THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

InSAR Research in China and Future Applications of ALOS/PALSAR

Xiaoli Ding

Department of Land Surveying and Geo-Informatics

Hong Kong Polytechnic University

InSAR Research in China

- InSAR research institutions
- Earth observation satellite series
- A sample of the research topics and results

InSAR Research Institutions

- Over 20 universities have started their research work on InSAR, including
  - Hong Kong Polytechnic University
  - Chinese University of Hong Kong
  - Wuhan University
  - Peking University
  - Tongji University
  - Xidian University
  - Beijing University of Aeronautics and Astronautics
  - Southwest Jiaotong University
  - National University of Defense Technology
  - Information Engineering University
  - Changan University

InSAR Research Institutions

- A number of institutes in the Chinese Academy of Sciences are doing InSAR research, including
  - Institute of Remote Sensing Applications
  - China Remote Sensing Satellite Ground Station
  - Institute of Electronics
  - Institute of Automation
  - Institute of Oceanography
  - Shanghai Astronomical Observatory

- Some other research institutions under various government departments
  - China Earthquake Administration:
    - Institute of Geophysics
    - Institute of Geology
    - Institute of Crustal Dynamics
    - Institute of Earthquake Science
    - 1st Earthquake Monitoring Centre

- Ministry of Land and Resources:
  - China Institute for Geo-Environmental Monitoring

Earth Observation Satellite Series in China

- China is building up five main remote sensing satellite series
  - Earth resources satellite series
  - Meteorological satellite series
  - Environment and hazards monitoring micro-satellite series
  - Ocean satellite series
  - Remote sensing series

Earth Resources Satellite Series

- For use in
  - Agriculture
  - Forest study and monitoring
  - Regional geological investigation
  - Water resources investigation and monitoring
  - Energy and environmental monitoring
  - City planning
  - Hazards monitoring
  - Engineering geology
  - Highways planning
  - Surveying and mapping

Earth Resources Satellite Series

- CBERS (ZY) 1/2 have been launched jointly with Brazil (ZY stands for 资源)
- ZY-2B, ZY-3, ZY-4 will be launched

Meteorological Satellite Series

- Up to now, the following satellites have been launched:
  - FY-1A (FY stands for 风云)
  - FY-1B
  - FY-1C
  - FY-2A
  - FY-2B
  - FY-2C
- FY-2D, FY-2E, FY-2F and FY-3 are being developed

Environment and Hazards Monitoring Micro-Satellite Series

- 1st phase (2+1) (2007):
  - HJ-1A (optical) (HJ stands for 环境)
  - HJ-1B (optical)
  - HJ-1C (S-band SAR)
- 2nd phase (to realize 4+4) (by 2010)

Ocean Satellite Series

- HY-1A (2003) (HY stands for 海洋)
- HY-1B (planned for 2006) (ocean colours and temperature, coastal monitoring)
- HY-2A (future) (ocean dynamic environments including winds, sea surface topography, tides, gravity, ocean circulation, surface temperature)
- HY-3A (future) (SAR, ocean environment)

Remote Sensing Satellite Series

- Remote sensing 1 was launched in April 2006
- For land use census, agricultural applications, hazards monitoring and mitigation

A Sample of InSAR Research Topics and Results

- Research areas cover theoretical aspects, system development, and applications

Examples of Research Topics

- Satellite SAR prototype
- Satellite SAR data communication schemes
- SAR antenna
- Satellite SAR T/R components
- Satellite SAR data processing and motion compensation

Examples of Research Topics

- Airborne SAR real-time data processing
- Satellite SAR data compression
- Dual-frequency multi-polarization SAR

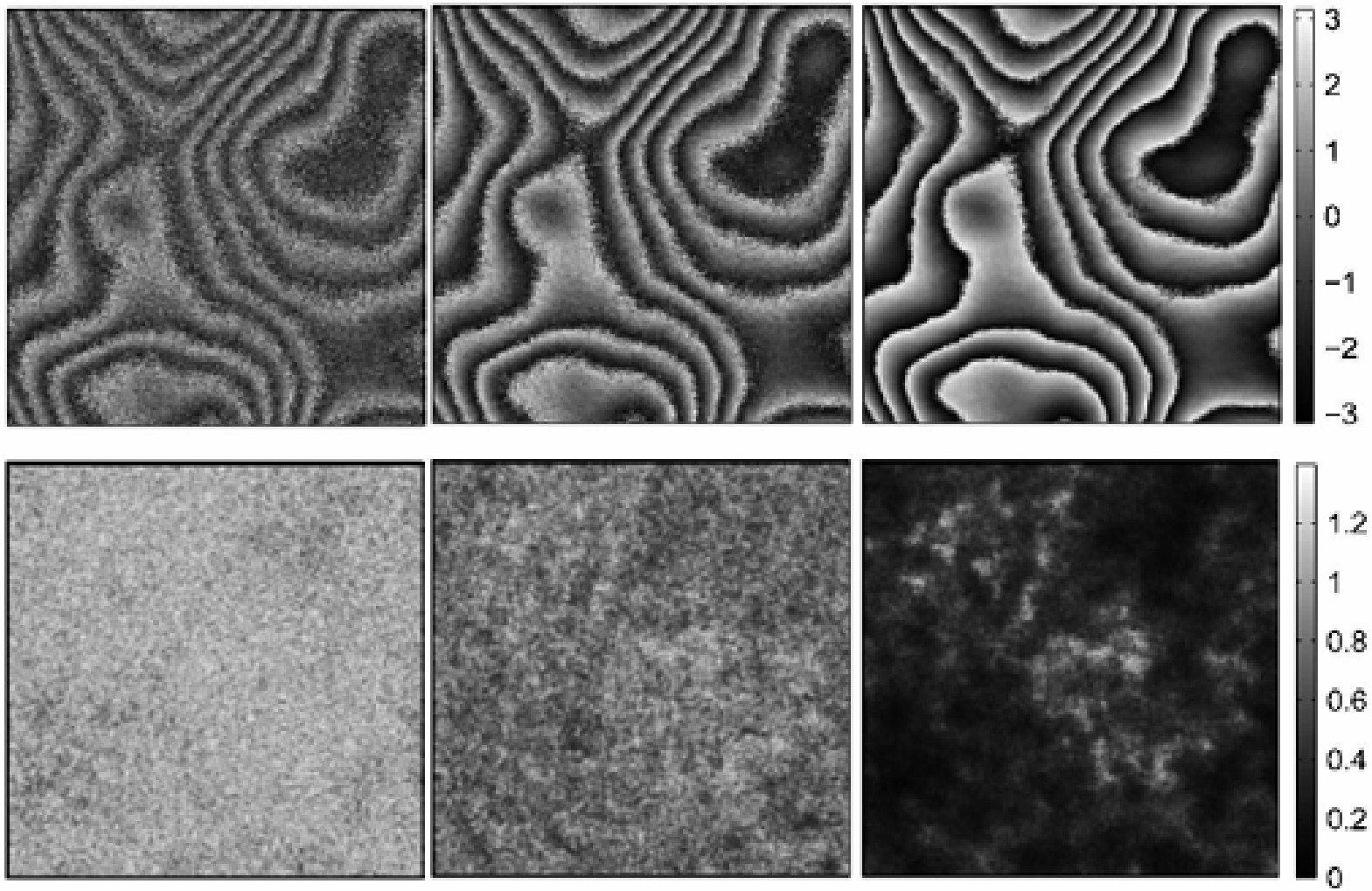
Examples of Research Topics

- Satellite SAR applications in
  - Ocean monitoring
  - Flooding and draught prediction
  - Geology
  - Landslides
  - Earthquakes
  - Land subsidence

SAR Interferogram Filtering

- 2D Vondrak filter
- Modified Goldstein filter

2D Vondrak Filter



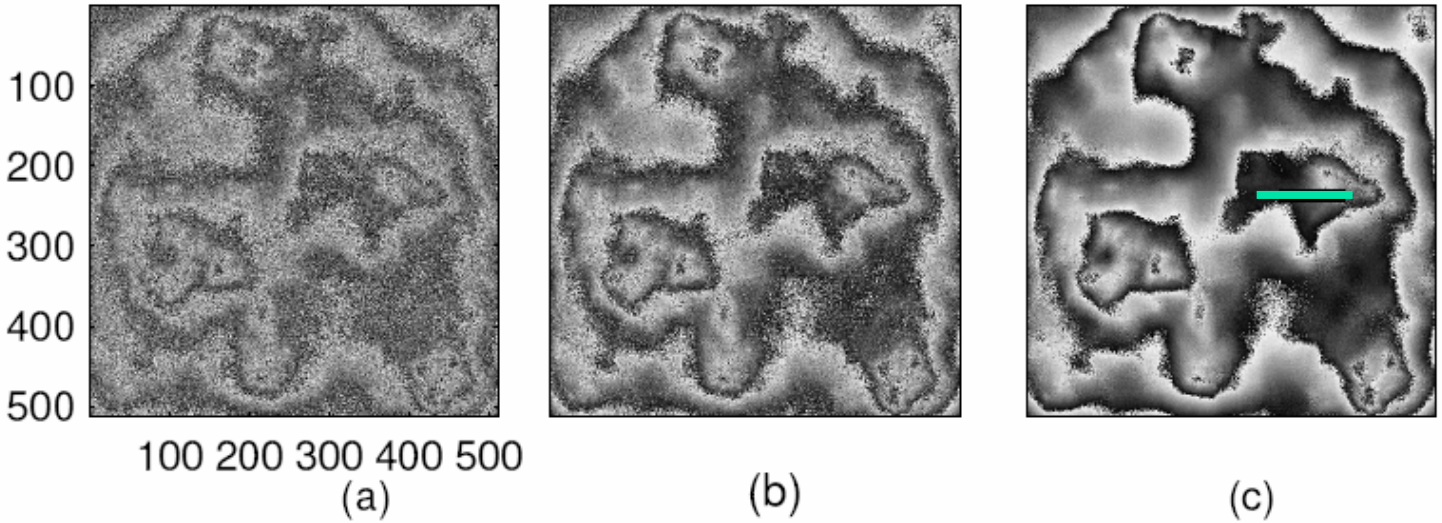
Example of Results

No filtering

Baran filter

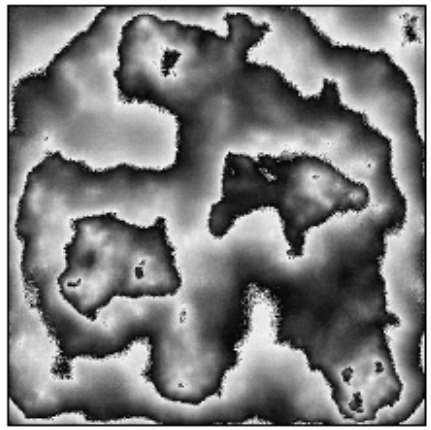
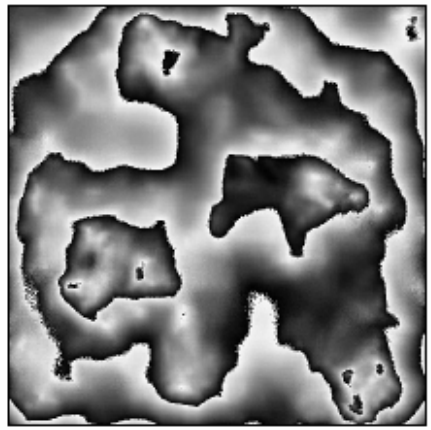
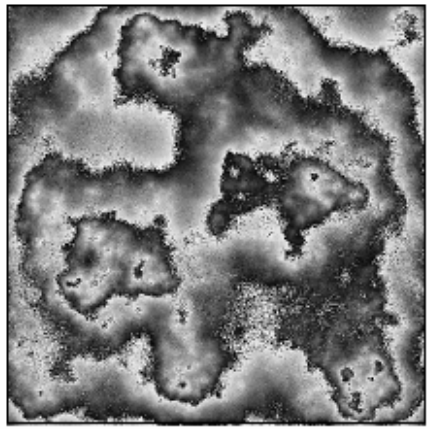
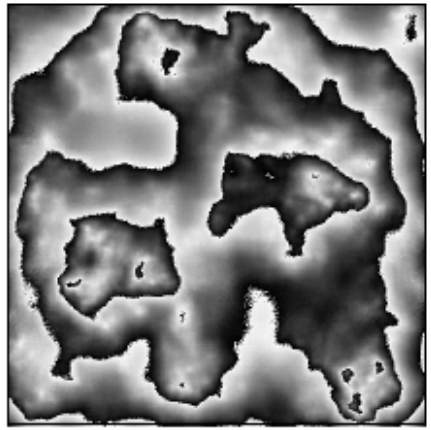
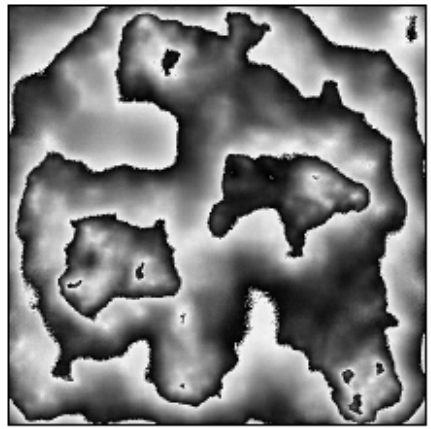
New filter

