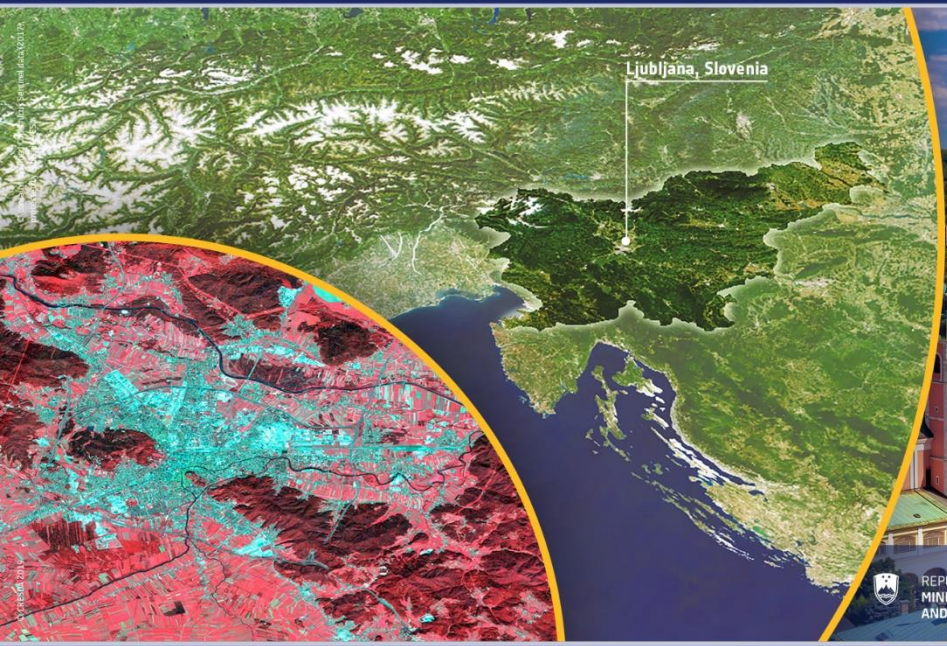
NASCC

esa



ESA–MOST Dragon Cooperation

2019 DRAGON 4 SYMPOSIUM

24–28 June 2019 | Ljubljana, Slovenia

中国科技部-欧洲空间局“龙计划”合作

2019 年“龙计划”四期学术研讨会

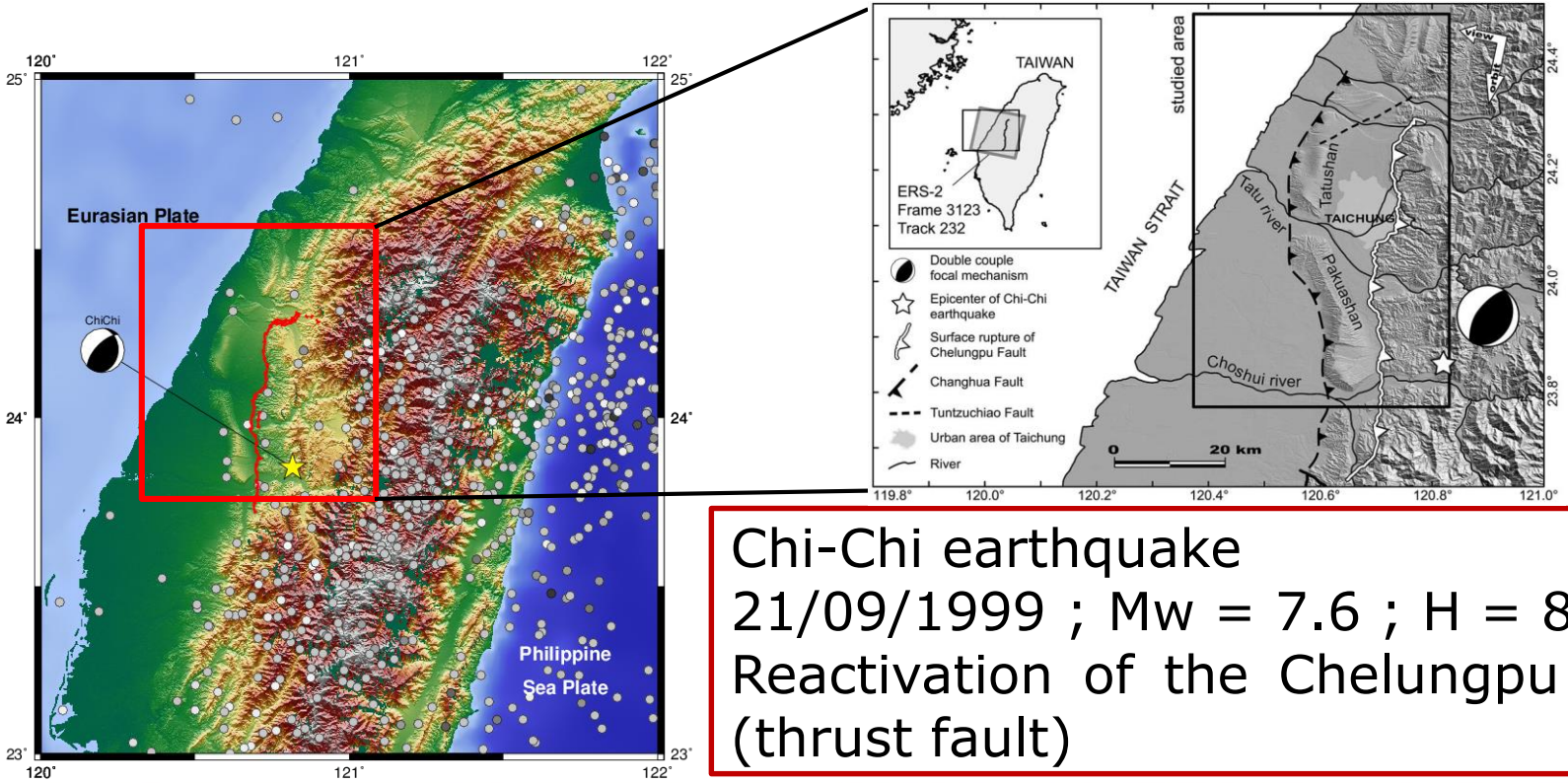
2019 年6月 24–28 日 斯洛文尼亚 卢布尔雅那

The 1999 Mw 7.6 Chi-Chi Earthquake Revisited: Co-seismic Deformation From Earth Observations

Marine Roger[1], Zhenhong Li[1], Peter Clarke[1],
Jyr-Ching Hu[2], Wanpeng Feng[3]

1: School of Engineering, Newcastle university, United Kingdom;
2: Department of Geosciences, National Taiwan University, Taiwan;
