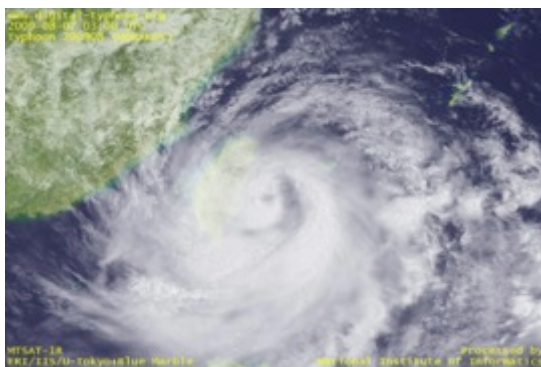
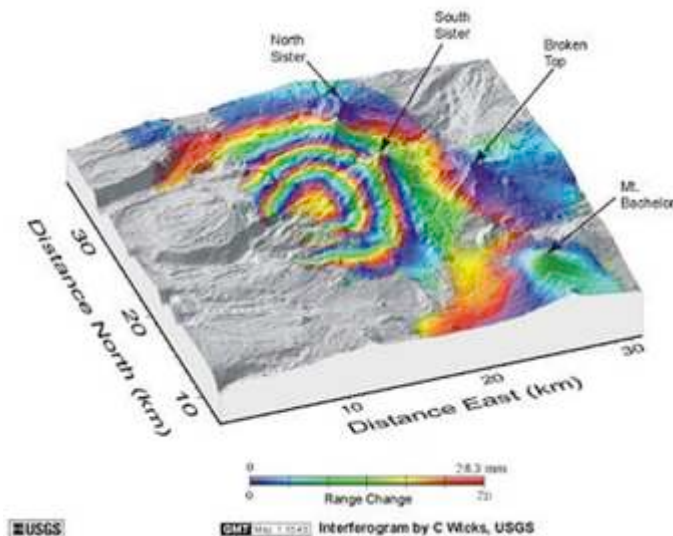