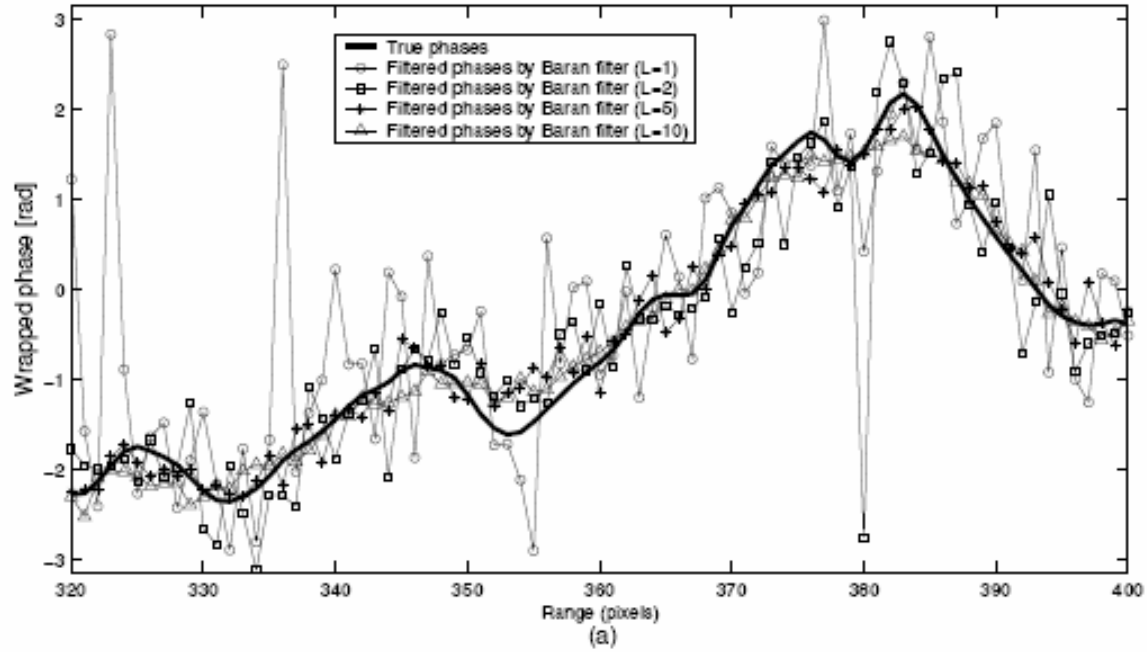
L=1



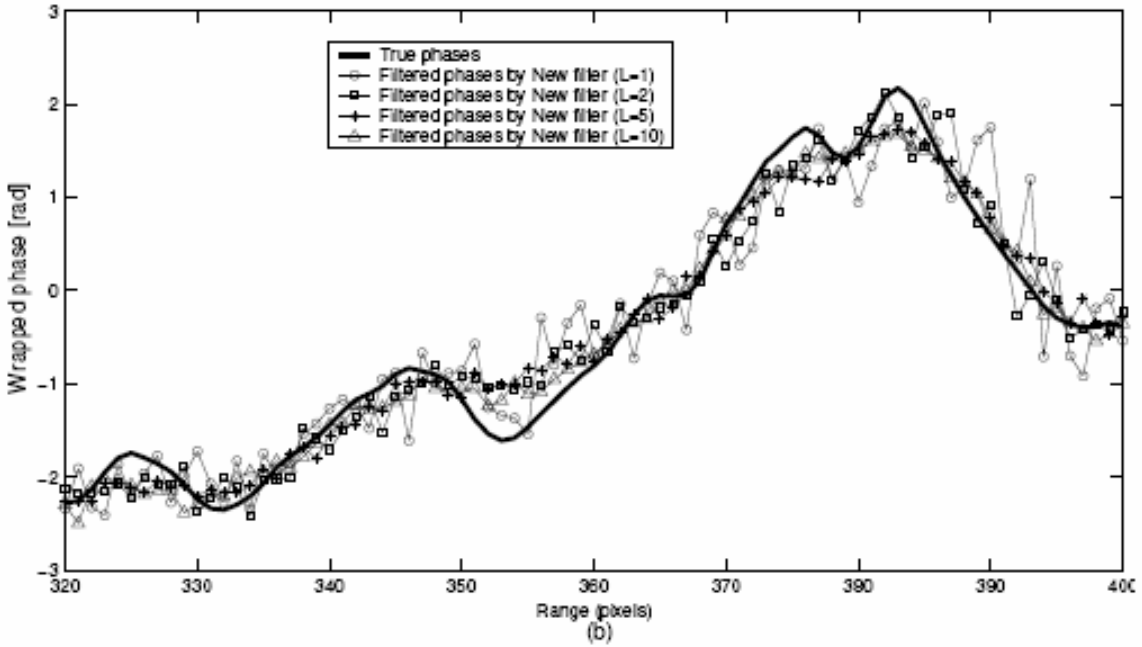
L=2

Example: Simulated Data

	No filtering	Baran filter	New filter
L=5	 (g)	 (h)	 (i)
L=10	 (j)	 (k)	 (l)


True phases
Filtered phases by Baran filter (L=1)
Filtered phases by Baran filter (L=2)
Filtered phases by Baran filter (L=5)
Filtered phases by Baran filter (L=10)
Wrapped phase [rad]
Range (pixels)

(a)

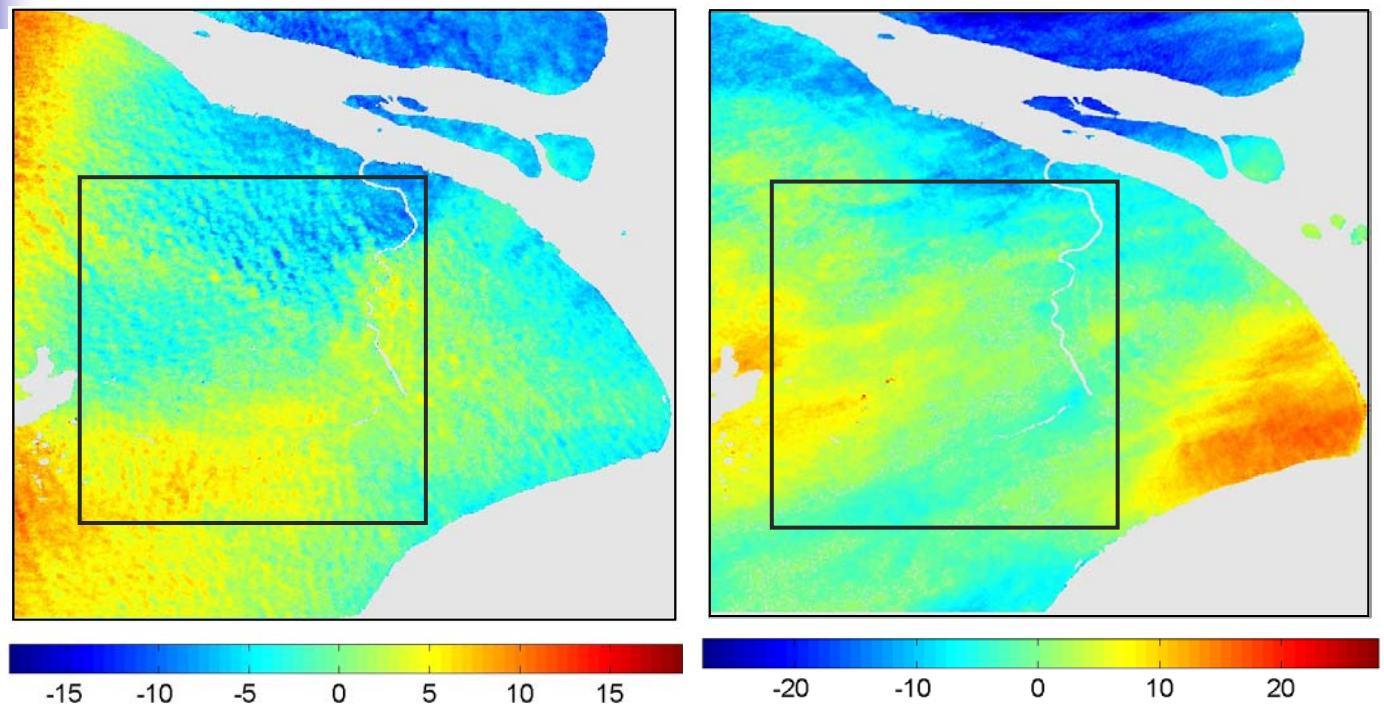

True phases
Filtered phases by New filter (L=1)
Filtered phases by New filter (L=2)
Filtered phases by New filter (L=5)
Filtered phases by New filter (L=10)
Wrapped phase [rad]
Range (pixels)

(b)

Atmospheric Effects on InSAR

- Characterization of effects
- Correction of effects

Differential Atmospheric Signal

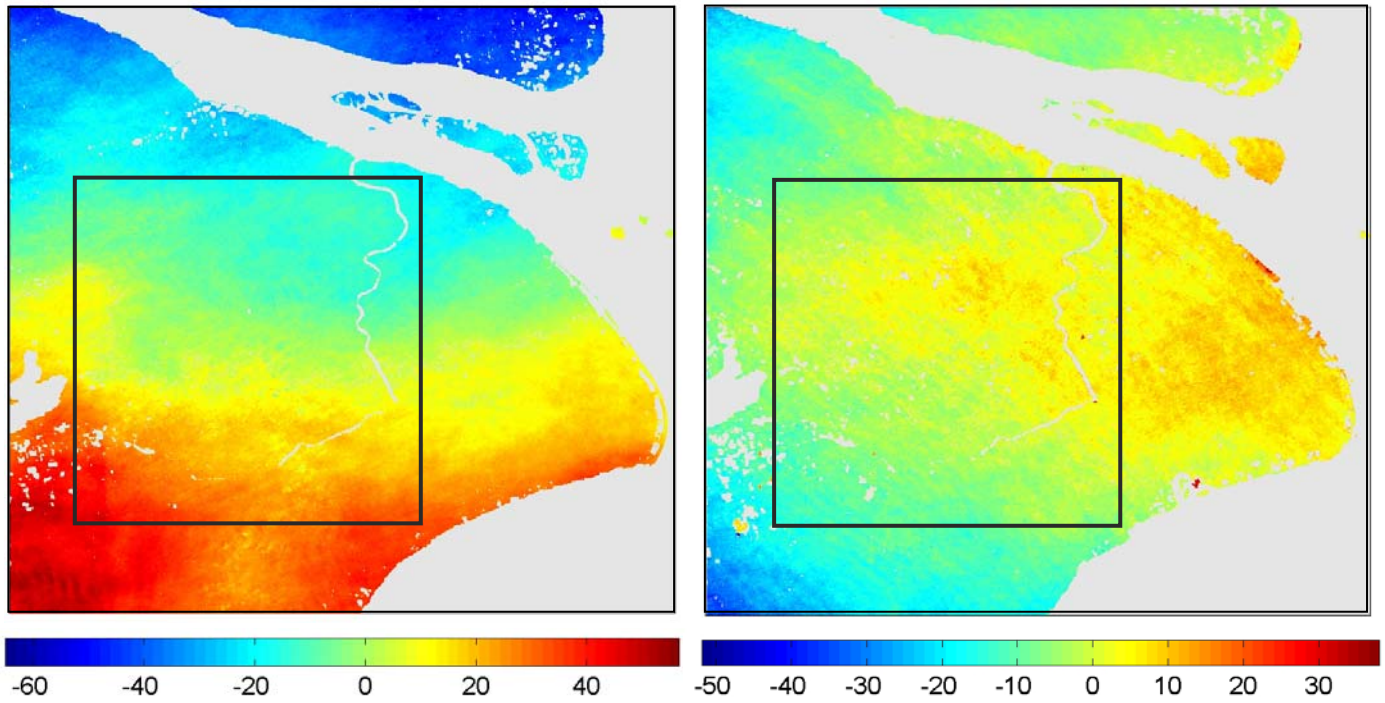


Unit: mm

(a) 19/02/1996 – 20/02/1996

(b) 25/03/1996 – 26/03/1996

Differential Atmospheric Signal



Unit: mm

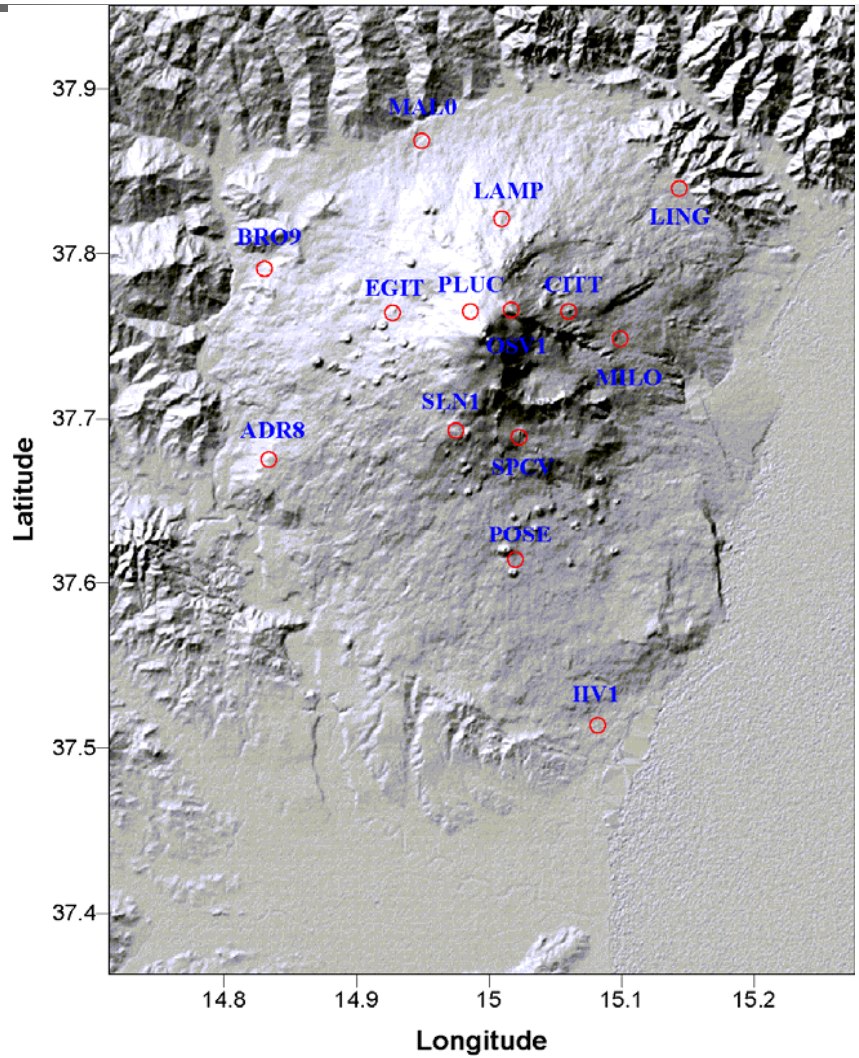
(c) 03/06/1996 – 04/06/1996

(d) 16/11/1999 – 21/12/1999

Atmospheric Correction over Mt. Etna Area

- Area
  - Mount Etna, Sicily, Italy
- Data set
  - SAR data
    - 6 September 2000 and 11 October 2000
  - External data
    - 14 CGPS tracking data
    - 1 Ground meteorological data

Atmospheric Correction over Mt. Etna: GPS Distribution



Atmospheric Correction over Mt. Etna: Model

- Model (Simple Kriging with Varying local mean)

$$z^*_{SKlm}(u) = \sum_{\alpha=1}^{n(u)} \lambda^{SK}_{\alpha}(u)[z(u_\alpha) - m^*_{SK}(u_\alpha)] + m^*_{SK}(u)$$

where

$$\sum_{\beta=1}^{n(u)} \lambda^{SK}_{\beta} C_R(u_\alpha, u_\beta) = C_R(u_\alpha, u) \qquad \alpha = 1, \mathrm{K}, \mathrm{n(u)}$$

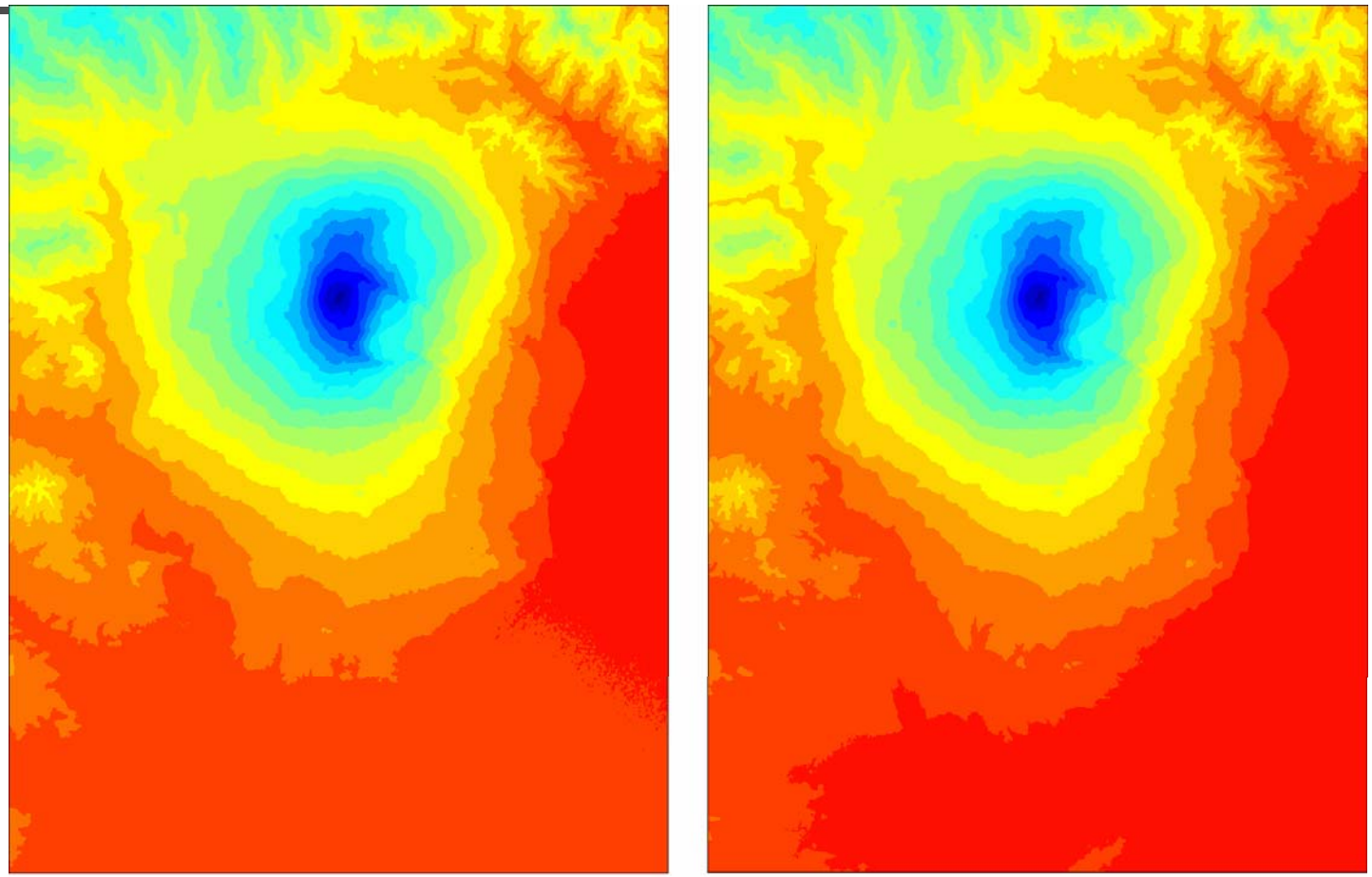
$$m^*_{SCK}(u) = 0.0022768 P_h + \nu U_h 10^{\gamma T_h}$$