3: School of Earth sciences and Engineering, Sun Yat-sen University, China

BACKGROUND Taiwan and the Chi-Chi earthquake



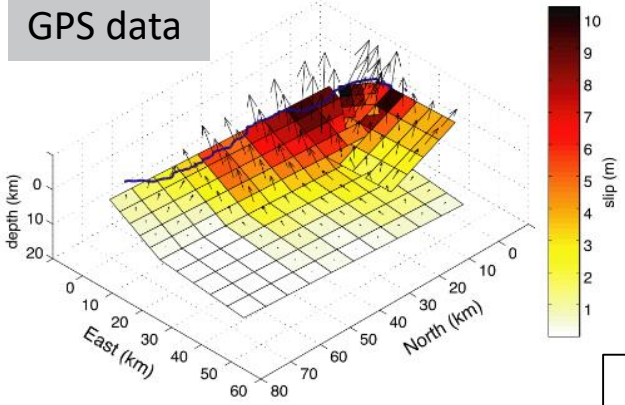
Pathier et al. [2003]

Chi-Chi earthquake
21/09/1999 ; Mw = 7.6 ; H = 8 km
Reactivation of the Chelungpu fault (thrust fault)

PREVIOUS MODELS

Based on GPS data

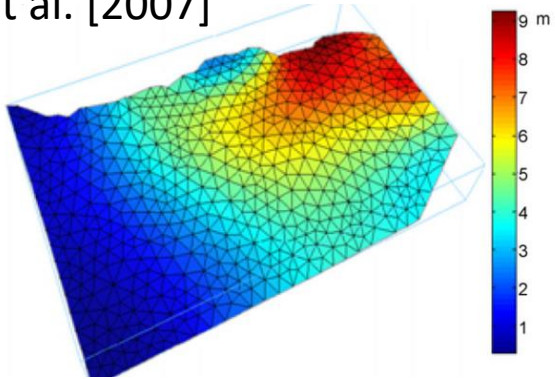
Johnson et al. [2004]



Amelioration of curved fault model but considering vertical and lateral elastic heterogeneity: ramp-décollement system with a lateral ramp at the northern end

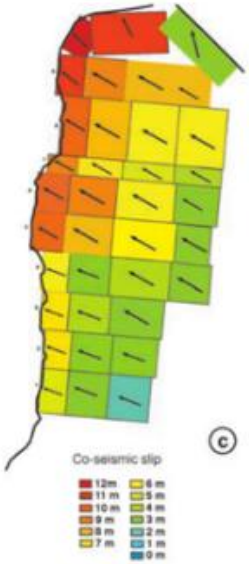
GPS & InSAR

Zhang et al. [2007]