整合航遙測技術於大規模崩塌災害評估與地表監測系統

中國文化大學地質學系陳柔妃 助理教授

國立成功大學林慶偉 教授

香港理工大學張磊 研究助理教授

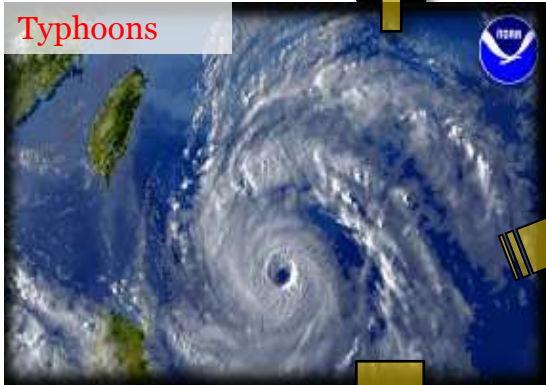


Outstanding problems and issues of the Taiwan main island

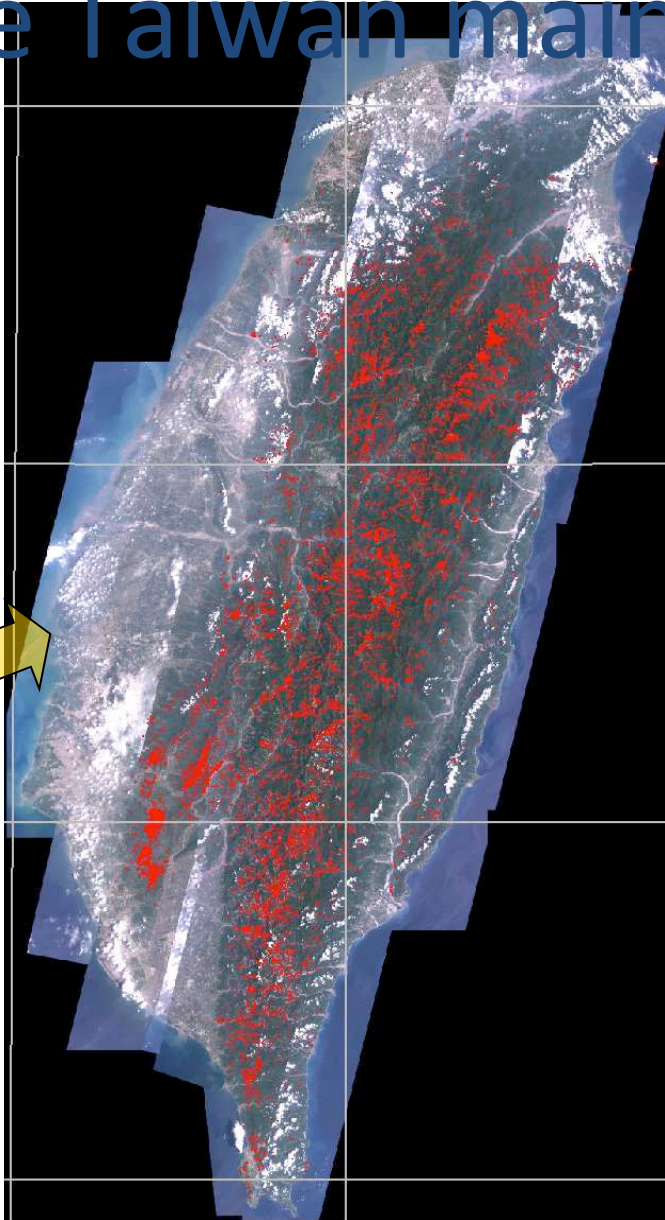
Earthquakes



Typhoons



Landslides



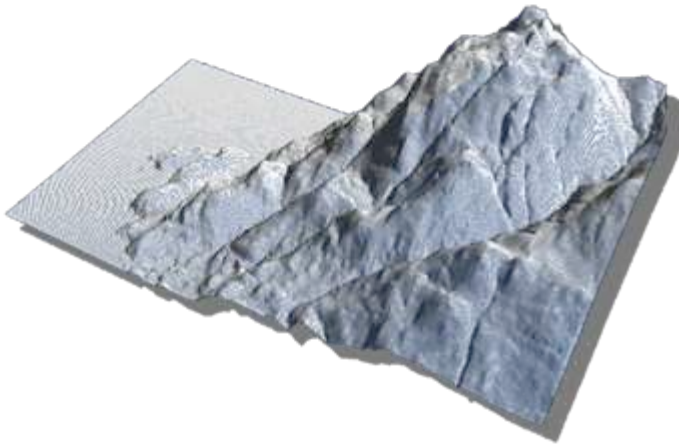
2009
HsiaoLin



- ✓ how to **identify potential sites** of Deep-Seated landslides, **evaluate their activity** and susceptibility become an important issue.