$$P_h = P_0(1 - 22.6 * 10^{-6}(h - h_0))^{5.26}$$

$$T_h = T_0 - k(h - h_0)$$

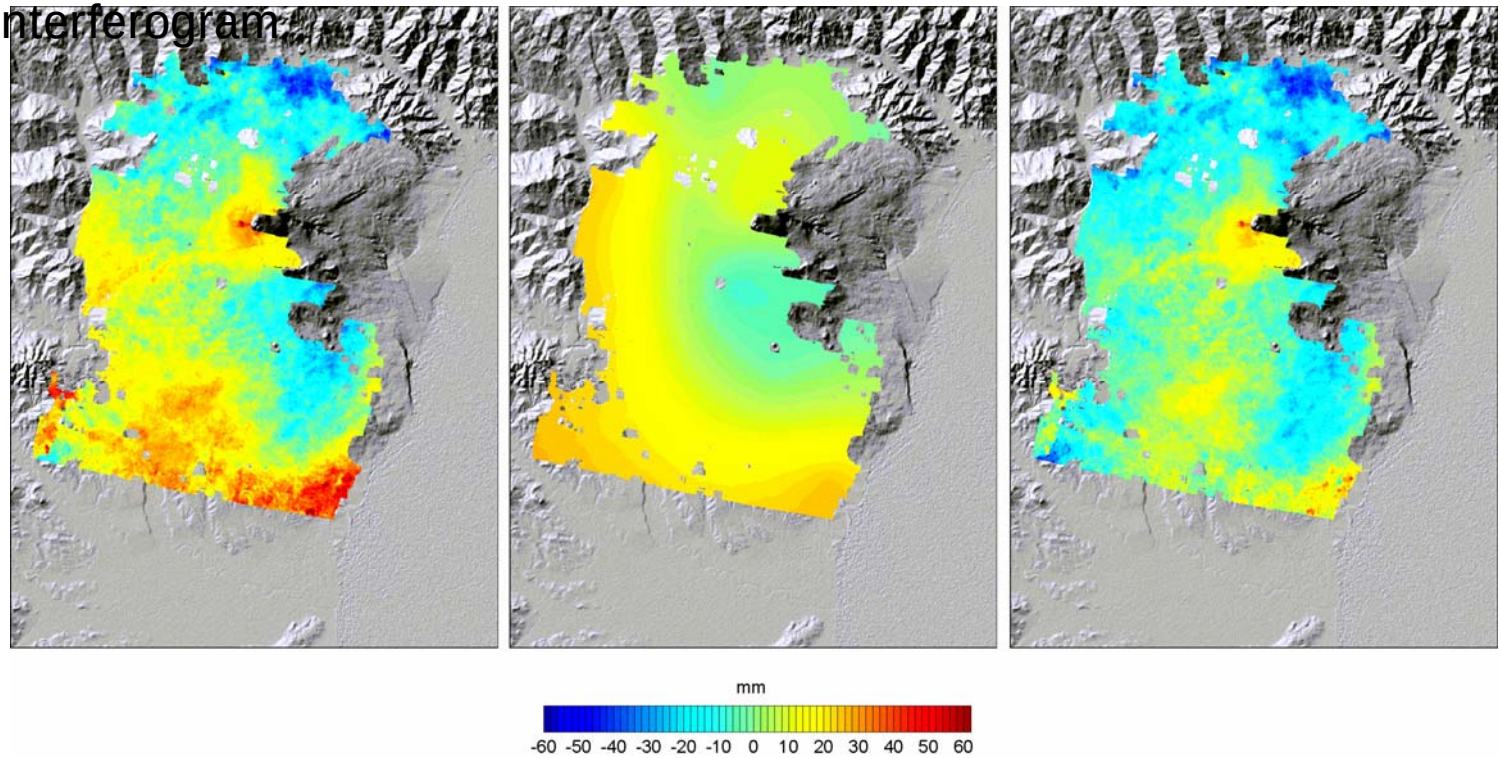
$$U_k = U_0$$

Atmospheric Correction over Mt. Etna: Atmospheric Delay Map



Atmospheric Correction over Mt. Etna: Corrected Results

Unwrapped interferogram Modeled atmospheric fields Corrected interferogram

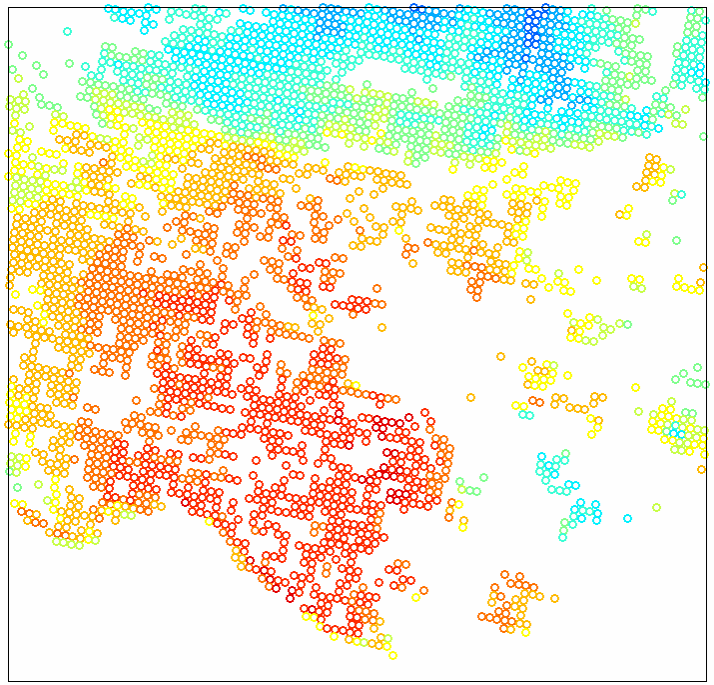


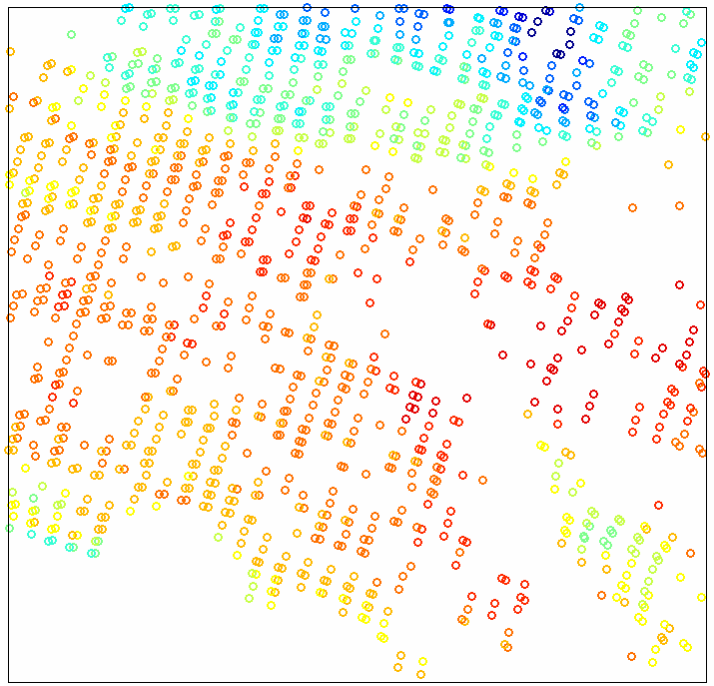
- Before correction: 16.9 mm
- After correction: 12.3 mm
- Improvement: 27.2%

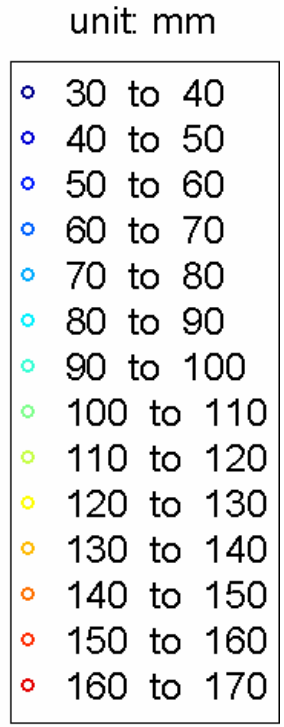
Atmospheric Correction over Los Angeles: Data Sets

- Area
  - Los Angeles, Southern California, USA
- Data Set
  - SAR data
    - 29 July 2000 and 18 August 2001
  - External data
    - MODIS data

