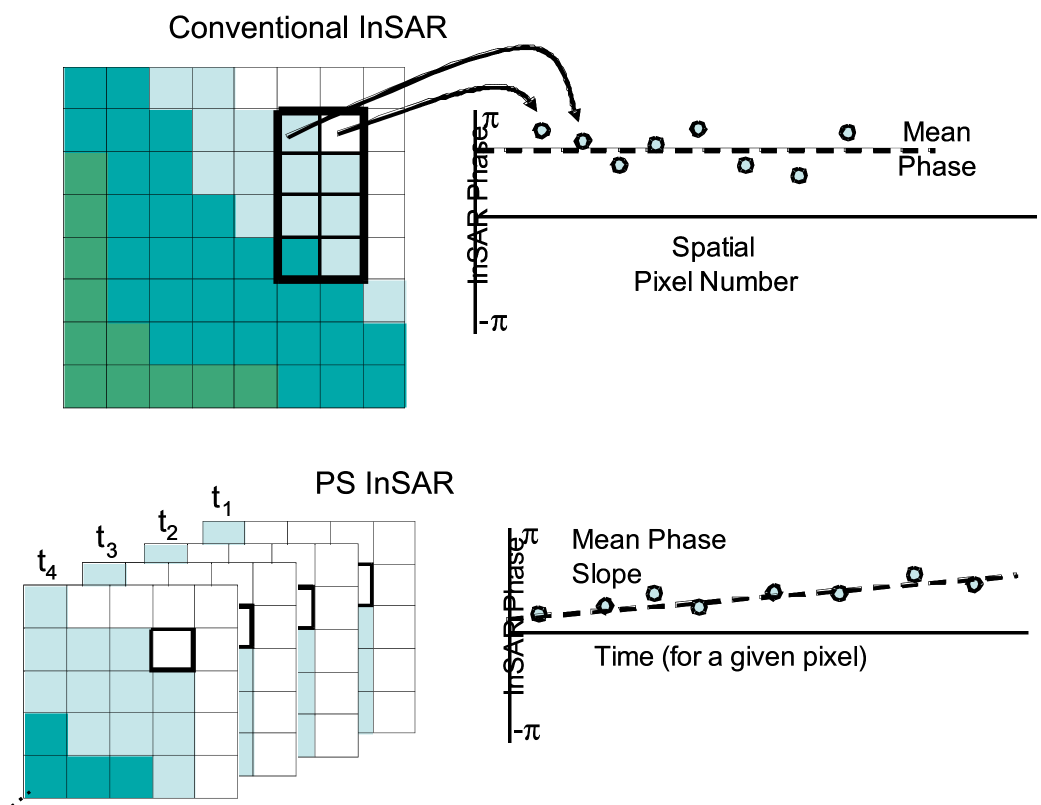
- Spatial decorrelation occurs over long time periods of interest.
  - But decorrelation is very good over short periods.
- Solution: use time series of short-time SAR data to build long-time series of displacements
- Incoherent sum of displacements produces final displacement result
- Note that in this approach the atmospheric water vapor contribution does not sum, but cancels in each successive displacement map

Spatial Coherence



ITSA - Single Pixel PS Approaches

- Pioneered (and patented) by faculty at Politecnico di Milano.
  - Now principals in a small company: TRE.
- Basic idea: coherence is critical to InSAR phase estimates. Consider an area for which a pixel with a good SNR is surrounded by pixels with high noise. In the process of averaging to obtain coherence, all information is lost.
- In PS approaches, phase (and coherence) is estimated along the temporal axis for a given pixel.
  - No spatial averaging nor spatial correlation assumed
  - In principle, atmospheric and DEM errors estimated and removed.
  - Significant disadvantage is that a target/ground motion model is required – typically linear.