1068 planar triangular dislocations elements used. 4 segments fault system. (similar to Johnson et al. [2004])

Dominguez et al. [2003]



GPS and SPOT images

Zhang et al. 2007	**Dip1** 26°	**Dip 3** 29°	**Dip 4** 4.2°	**Length** 27km	**Depth** 7.7km
Johnson et al. 2004	26°	23°	0°	27km	7.7km

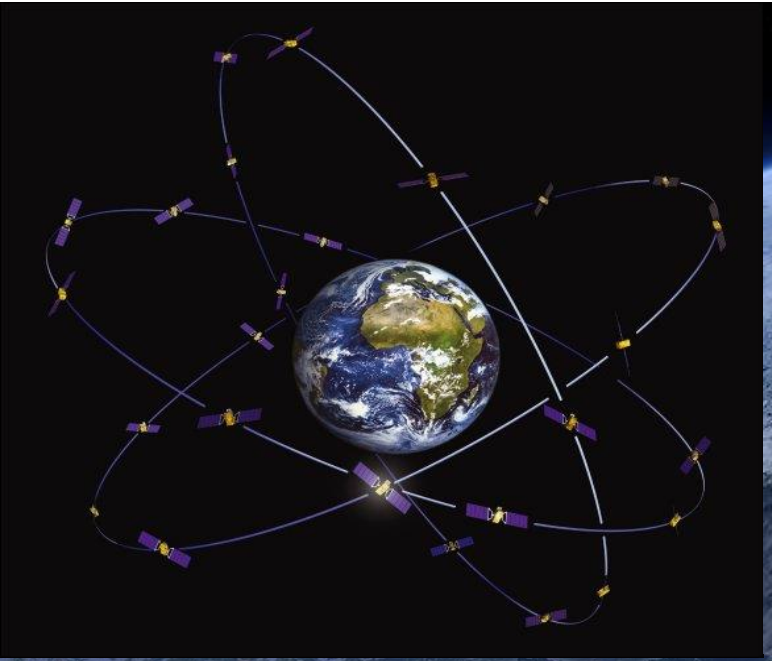
OBJECTIVES: Co-seismic modelling

1. Process and combine 4 datasets of observation data:
    - GNSS
    - Leveling
    - InSAR (ERS-2 images)
    - Optical correlation (SPOT 1-2 images)

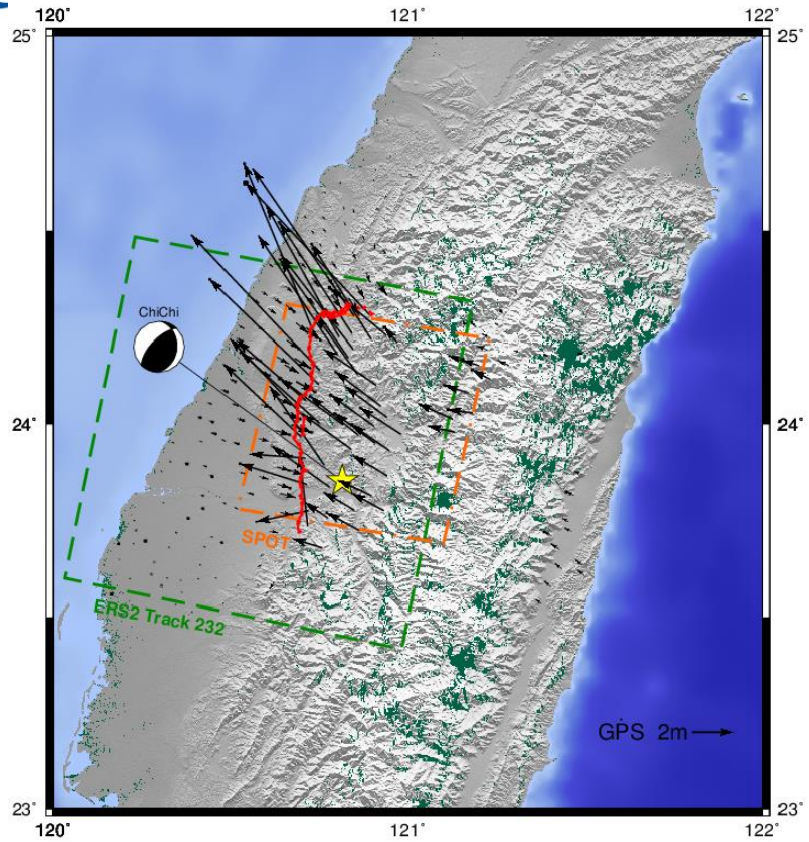
2. Relative weights determination: gABIC (Yi et al. 2017)