Conventional methods for landslide monitoring

DEM



Leveling



GPS



Optical image



Traversing



Fiber-optic sensors

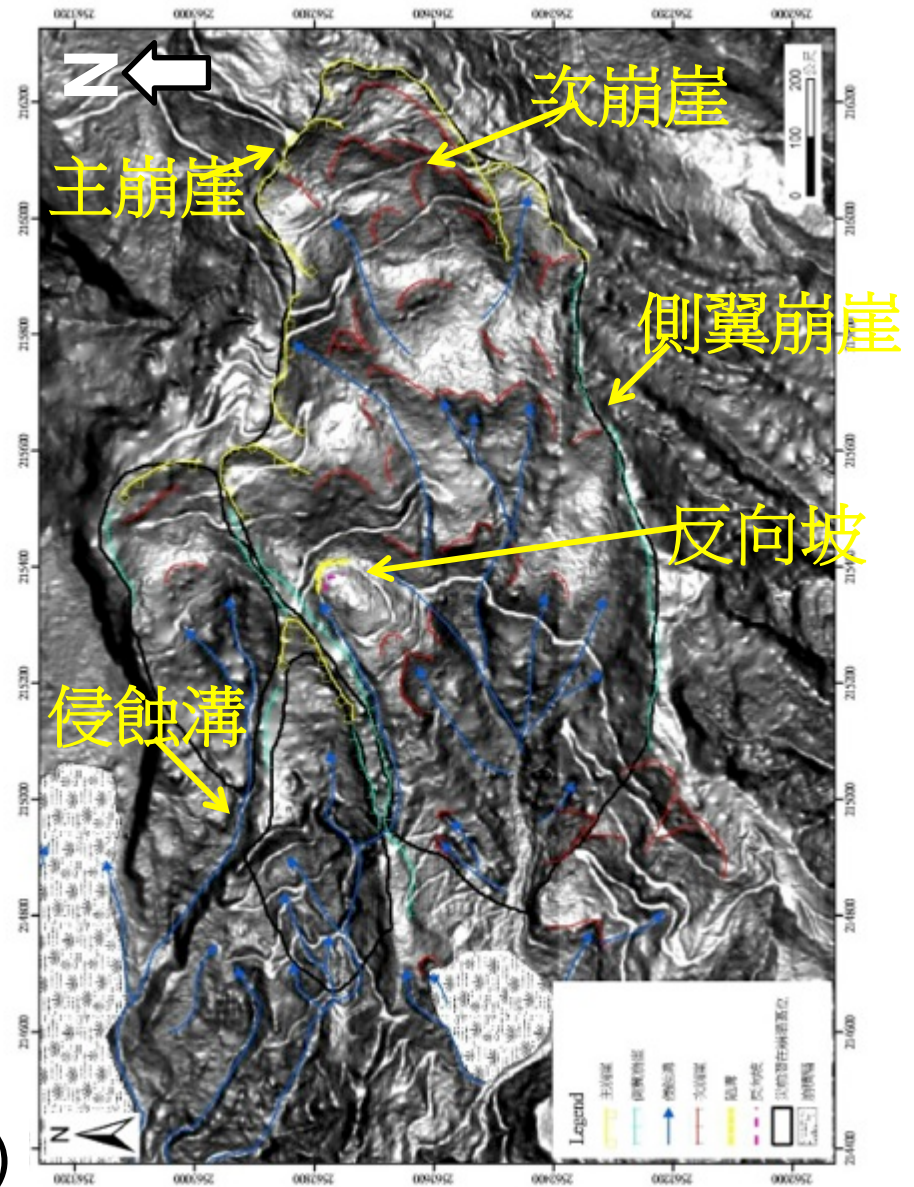
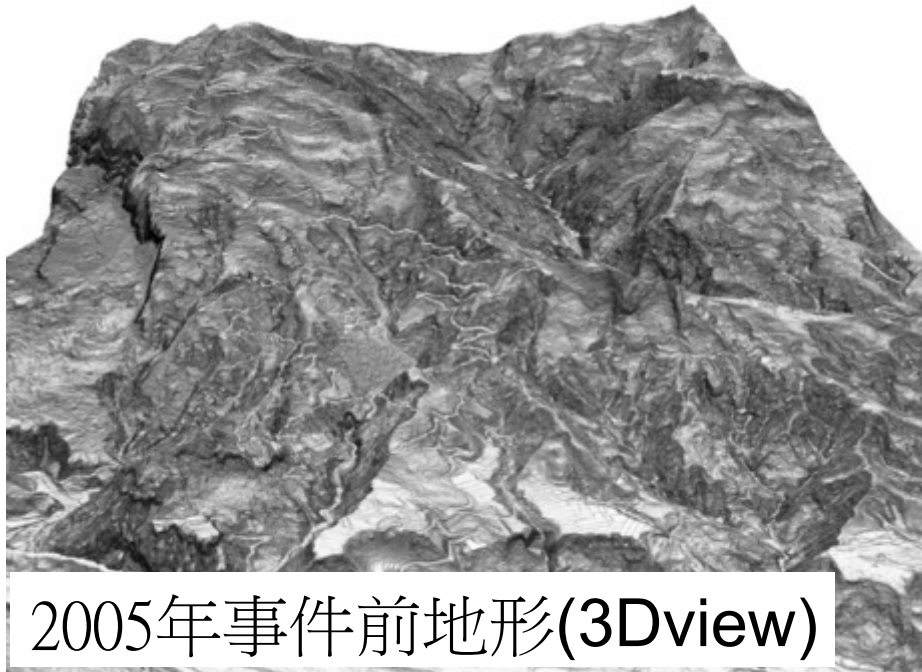