Atmospheric Correction over Los Angeles: MOSID WZD Samples



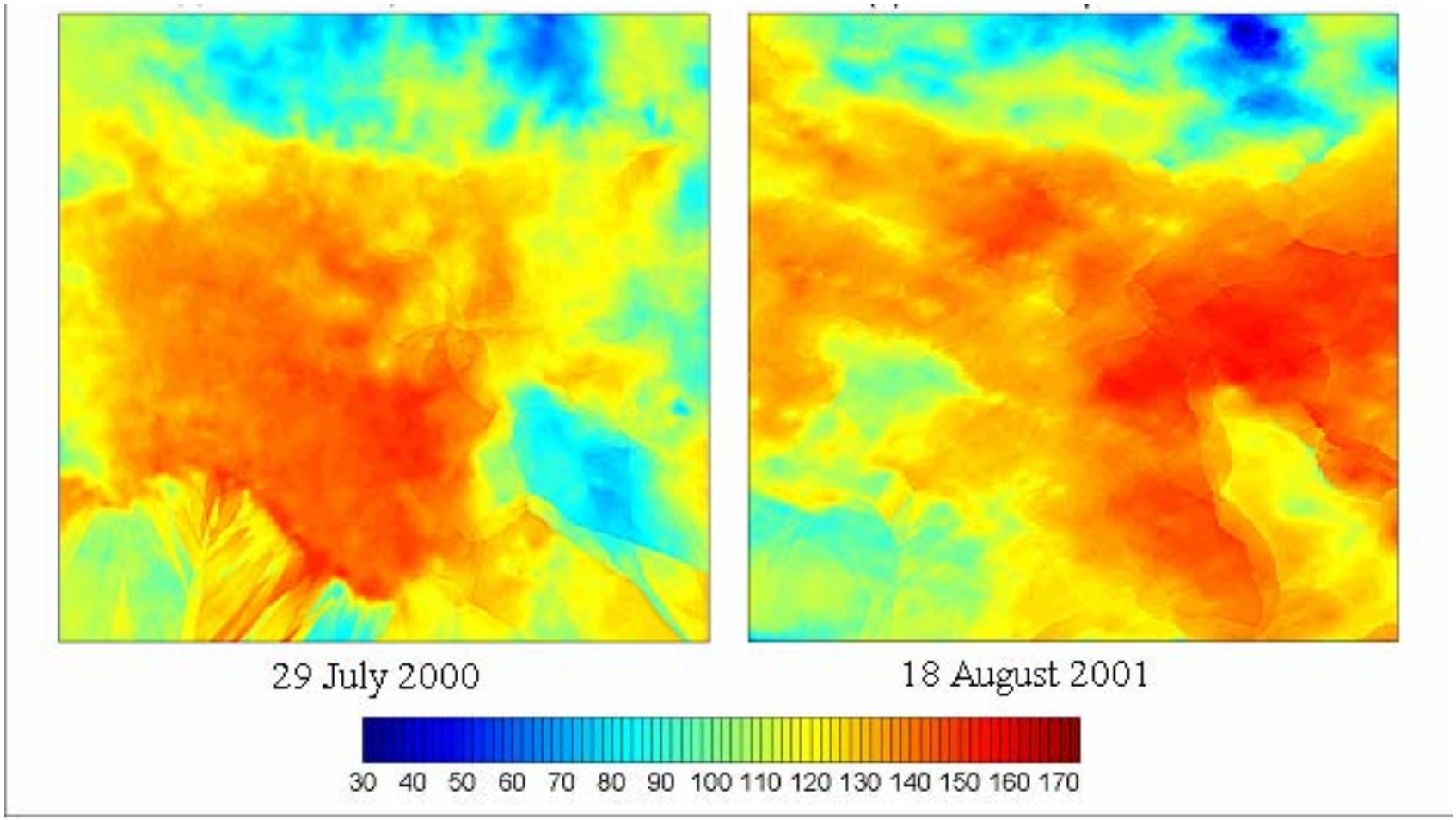




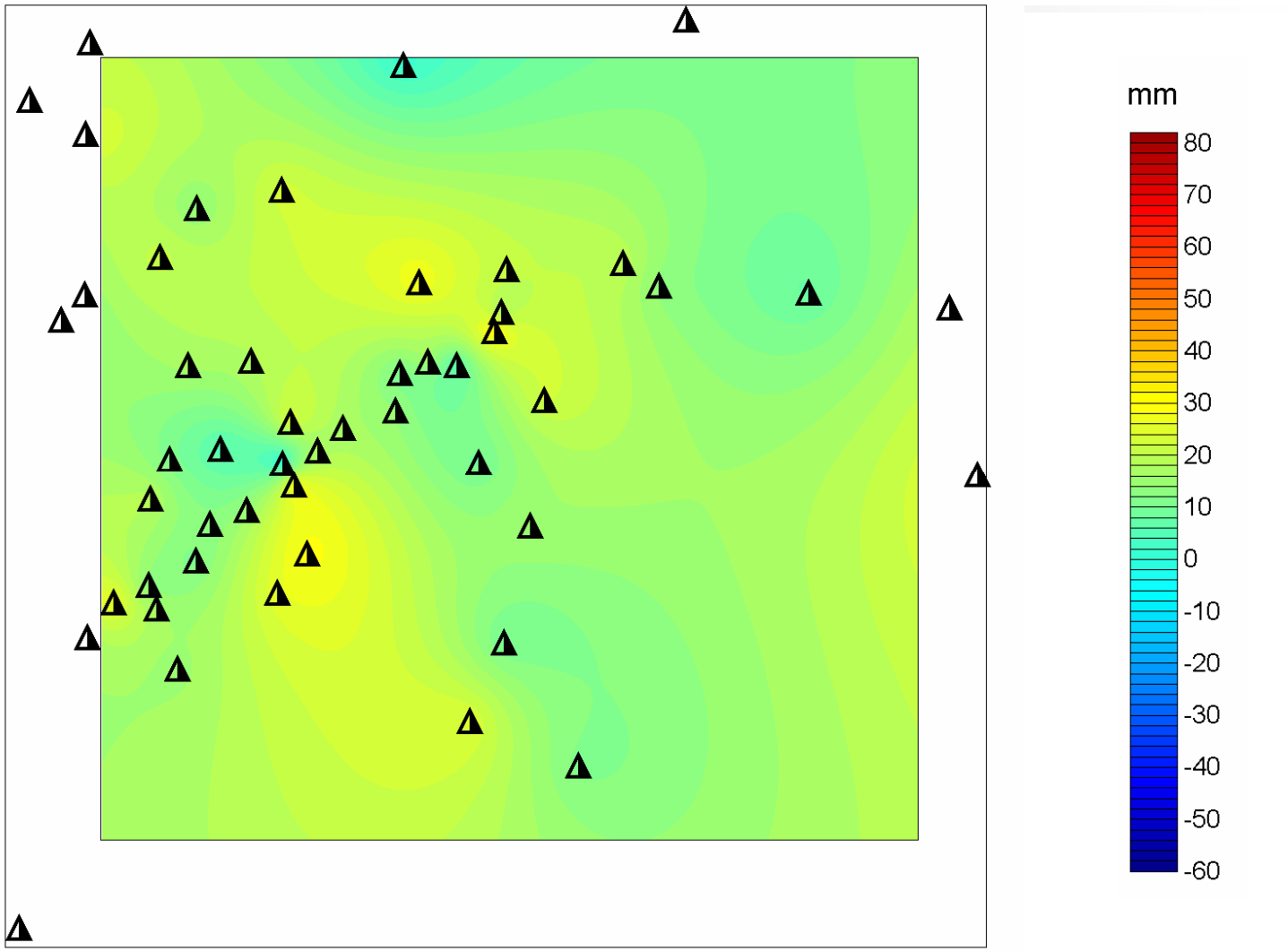
29 July 2000

18 August 2001

Atmospheric Correction over Los Angeles: Atmospheric Delay

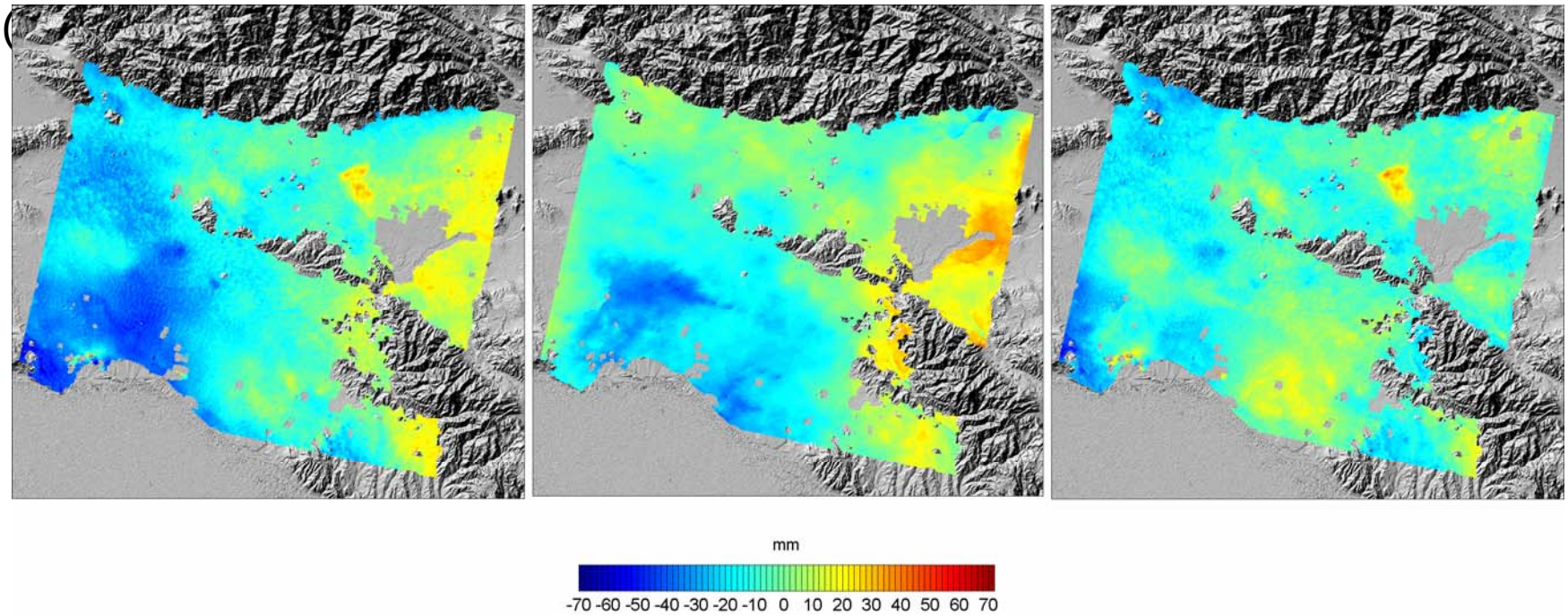


Atmospheric Correction over Los Angeles: Deformation from GPS



Atmospheric Correction over Los Angeles: Corrected Results

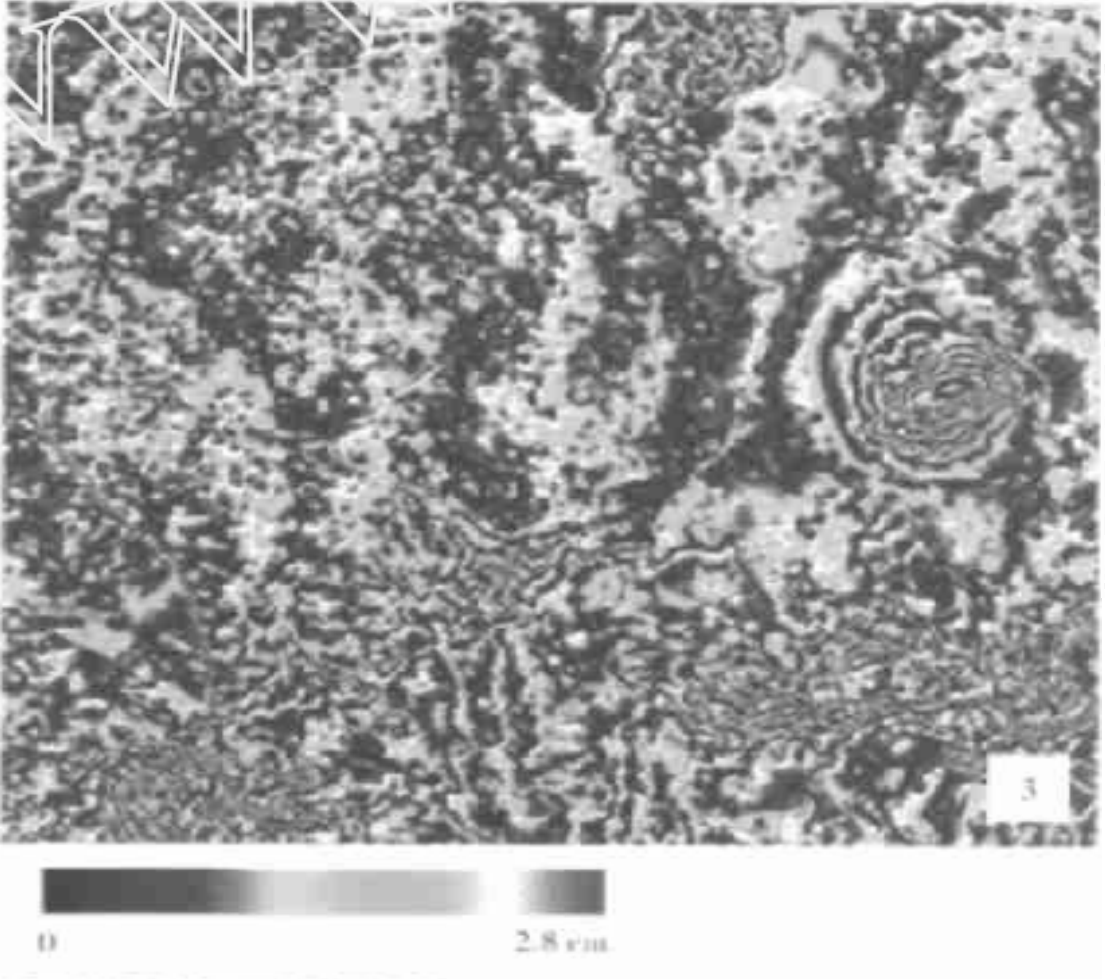
Unwrapped interferogram | Modeled atmospheric fields | Corrected interferogram

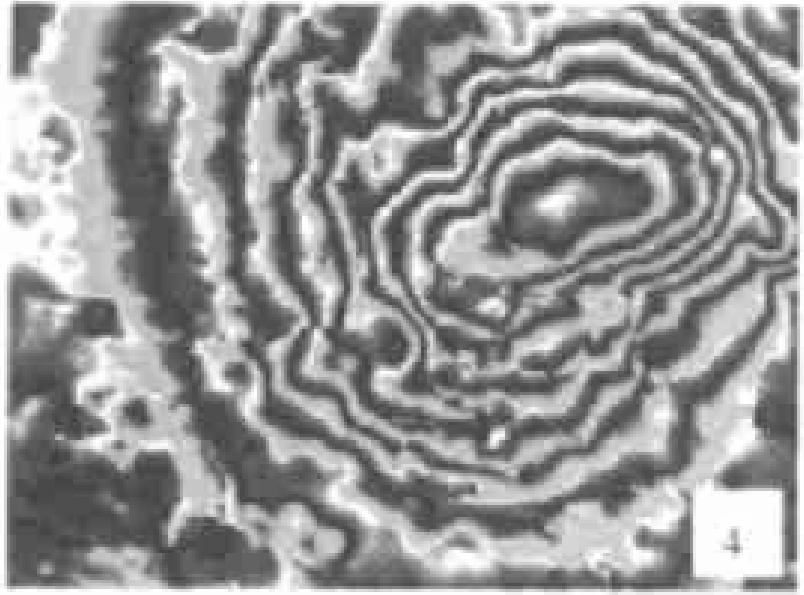


- Before correction: 14.9 mm
- After correction: 10.6 mm
- Improvement: 28.9%

Earthquake Studies

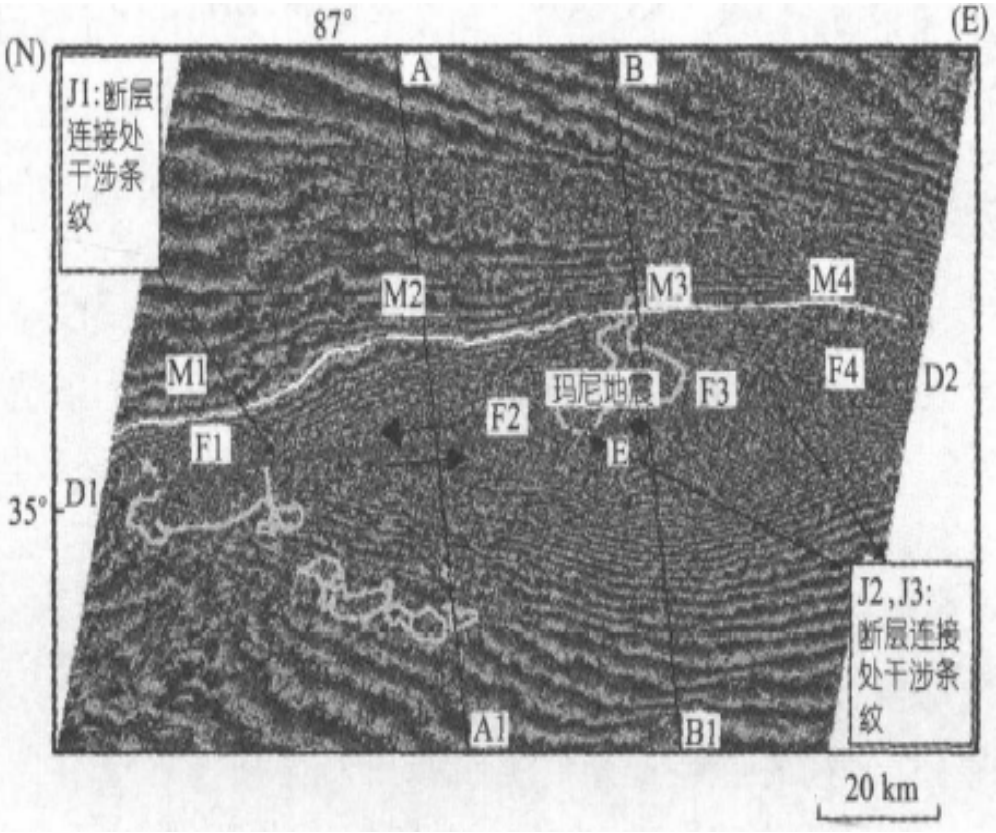
- Zhangbei-Shangyi (Ms 6.2)
- Mani,Tibet (Ms 7.9)
- Chi Chi, Taiwan (Ms 7.6)

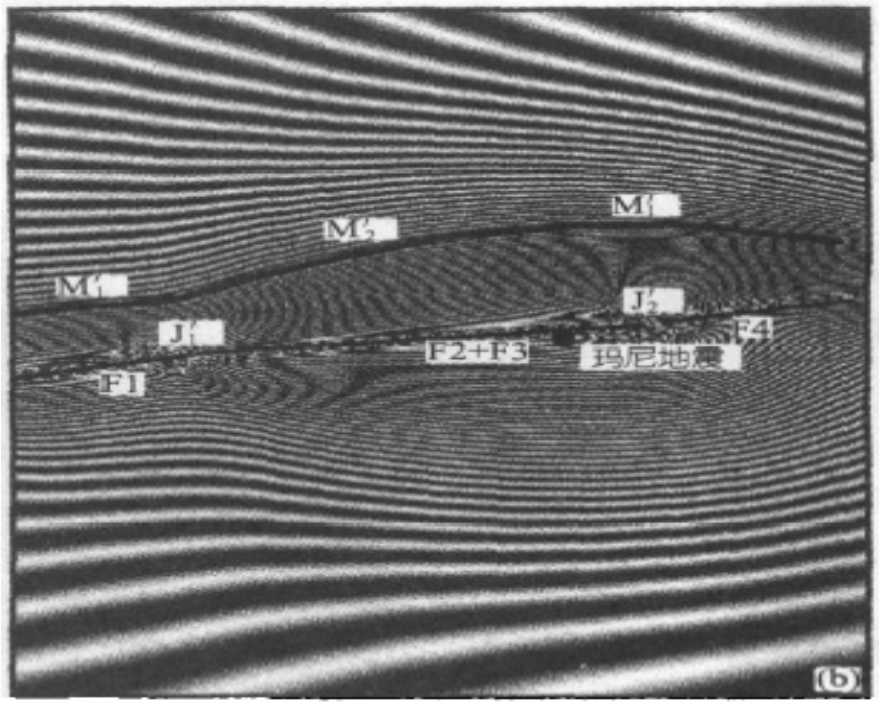




Coseismic Deformation Associated with Zhangbei-Shangyi (Ms 6.2) Earthquake (Maximum Deformation in Look Direction : 25cm)