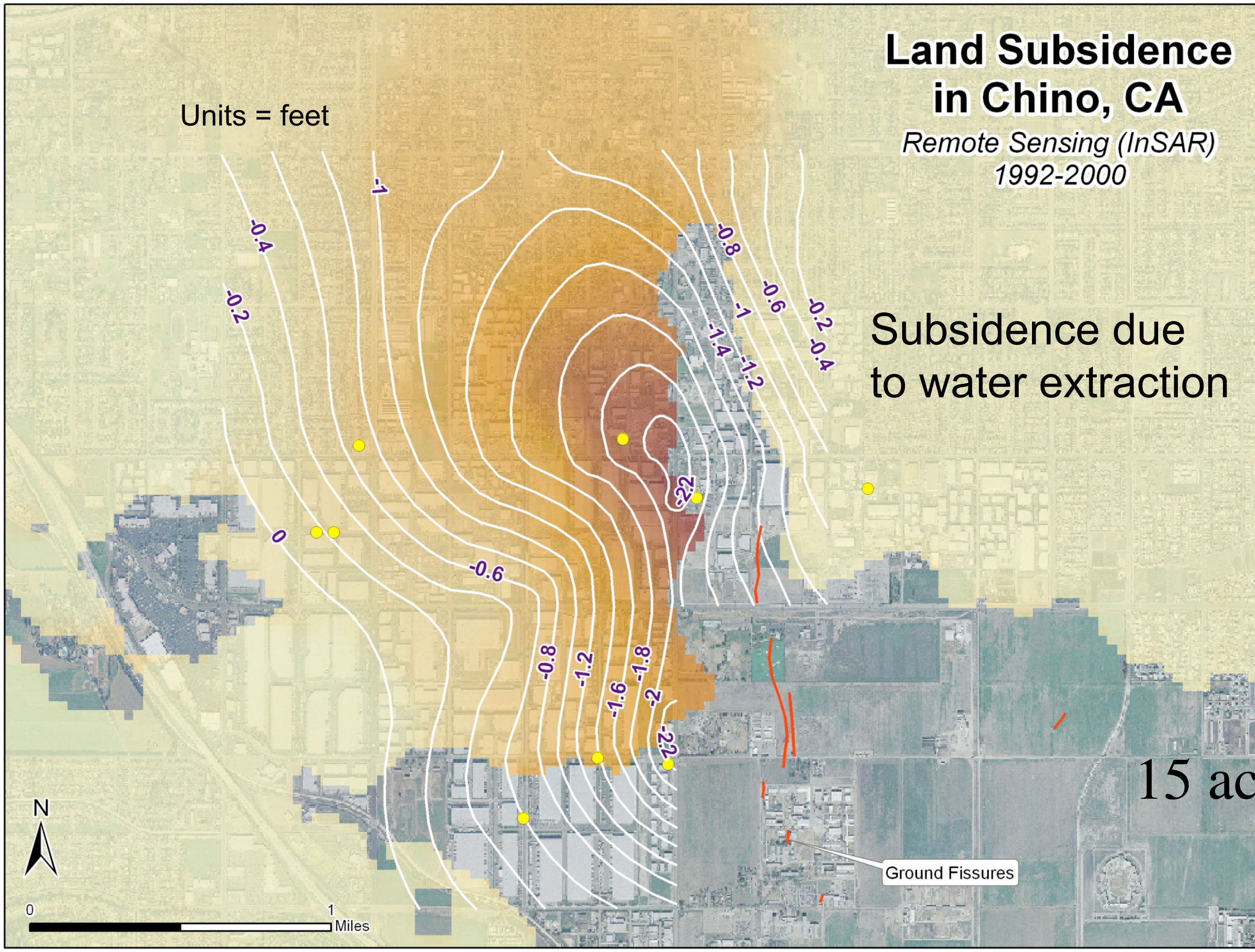
All ground motion results from this approach are linear

Published PS Activities

- Tele-Rilevamento Europa (spinoff of POLIMI)
  - Innovator of PS algorithm
  - Robust results for linear model
  - Combination of research and providing as service
  - Principals: Ferretti, Prati, Rocca
- Gamma Remote Sensing (Switzerland)
  - Have applied to L-band data
  - Mine subsidence interests
  - Research and product
- Universitat Politecnica de Catalunya (Barcelona)
  - Focussing on a reduced data set and nonlinear models
  - Research
  - Principal: Mora
- Stanford University
  - Unique algorithm that is not constrained by linear model
  - Developed for geophysical measurements – should give good measurements in urban areas with distributed subsidence
  - Purely research
- CNR-ISSIA (Bari, Italy)
  - Contributing new technique for choosing PS using a classification approach
  - Research
- Vexcel
  - Primarily linear modeled deformation
  - No refereed publications on topic
  - Selling as product

Institution	Technology
TRE/POLIMI	PPS
Gamma	IPTA
UPC	CPT
Stanford	PS
CNR	SBAS
Vexcel	CTM