3. Geodetic inversion: PSOKINV (Feng et al. 2013) to determine the fault geometry and the slip distribution

DATASETS AND PROCESSING TECHNIQUES



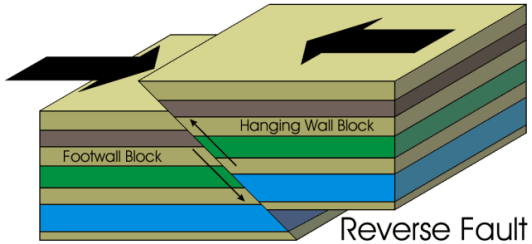
1. GNSS



Data extracted from Yu et al. [2001]

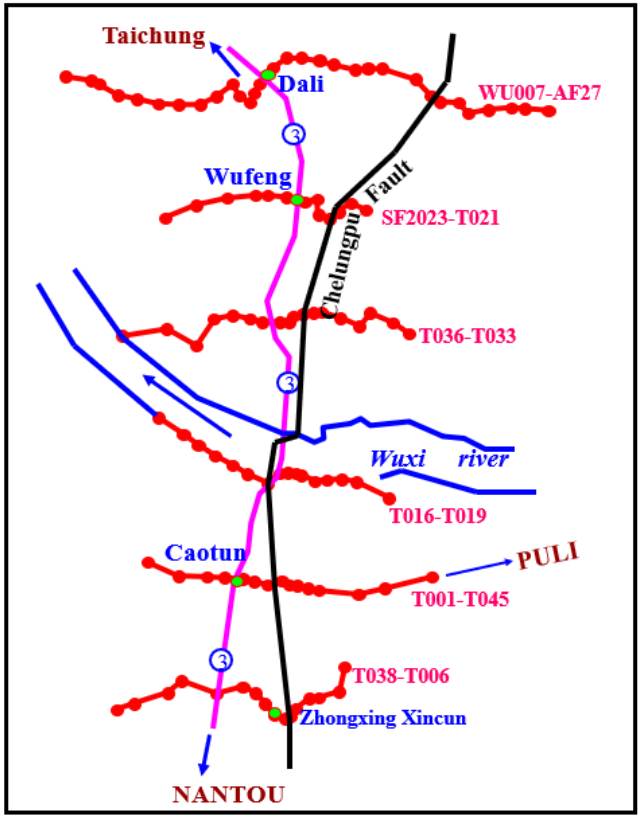
- 101 Campaign-surveyed GPS &
- 41 permanent stations (CWB, MOI & IESAS)

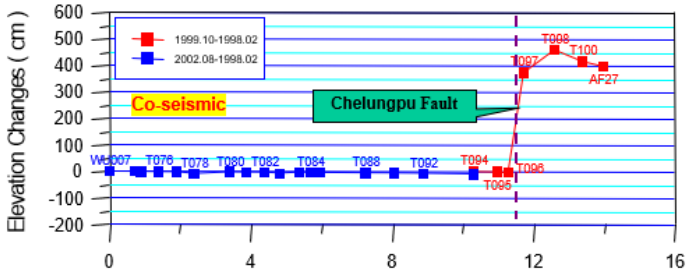
FOOTWALL	HANGING-WALL
Subsidence ~0.3m	uplift -> 4.4m
Displacement 1.5m	9m



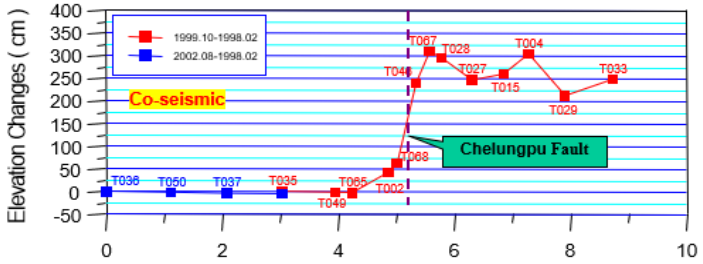
https://grickarnure.weebly.com/reverse.html