C. Wang et al., 2000



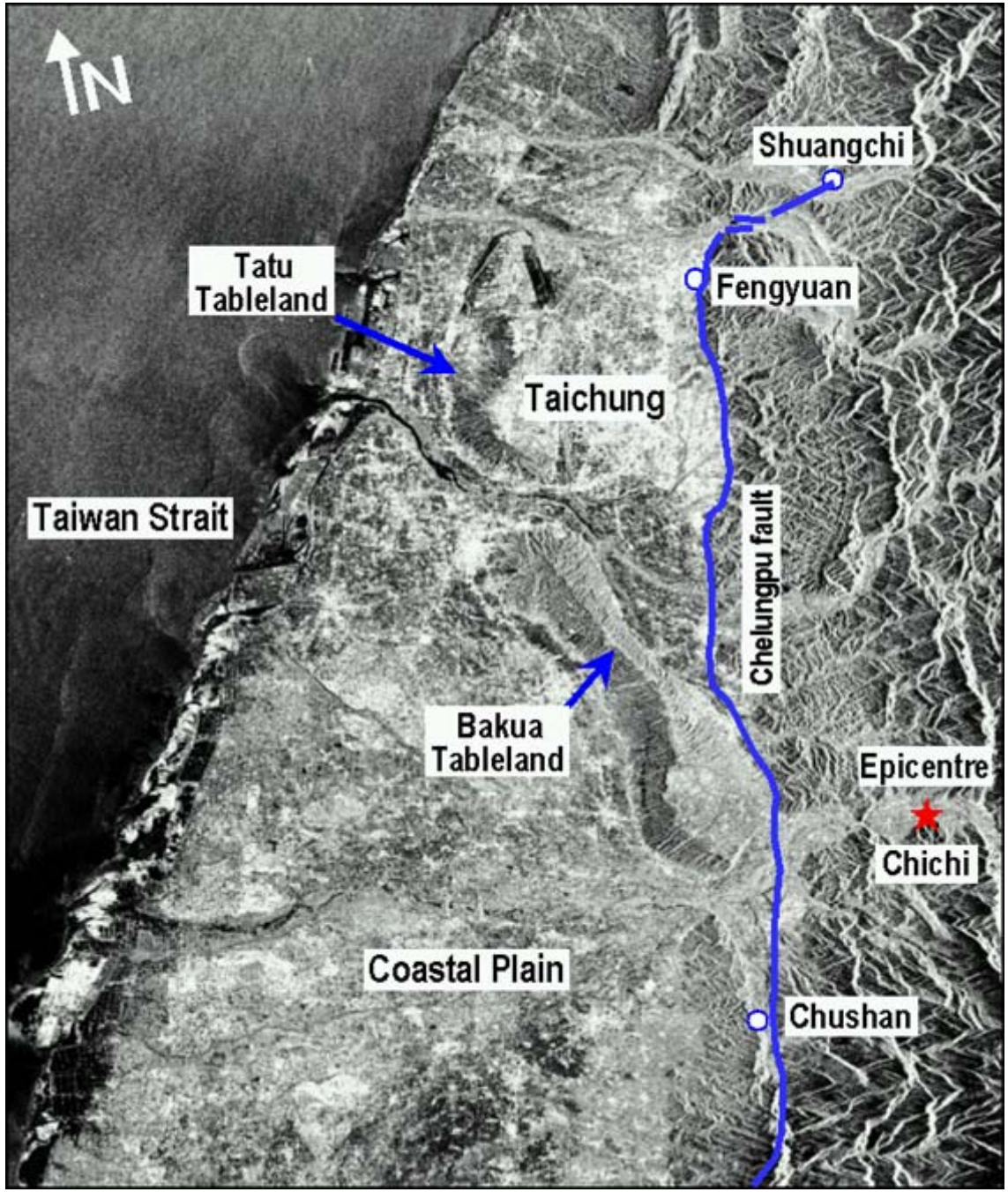


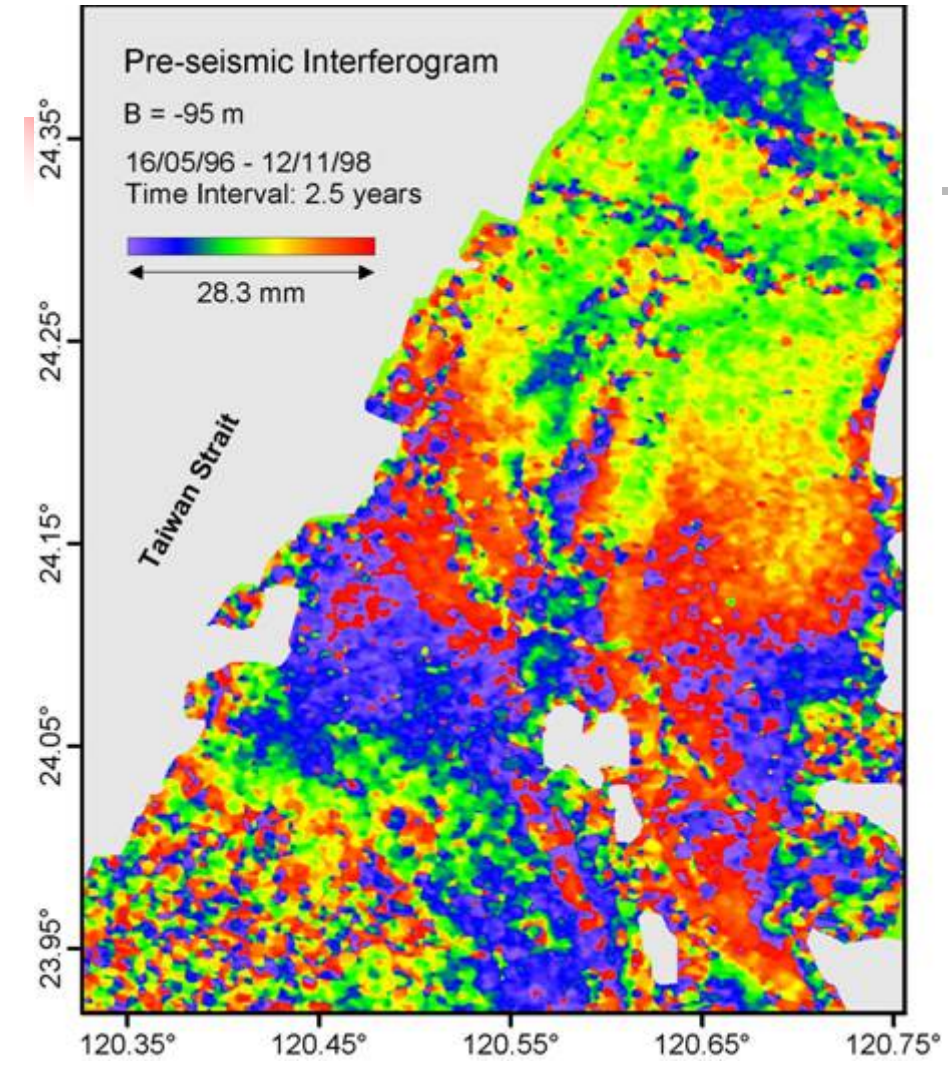
Coseismic Deformation of Mani, Tibet (Ms 7.9) Earthquake (Maximum Deformation is up to 0. 5m)

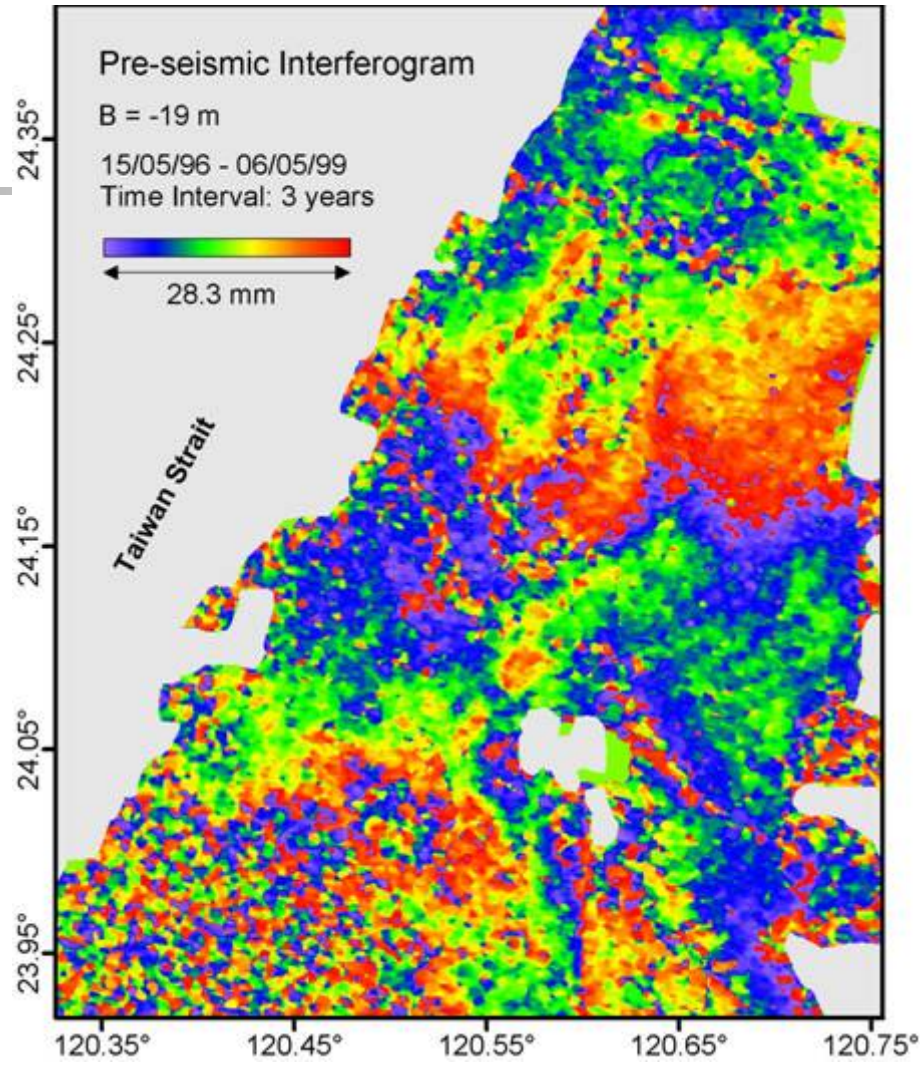
X.J. Shan et al., 2002

J.F. Zhang et al., 2002

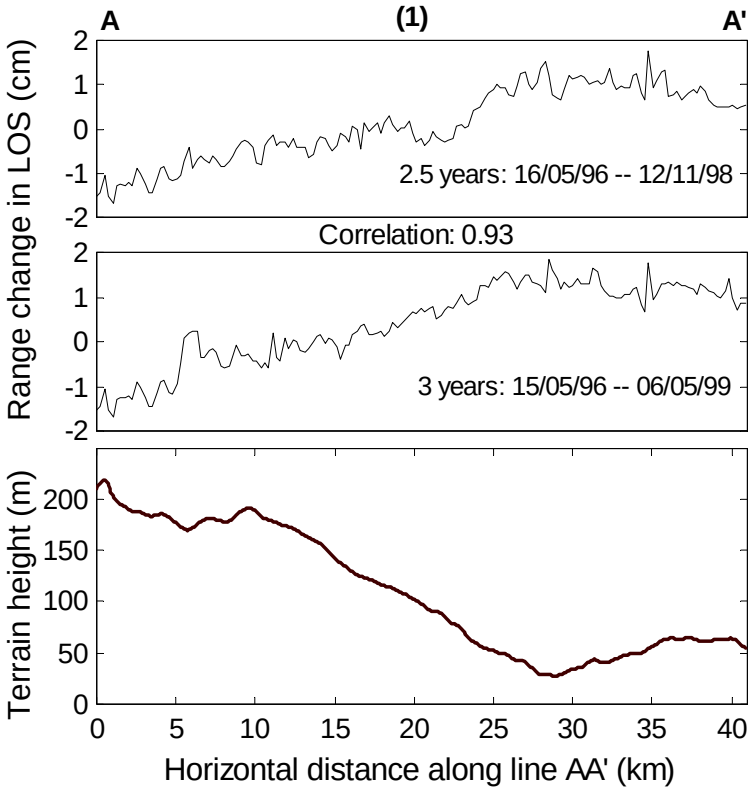
Pre- and co-seismic ground deformation related to 1999 Chi-Chi, Taiwan earthquake

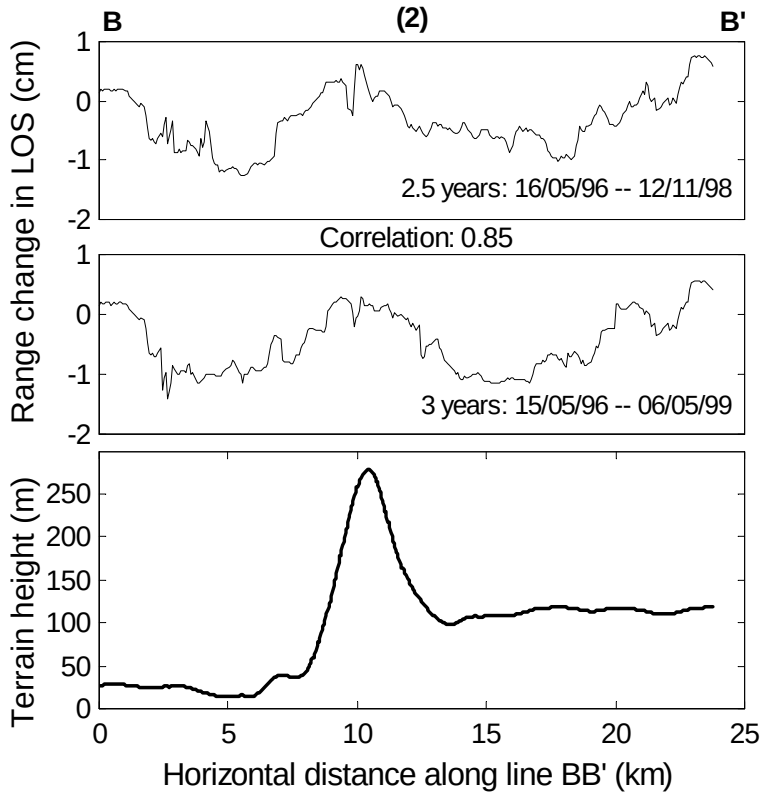


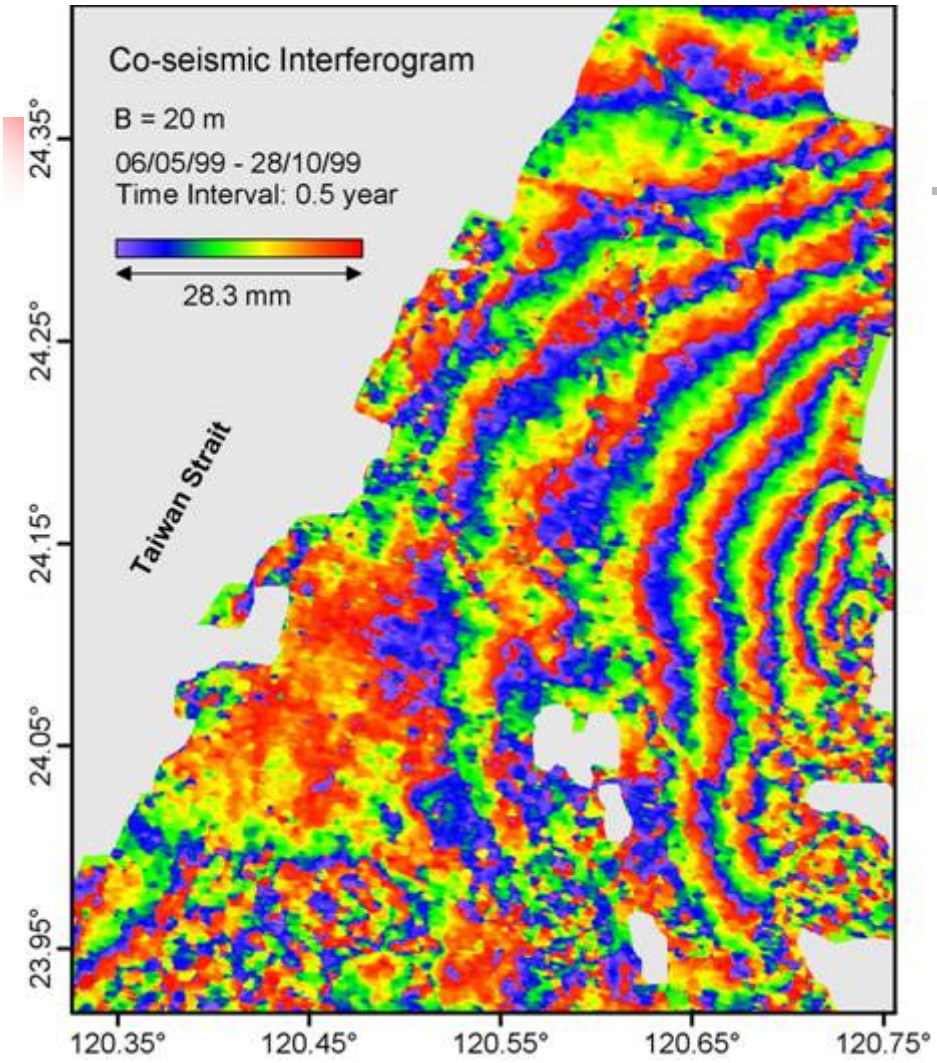

Pre-seismic Interferogram
B = -95 m
16/05/96 - 12/11/98
Time Interval: 2.5 years
28.3 mm
Taiwan Strait
24.35°
24.25°
24.15°
24.05°
23.95°
120.35°
120.45°
120.55°
120.65°
120.75°