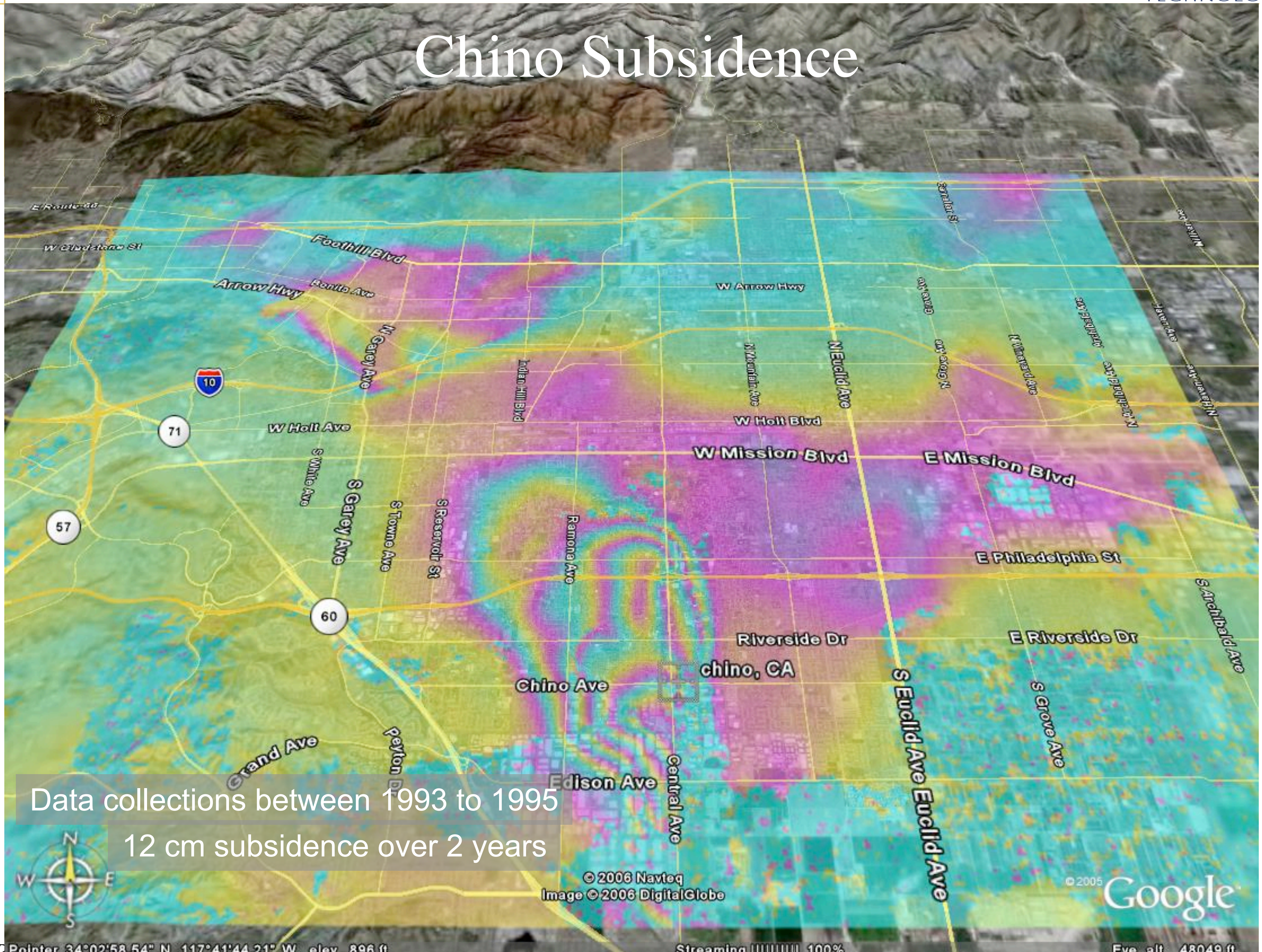
Multiple Data Acquisitions



15 acquisitions

Derived from ERS SAR

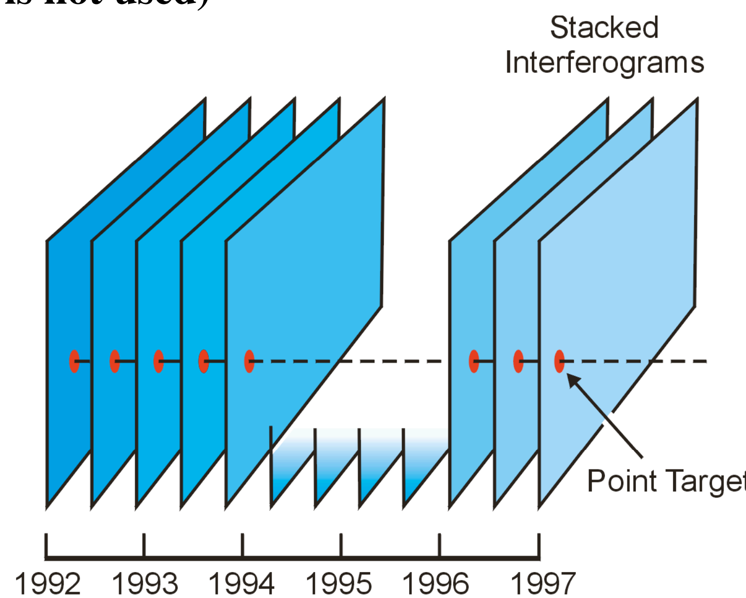
Chino Subsidence



Using Multiple Coherent Observations: London Example

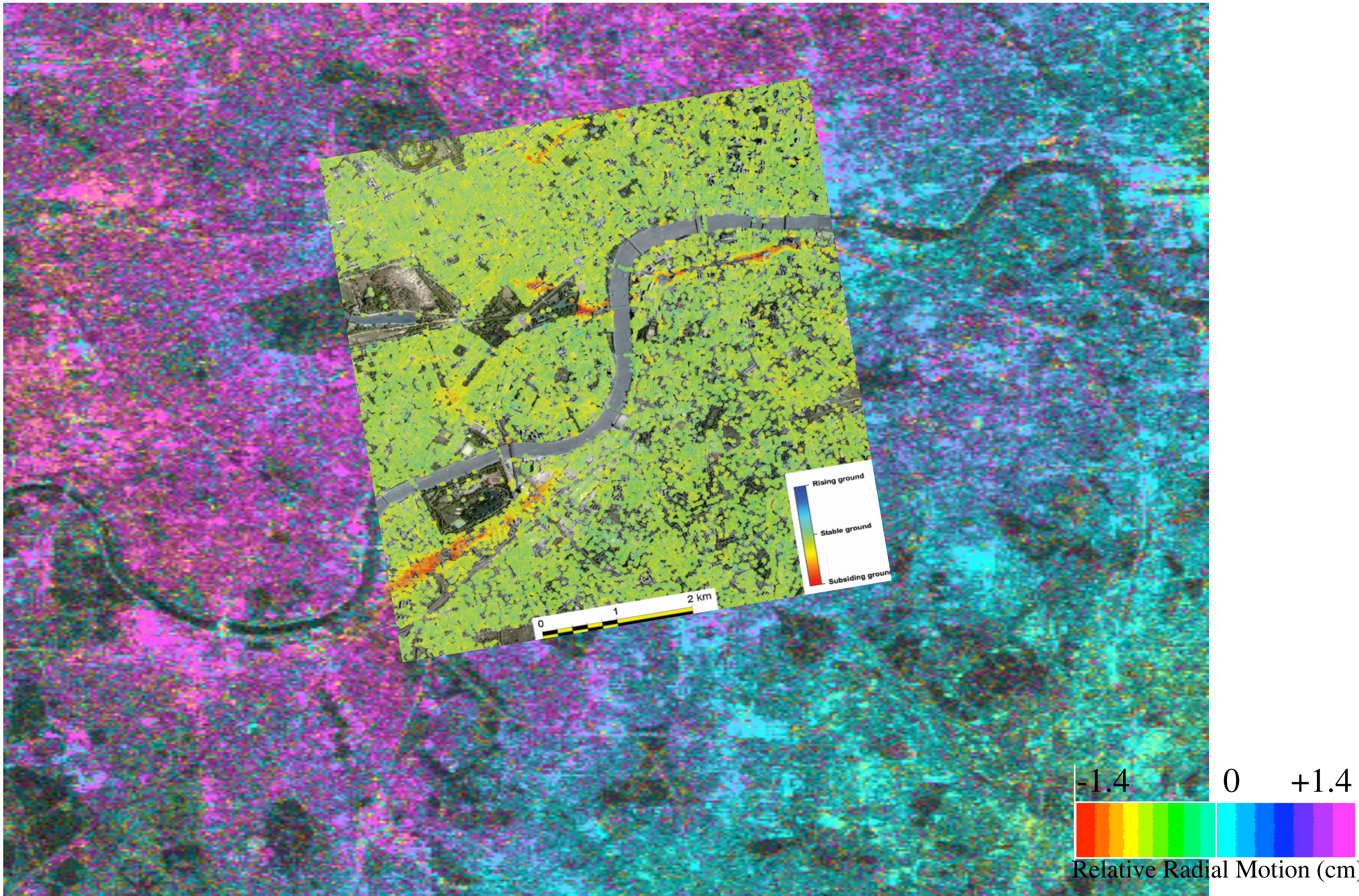
Master Image: 6/27/1997		
Date of Image	Time Seperation (days)	Perp Baseline (m)
05/05/92	-1879	107
06/09/92	-1844	-225
08/18/92	-1774	113
09/22/92	-1739	-209
02/09/93	-1599	-147
08/03/93	-1424	-233
04/13/95	-806	139
07/27/95	-701	-306
08/31/95	-666	-111
09/01/95	-665	-68
08/16/96	-315	-106
09/20/96	-280	-144
01/03/97	-175	-62
03/14/97	-105	-243
05/23/97	-35	-30
08/01/97	35	-106
10/09/97	104	-241
11/14/97	140	-132
12/19/97	175	-2
01/23/98	210	121
04/03/98	280	76
03/19/99	630	-120
07/02/99	735	-318
10/15/99	840	42
12/24/99	910	-91
01/27/00	944	44
04/07/00	1015	-11
11/03/00	1225	-85
01/12/01	1295	-296

- **31 available ERS images (05/05/1992 – 01/12/2001)**
- **Master image used for CTM processing: 06/27/1997**
- **29 interferometric pairs available for CTM processing (shown at left, 01/28/00 ERS data is not used)**