2. LEVELING

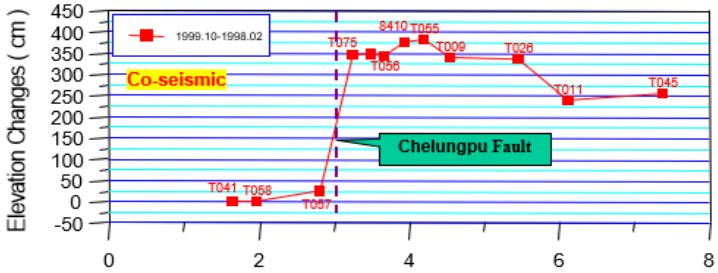




WU007-AF27



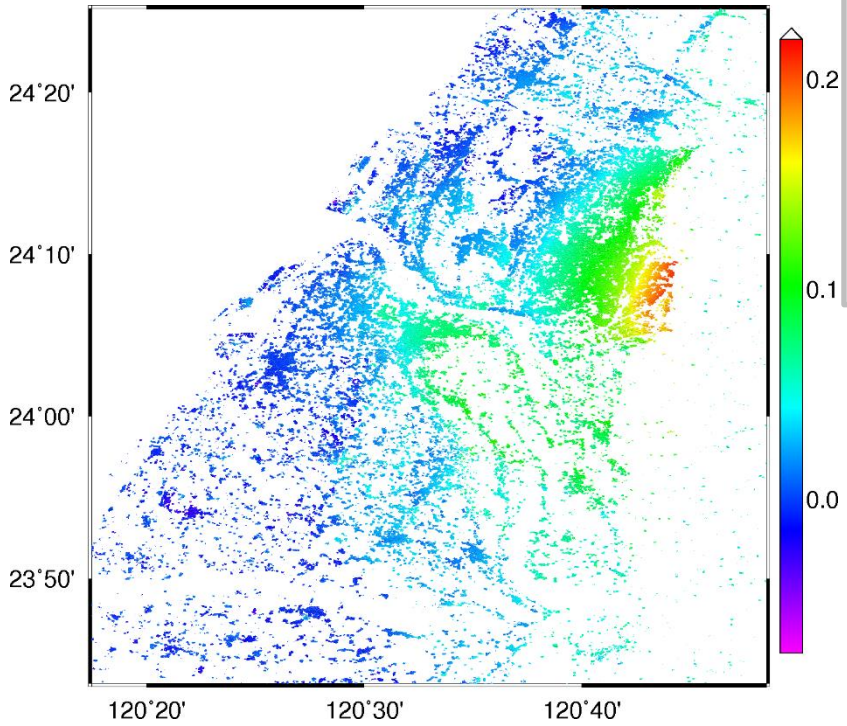
T036-T033

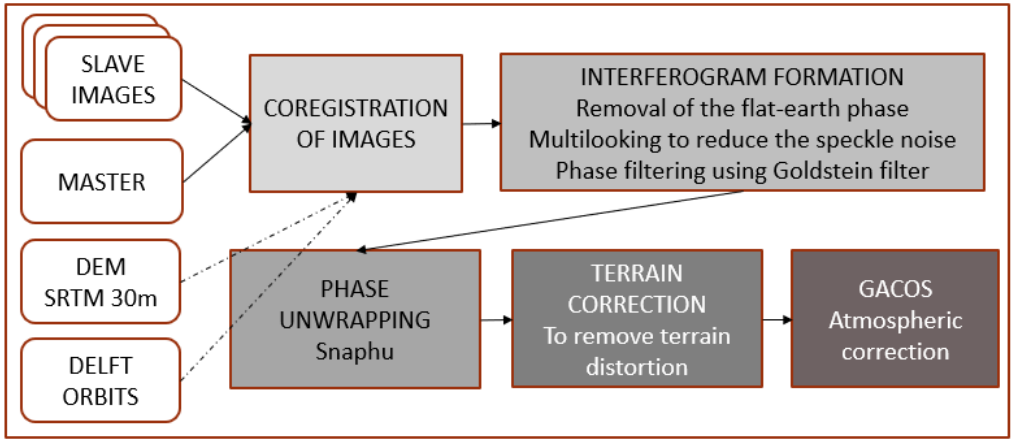


T001-T045

3. INSAR

ERS2 images: Track 232,
descending 28/10/1999 // 21/01-06/05-15/07/1999
Processing: SNAP/SNAPHU
About **12 fringes** (1 fringe = 2.8 cm), so **~33cm** of deformation. No coherence on the hanging-wall due to dense vegetation.