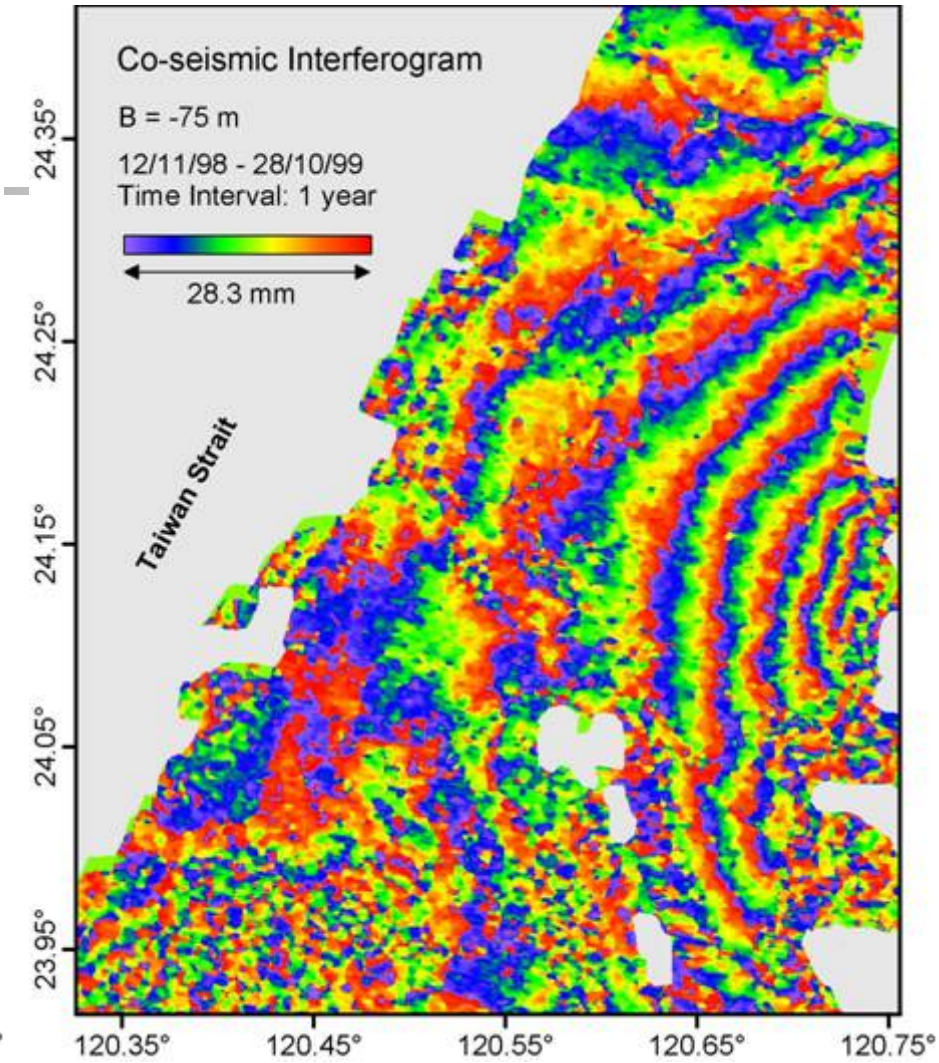

Pre-seismic Interferogram
B = -19 m
15/05/96 - 06/05/99
Time Interval: 3 years
28.3 mm
Taiwan Strait
24.35°
24.25°
24.15°
24.05°
23.95°
120.35°
120.45°
120.55°
120.65°
120.75°

Pre-seismic deformation profile

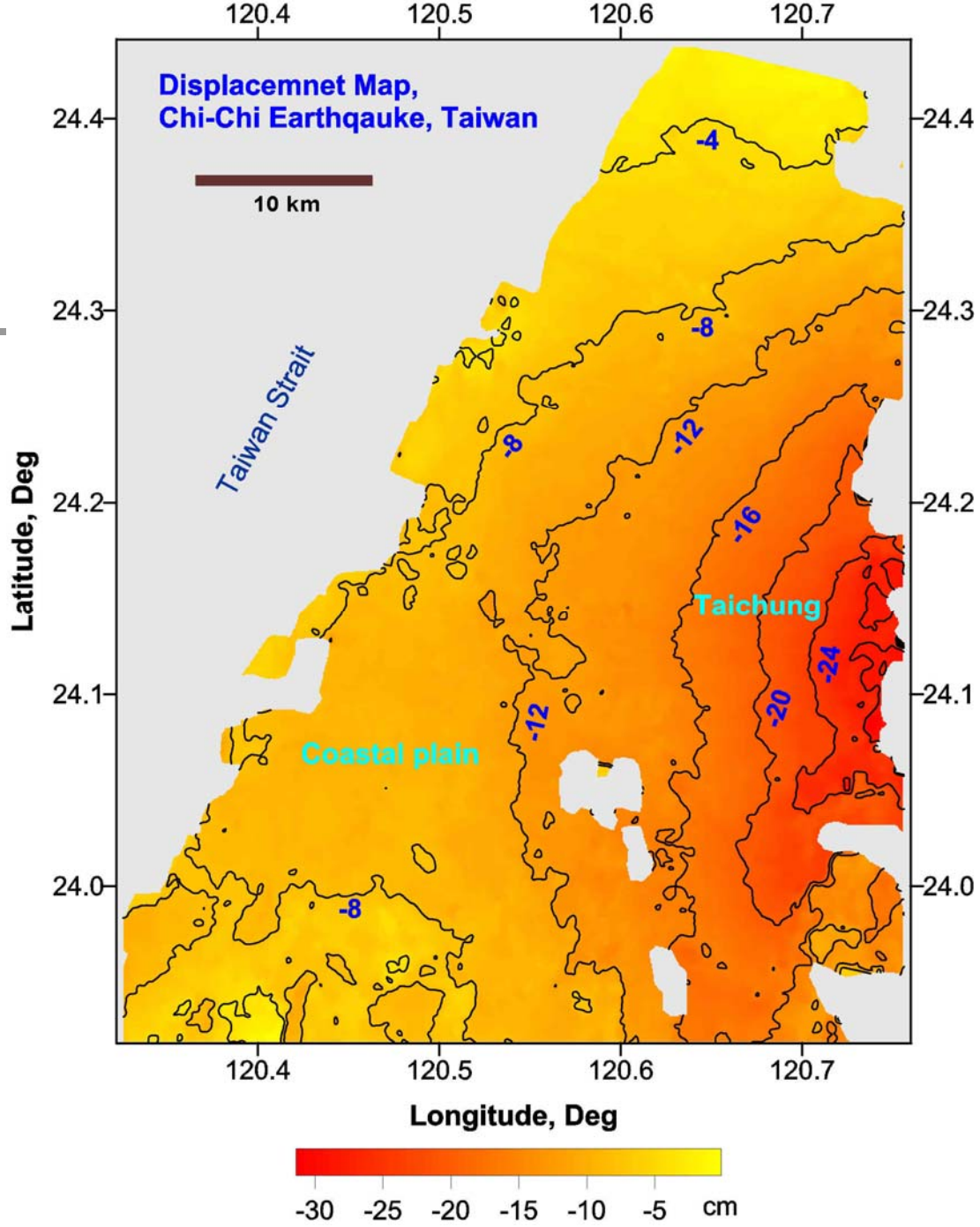


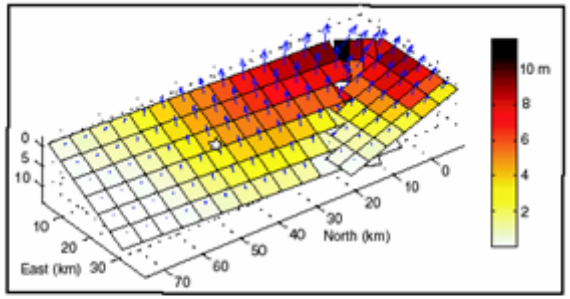



Co-seismic Interferogram
B = 20 m
06/05/99 - 28/10/99
Time Interval: 0.5 year
28.3 mm
Taiwan Strait
24.35°
24.25°
24.15°
24.05°
23.95°
120.35°
120.45°
120.55°
120.65°
120.75°

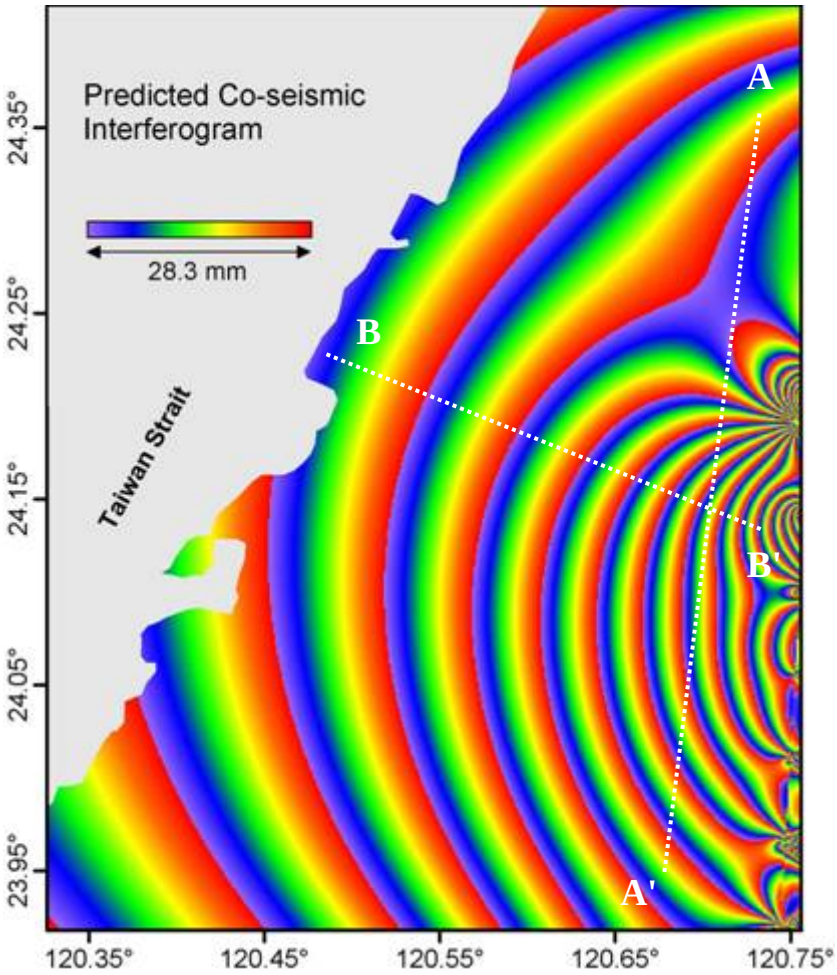

Co-seismic Interferogram
B = -75 m
12/11/98 - 28/10/99
Time Interval: 1 year
28.3 mm
Taiwan Strait
24.35°
24.25°
24.15°
24.05°
23.95°
120.35°
120.45°
120.55°
120.65°
120.75°

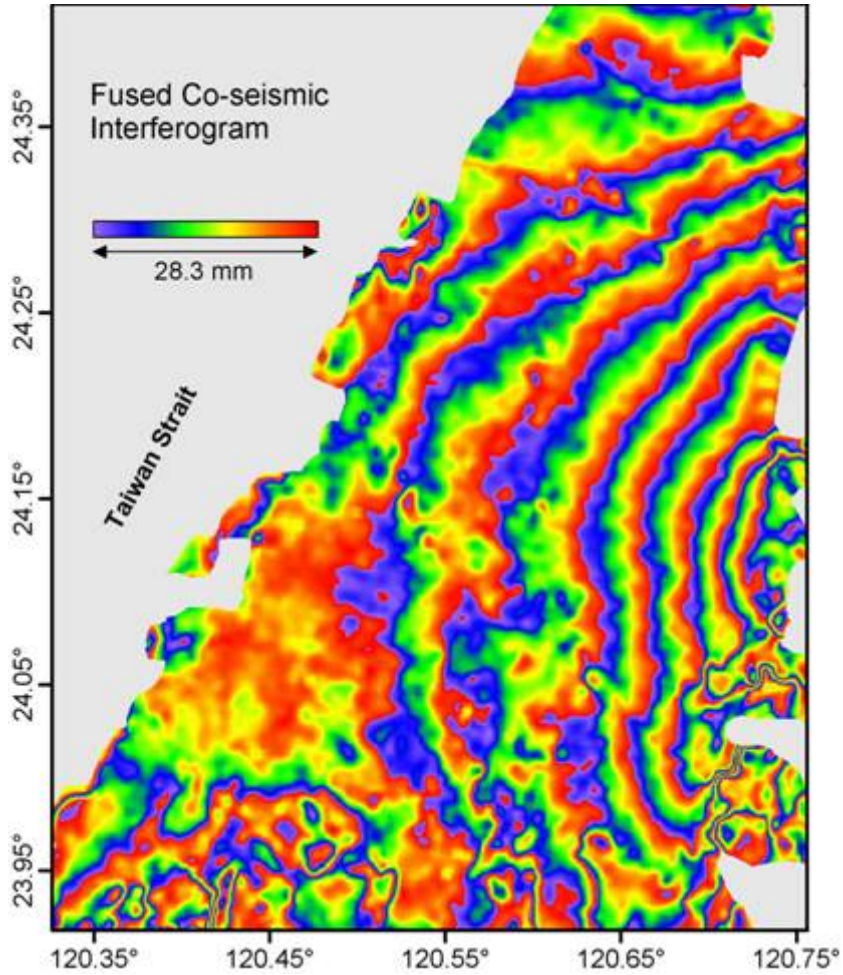
Final Co-Seismic Displacement Map in UTM projection