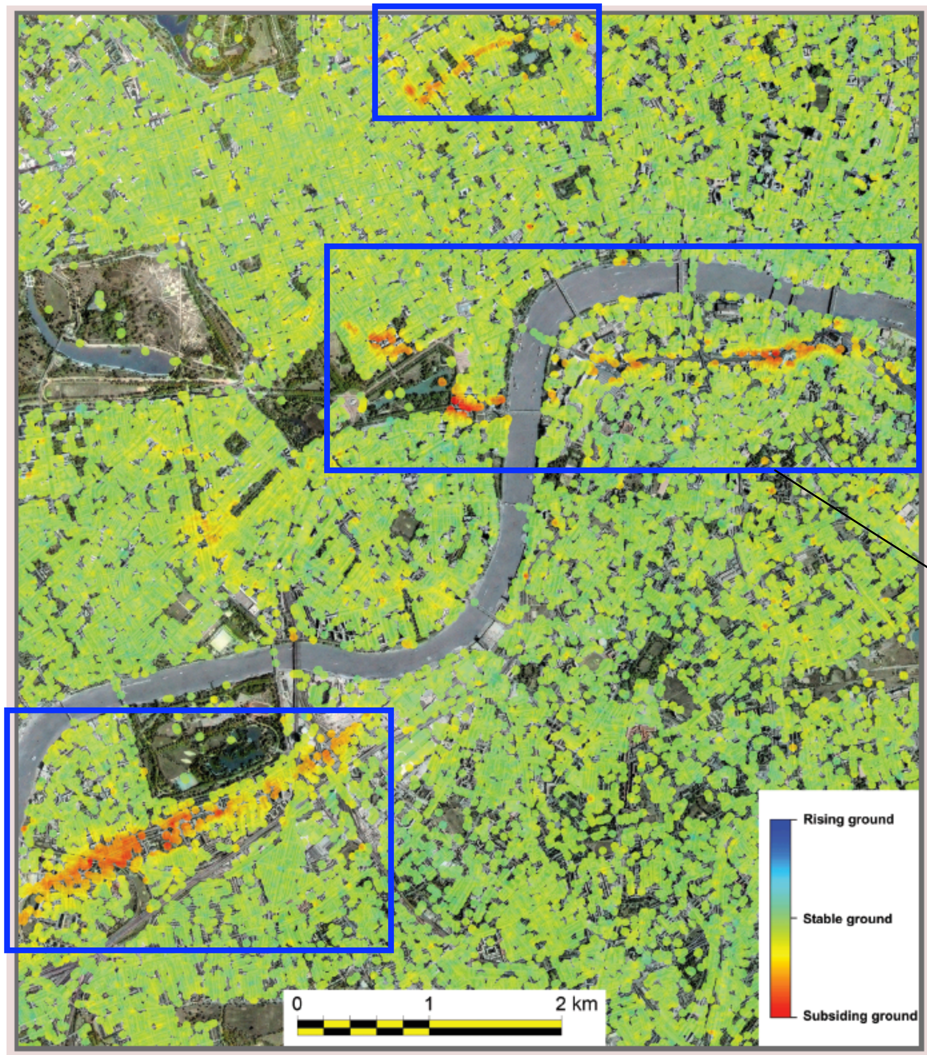


R. Carande: SAR Interferometry

2-pass/N-pass London Data



Detection of Tunneling Activity

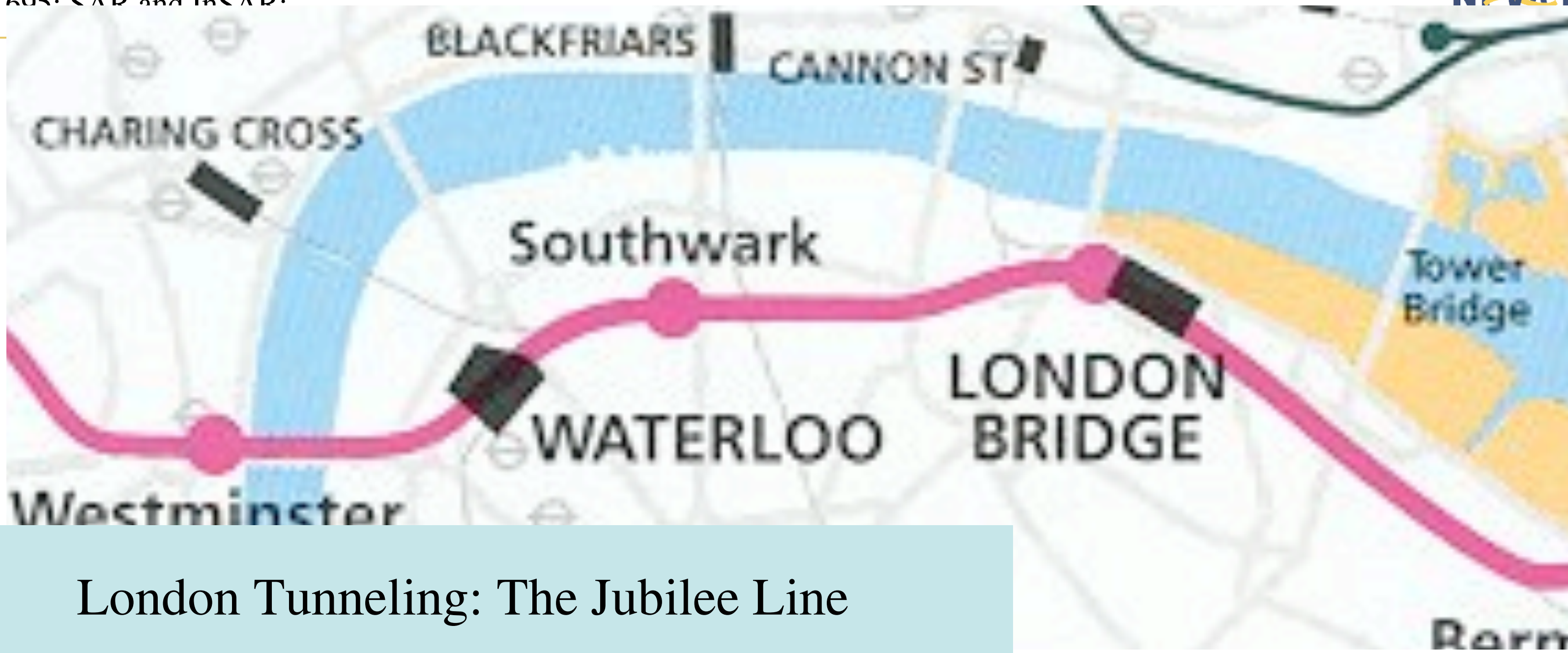


ERS SAR data

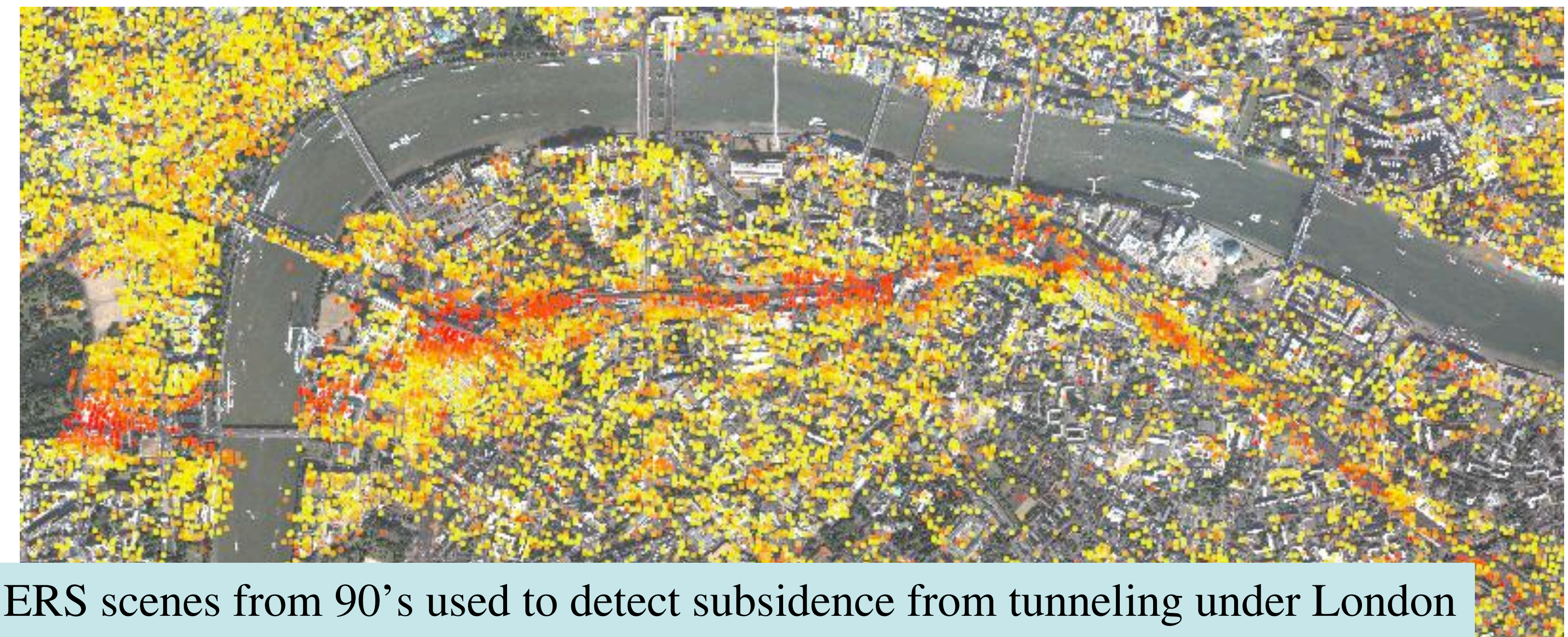
London, England

Jubilee underground train line and electrical tunnels

Multiple observations can be used to remove atmospheric noise and detect more subtle subsidence, in this case, an underground tunnel has subsided and is detected.