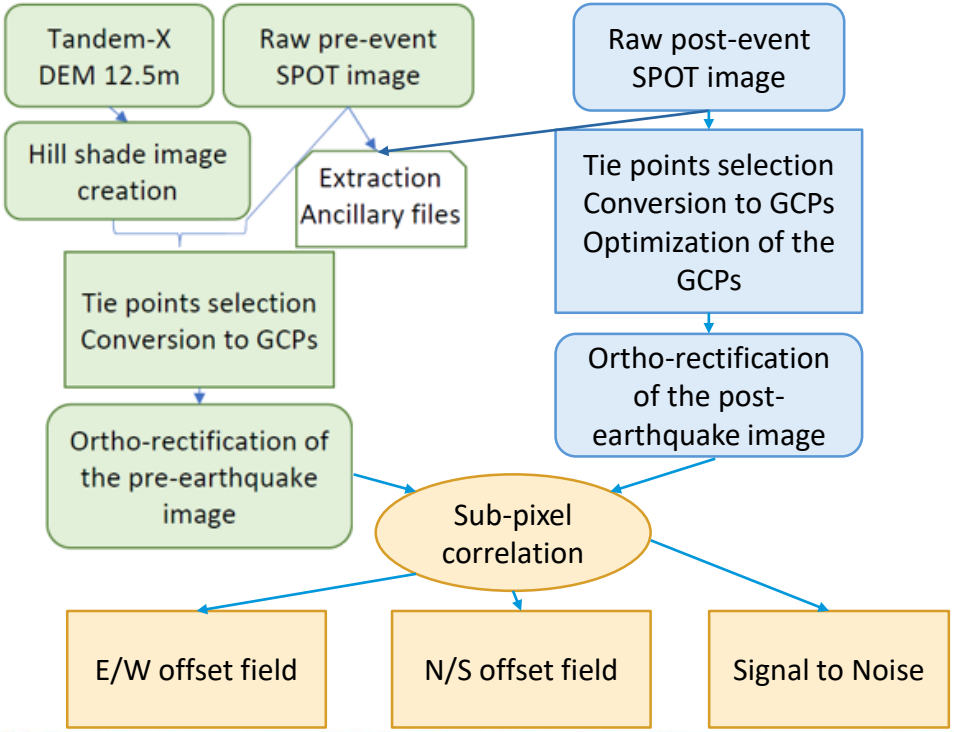


4. SPOT IMAGES, OPTICAL CORRELATION

SPOT images correlation using Cosi-Corr (Co-registration of Optically Sensed Images and Correlation)

Acquisition date	Satellite	Resolution	Orientation
06/03/1999	SPOT 2	10m	Left
21/11/1999	SPOT 2	10m	Left
29/01/1999	SPOT 2	10m	Right
23/11/1999	SPOT 1	10m	Right

Cloud cover	Incidence angle	Sun elevation	Sun azimuth
4%	12.4°	54.3°	145.1°
4%	12.4°	44.5°	162.3°
10%	2.9°	42.9°	151.0°
0%	2.5°	43.4°	159.7°



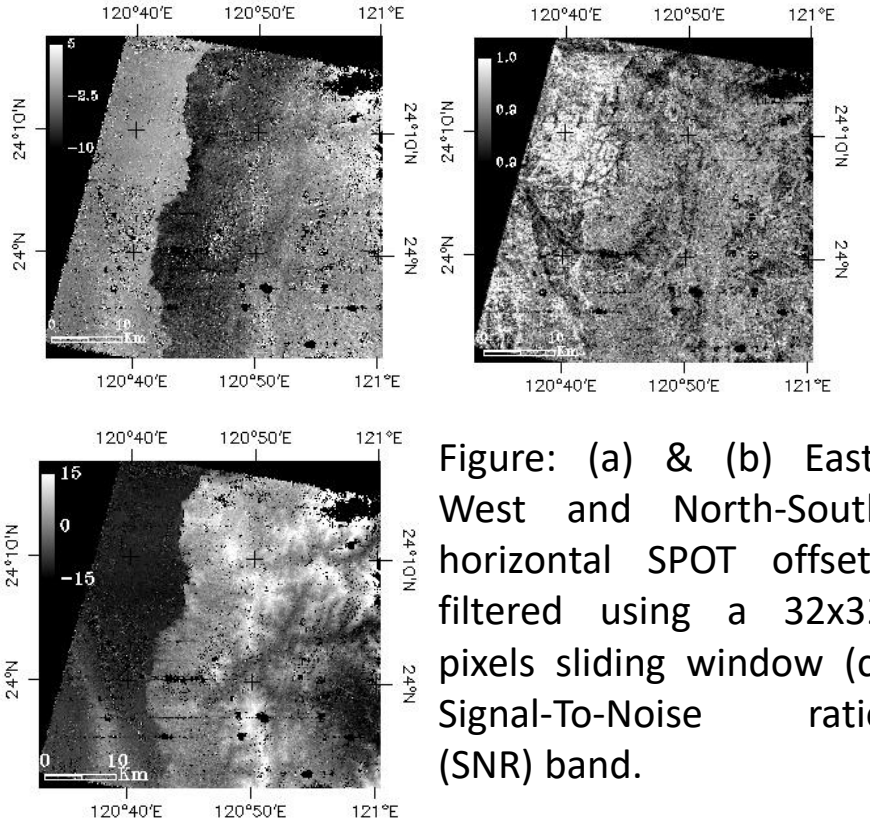
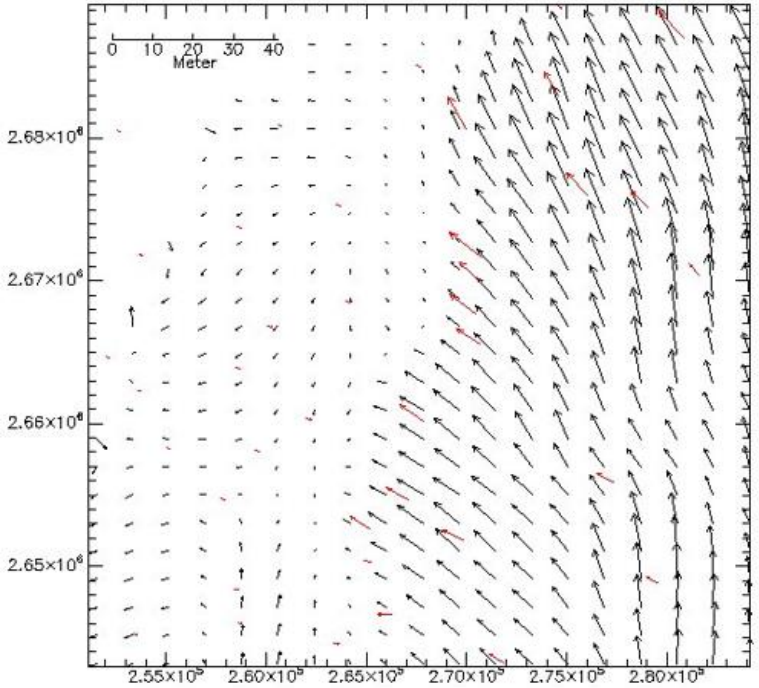