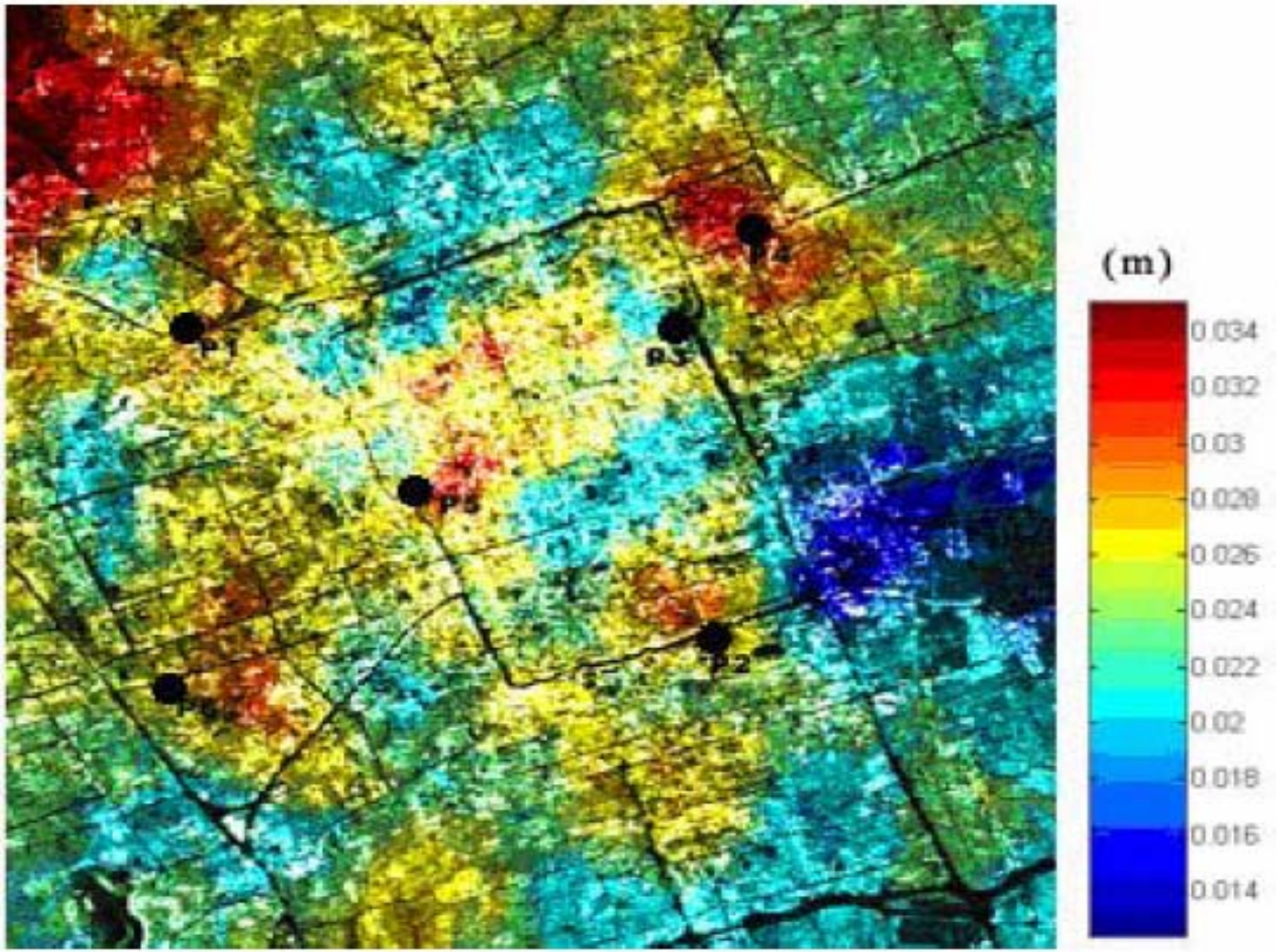
Verifying Johnson's Fault Model with InSAR Measurements





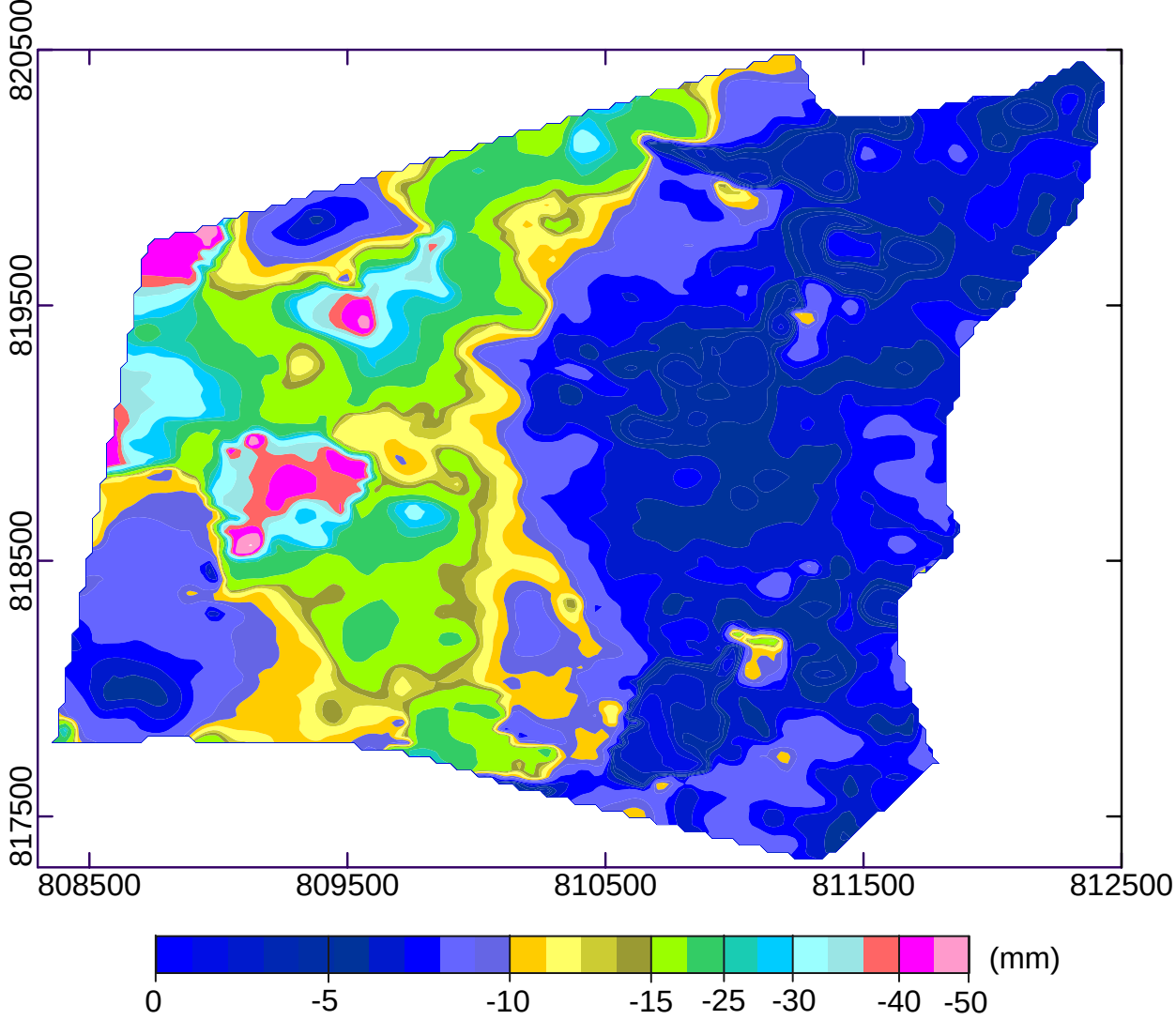
Ground Subsidence

- Su Zhou
- Hong Kong
- Cang Zhou
- Shanghai



Subsidence map of Su Zhou urban area: 1992 – 2000

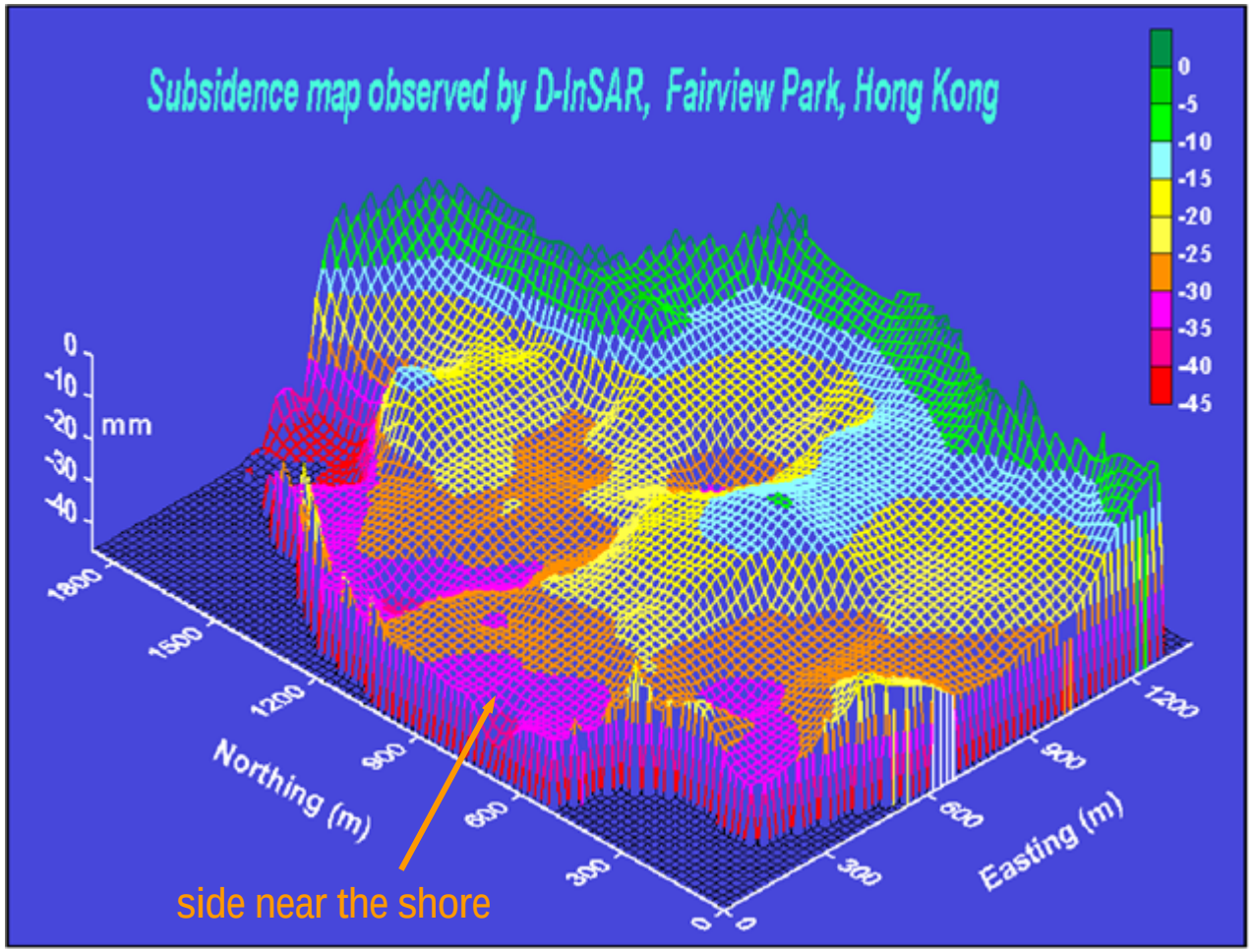
(Tang et al., 2006)



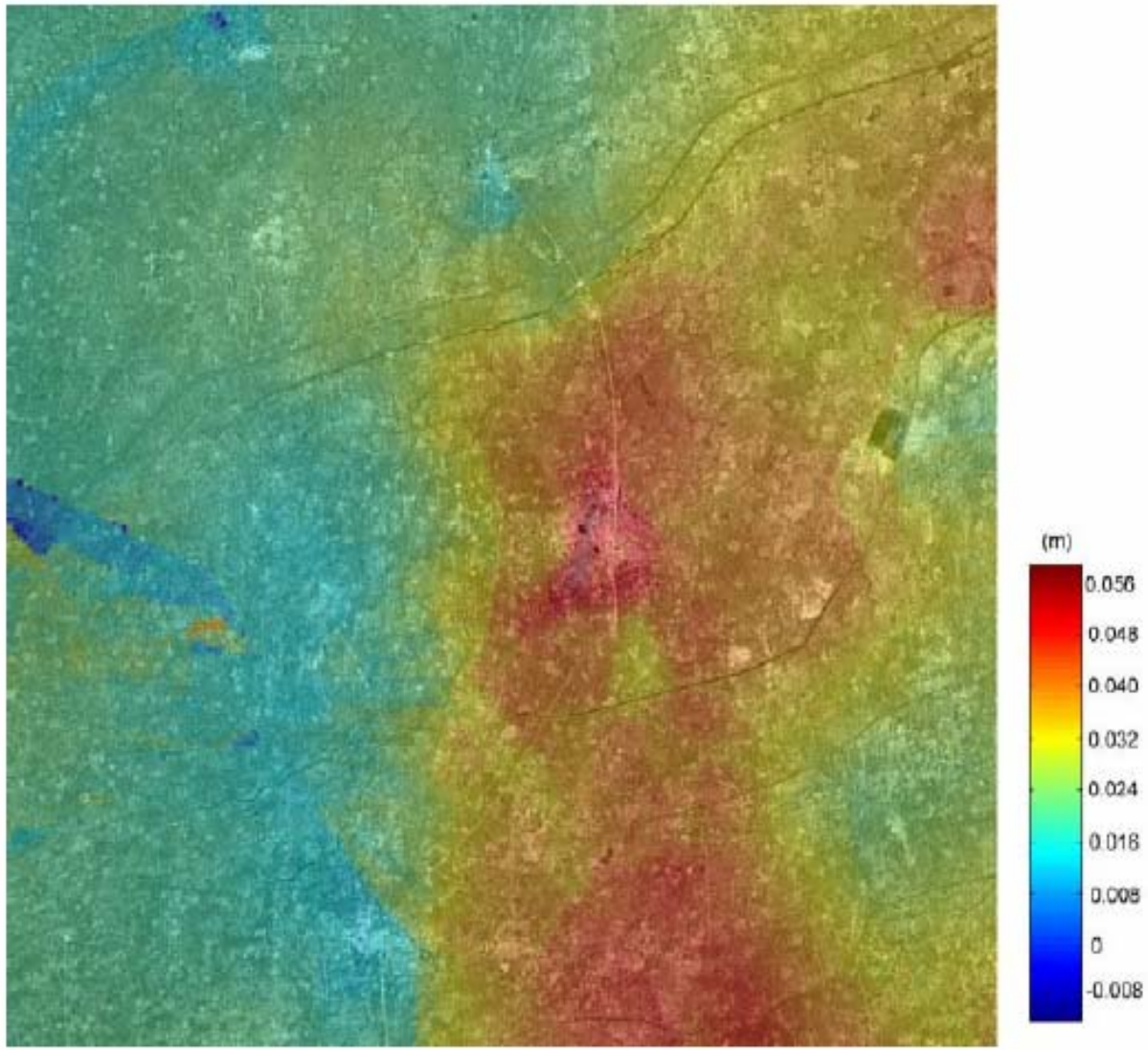
29/12/1998 - 9/11/1999 (time internal: 315 days)