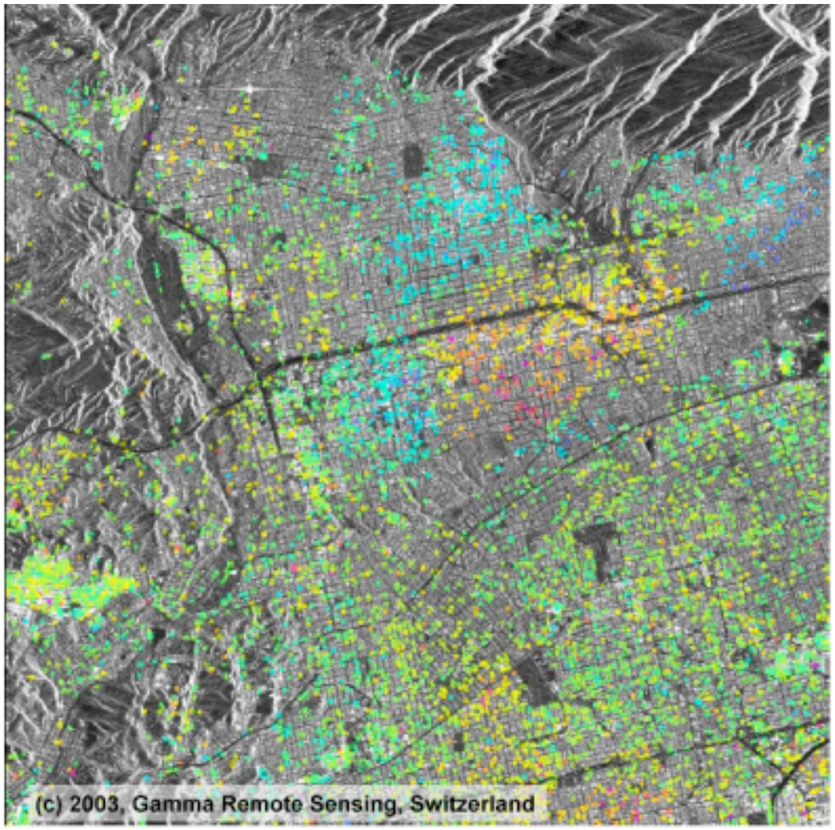


London Tunneling: The Jubilee Line

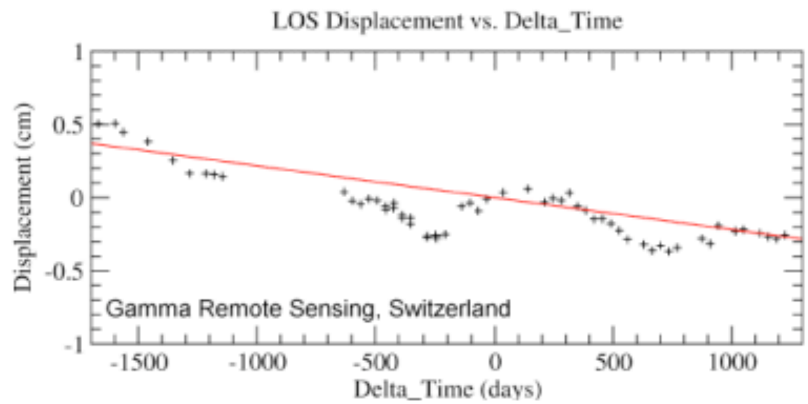


30 ERS scenes from 90’s used to detect subsidence from tunneling under London

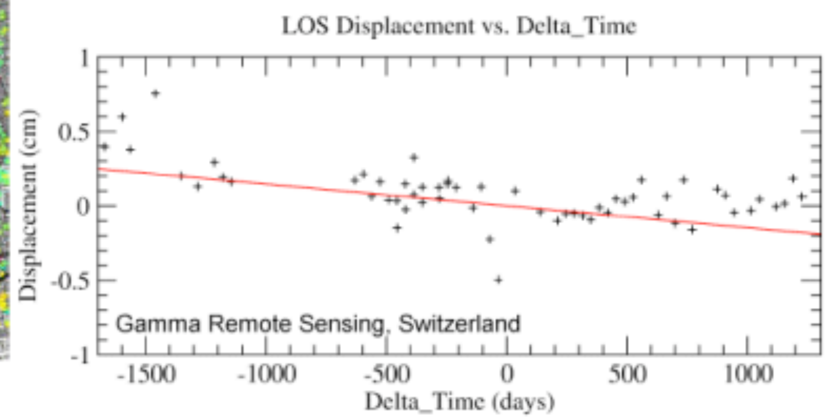
Interferometric Point Target Analysis (IPTA)