Figure: (a) & (b) East-West and North-South horizontal SPOT offsets filtered using a 32x32 pixels sliding window (c) Signal-To-Noise ratio (SNR) band.

Displacement field of the Chi-Chi earthquake from a pair a SPOT images (Black arrows).
Red arrows are the GPS displacements.



MODELLING

gABIC (generalized Akaike's Bayesian Information Criterion)

(Yi et al. 2017)

The observation equations and prior constraints (spatial and temporal smoothness):

$$d = Ha + e$$

$$0 = Sa + \varepsilon$$

d: N dimensional vector containing P observations

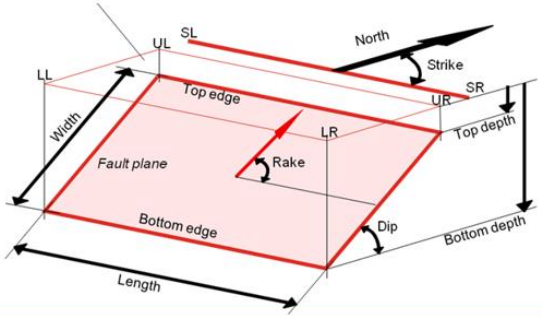
H: NxM coefficient matrix

S: N_2xM coefficient matrix containing Q types of prior constraints

a: M dimensional model parameter vector

e, ε: vectors of the gaussian distribution errors of observations and constraints.

PSOKINV (Particle Swarm Optimization and Okada Inversion package)



Fault geometry

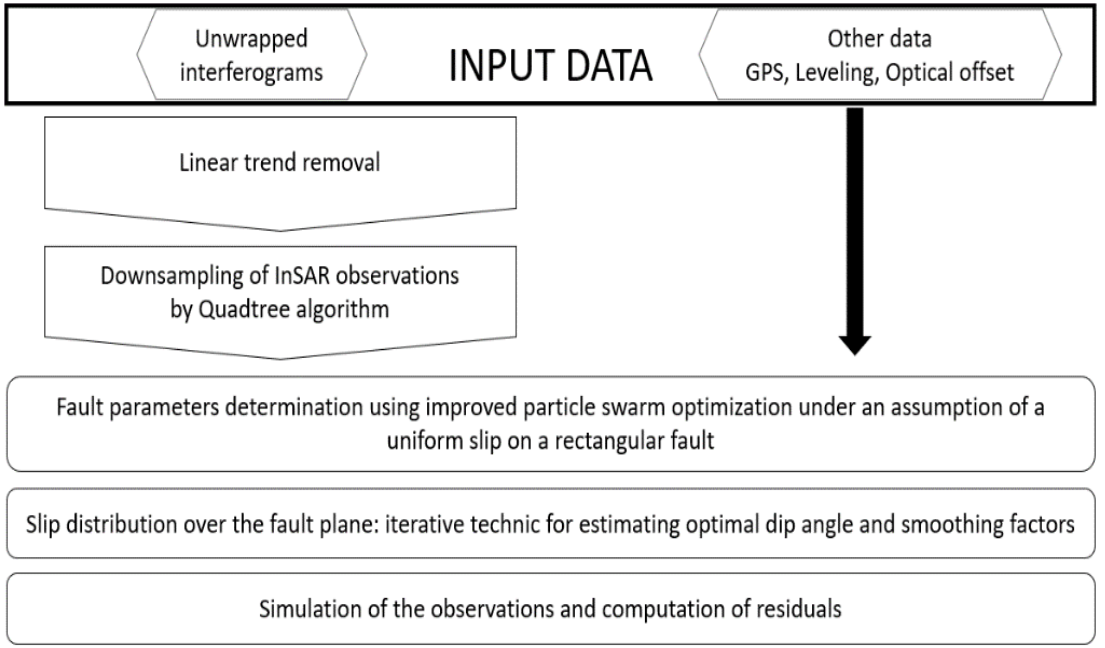
(image from http://diss.rm.ingv.it)