Settlement of Chek Lap Kok airport, Hong Kong

Settlement of a Reclaimed Residential Area

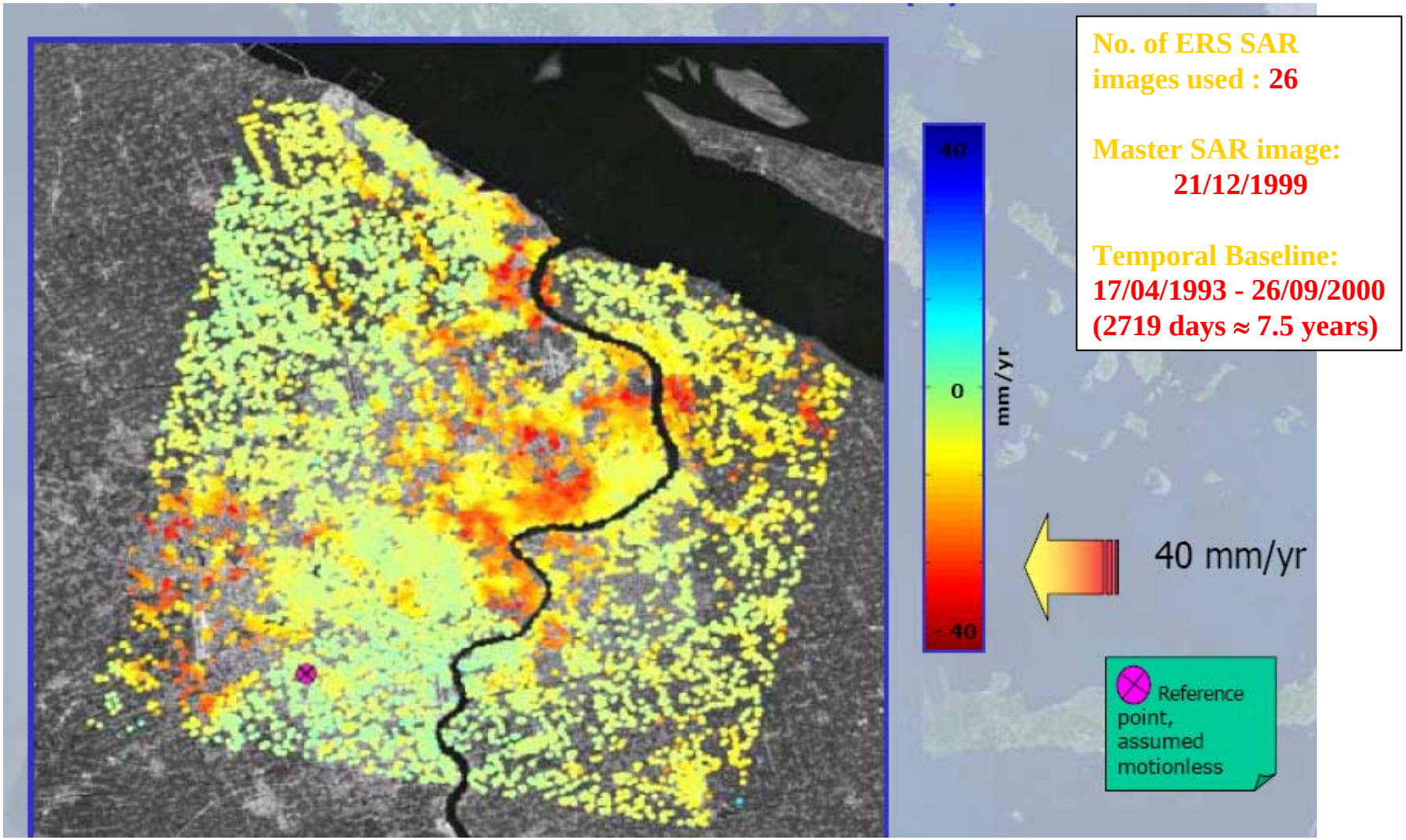


3D-settlement map near 3 years around Fairview Park, HK



Subsidence rate map of Cang Zhou

(Tang et al., 2006)



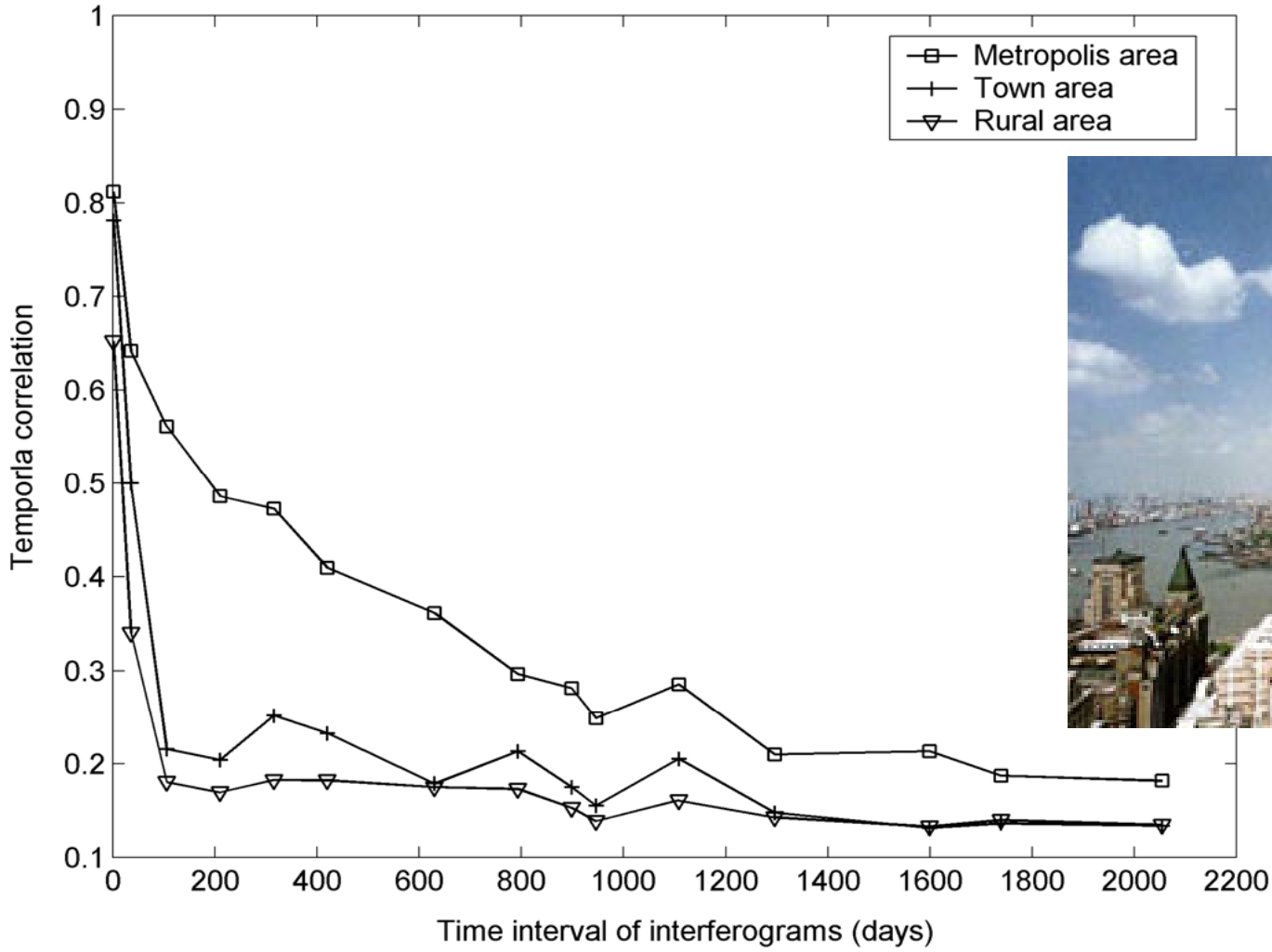
Subsidence map of Shanghai

(Li et al., 2005)

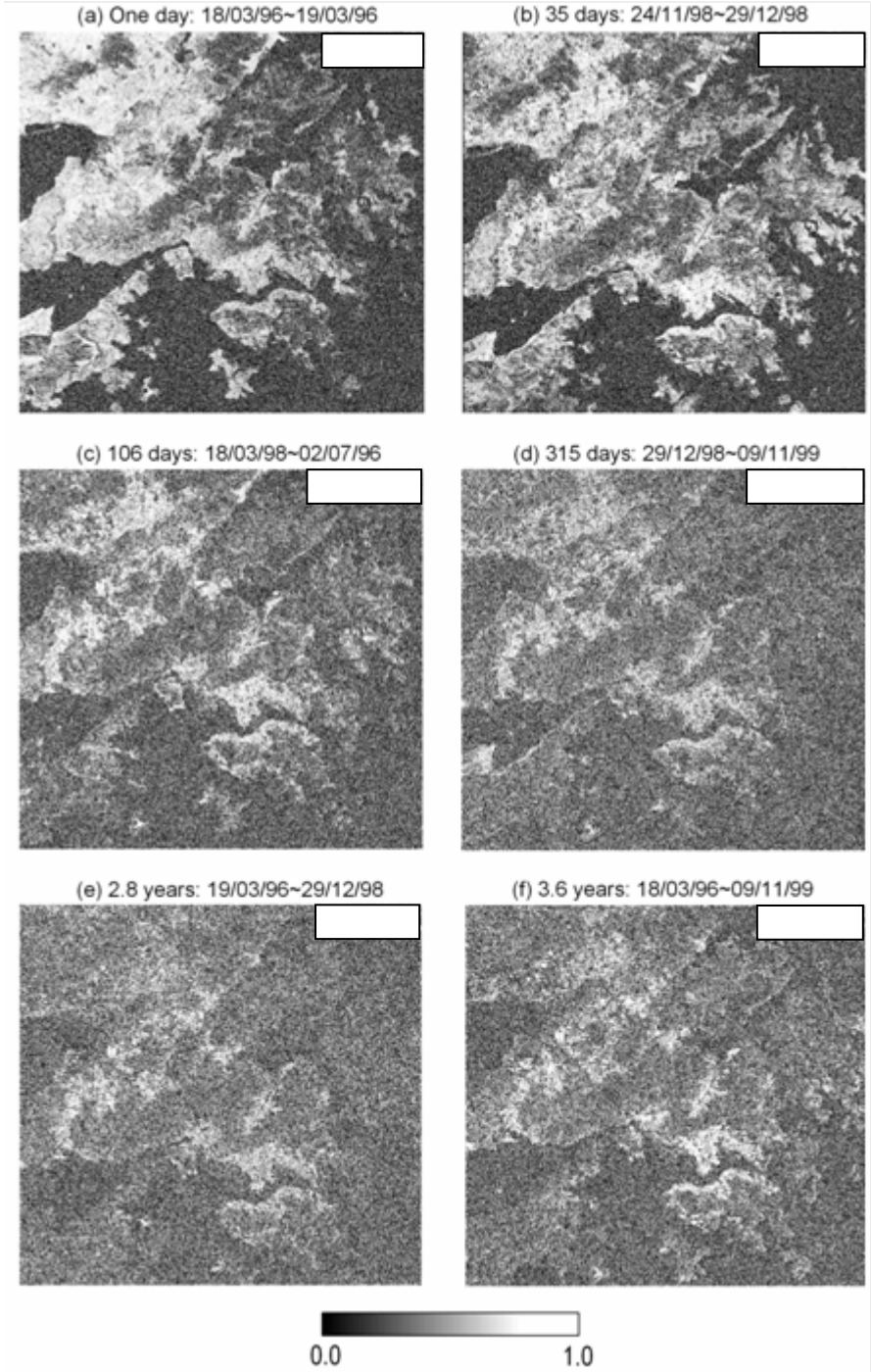
Future Applications of ALOS/PALSAR

Ground Subsidence Monitoring

- Large areas in China are experiencing problems of ground subsidence.
- Many of the areas are difficult to be monitored with C-band SAR data
- ALOS/PALSAR data offer opportunities for more comprehensive study



Variation of Coherence with time in Shanghai (ERS Data)

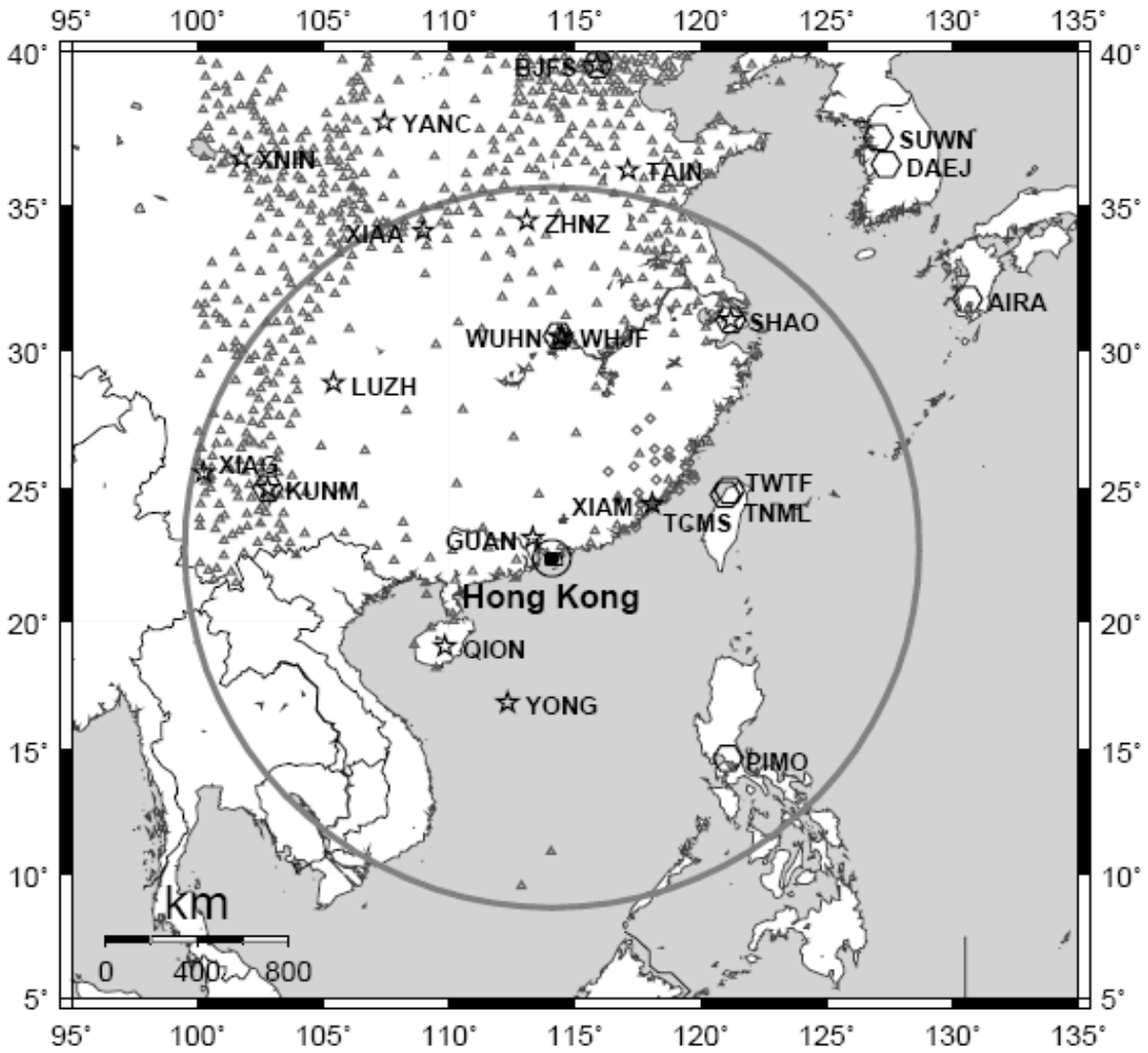


Variation of coherence in space and time (Hong Kong, ERS data)

Regional Crustal Deformations for Earthquake Studies

- C-band SAR data can hardly be used to study regional deformations comprehensively
- It is hoped that the ALOS data will significantly improve the situation
- There are many such regions in China to be carefully studied

For example, what is the potential to have a major earthquake in Hong Kong?



Mountain Glaciers in China

- How fast are they disappearing?
- How are these changes related to the global environmental changes?

Soil Erosion Problems

- Better quantify the problems with InSAR

Summary

- The interest in InSAR in China is strong
- Excellent progress in InSAR research has been made
- It can be expected that InSAR will become more useful and more used

Summary

- ALOS/PALSAR will make an important contribution to InSAR development and applications

International Association of Geodesy SC4.4

- Steering Committee
  - Prof. Xiaoli Ding, Chair
  - Dr. Linlin Ge, Vice-Chair
  - Prof. Makoto Omura, Secretary
  - Dr. Ramon Hanssen, Member at Large

International Association of Geodesy SC4.4

- Working Groups
  - W4.4.1: PS-InSAR, CR-InSAR, Tranponder-InSAR (F. Roca)
  - W4.4.2: Atmospheric effects on InSAR (L. Ge)
  - W4.4.3: InSAR for polar regions (M. Omura)
  - W4.4.4: Imaging system for ground subsidence monitoring (A. Menu)

Conclusion

InSAR research is filled with excitement, opportunities, and challenges

Thank you!