Pasadena, CA



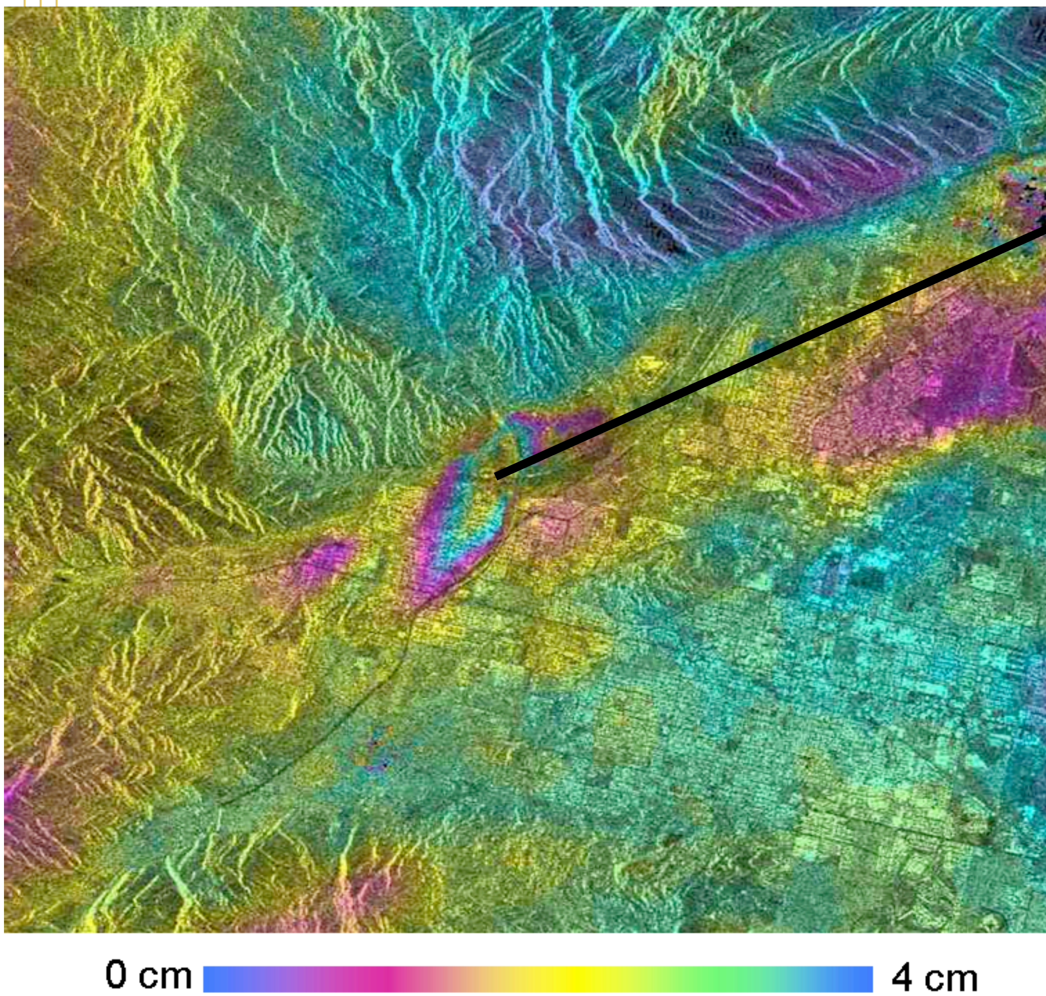
Regional deformation history

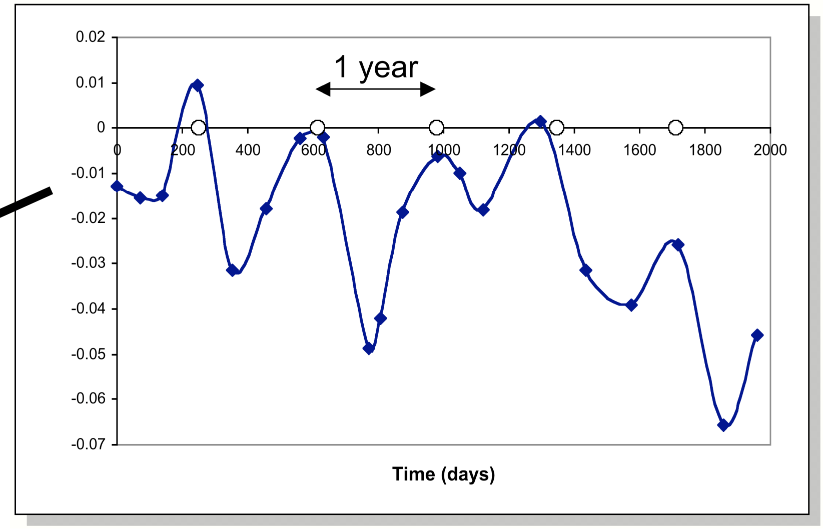


Point-wise deformation history

Courtesy Gamma Remote Sensing

InSAR Oscillations





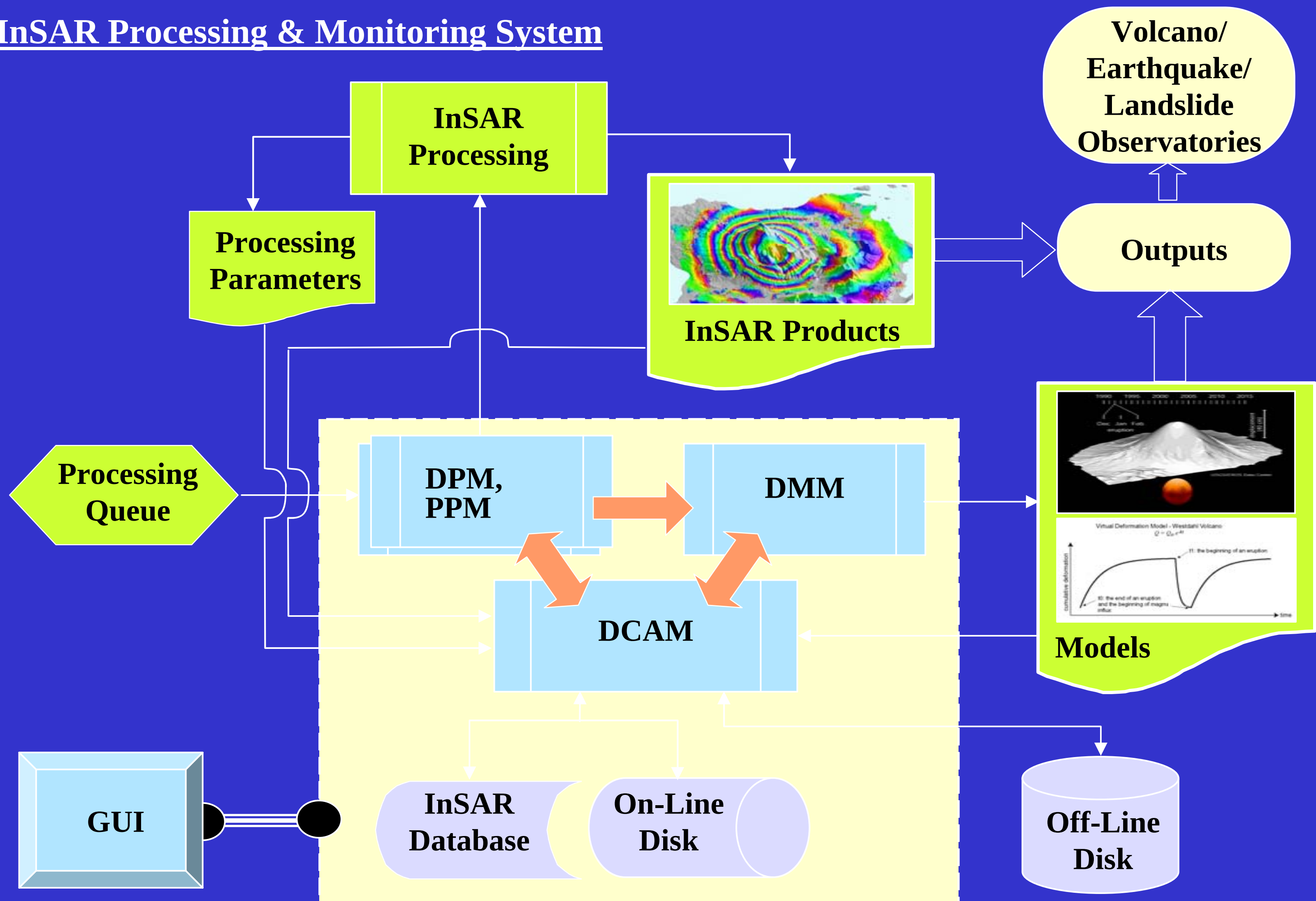
- Western US subsidence measured with ERS InSAR
- This 3-month interval shows 4 cm of motion
- Analysis of the time series shows yearly oscillations
- In this case, behavior likely corresponds to seasonal groundwater cycle

Long-term monitoring
Example: Volcanoes

Courtesy: Zhong Lu

InSAR Future: from research to operation

InSAR Processing & Monitoring System



DPM:	Data Processing Module	DMM:	Deformation Modeling Module
PPM:	PSInSAR Processing Module	GUI:	Graphic User Interface
DCAM:	Data Cataloging and Archiving Module		