Length = 55km | Width = 25km

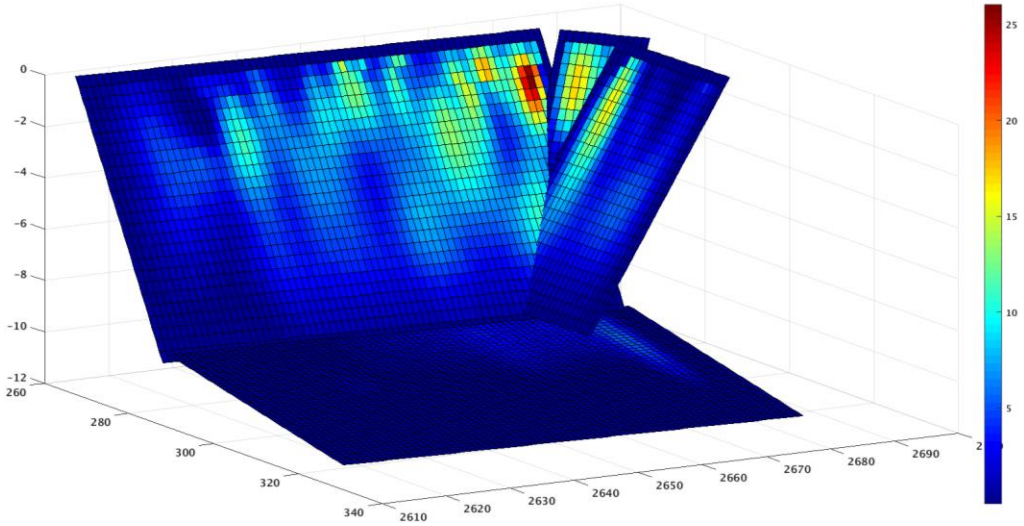
Dip = 34.5° | Rake = 65° | Strike = 5°

Top depth = 5km

Slip opening = 1.67m



GNSS & LEVELLING



- Similar slip distribution as previous models from GNSS inversion

- Underestimation from InSAR only

- Similar result from SPOT correlation and GNSS, but over estimation on the north part.

CONCLUSION

- Use of different type of datasets is essential to refine the parameters
- gABIC & PSOKINV is a powerful combination to model a fault using earth observations
- Improve the modelling thanks to the implementation of gABIC

m.roger2@newcastle.ac.uk

COSI-CORR S. Leprince, S. Barbot, F. Ayoub and J. P. Avouac, "Automatic and Precise Ortho-rectification, Coregistration, and Subpixel Correlation of Satellite Images, Application to Ground Deformation Measurements", IEEE Transactions on Geoscience and Remote Sensing, Vol.45, No.6, June 2007

PSOKINVW. Feng, Z. Li, J.R. Elliott, Y. Fukushima, T Hoey, A. Singleton, R. Cook, and Z. Xu. The 2011 Mw 6.8 Burma earthquake: fault constraints provided by multiple SAR techniques. Geophysical Journal International, 195(1):650–660, 2013. doi:10.1093/gji/ggt254

gABIC L. Yi, C. Xu, X. Zhang, Y. Wen, G. Jiang, M. Li, and Y. Wang. Joint inversion of GPS, InSAR and teleseismic data sets for the rupture process of the 2015 Gorkha, Nepal, earthquake using a generalized ABIC method. Journal of Asian Earth Sciences, 148:121 – 130, 2017. ISSN 1367-9120. doi: doi.org/10.1016/j.jseaes.2017.08.029.

GPS S-B. Yu, L-C. Kuo, Y-J. Hsu, H-H. Su, C-C. Liu, C-S. Hou, J-F. Lee, T-C. Lai, C-C. Liu, C-L. Liu, T-F. Tseng, C-S. Tsai, and T-C. Shin. Preseismic deformation and coseismic displacements associated with the 1999 Chi-Chi, Taiwan, earthquake. Bulletin of the Seismological Society of America, 91:995–1012, 2001. doi: 10.1785/012000072