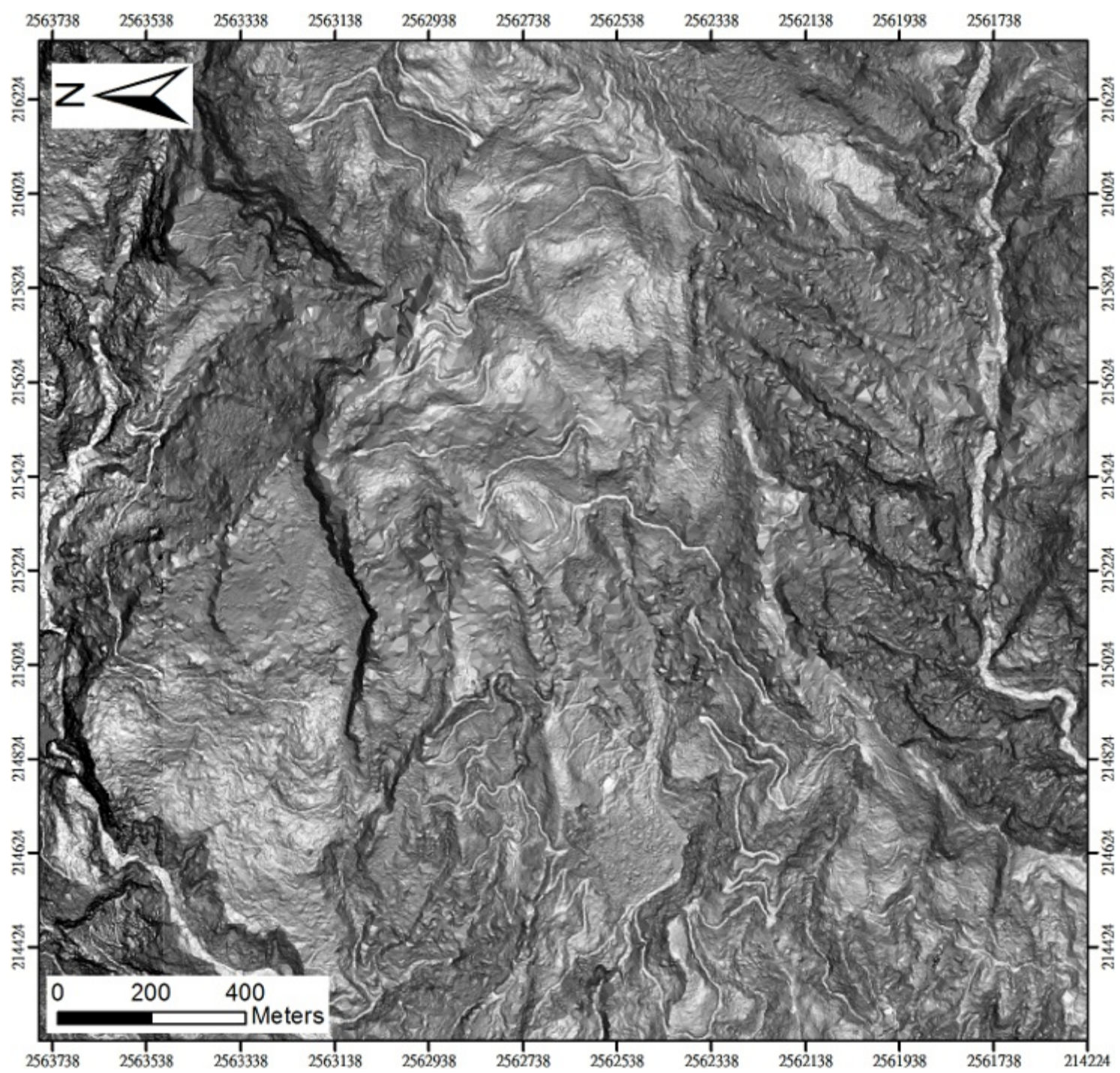
航空遙測與衛星資訊

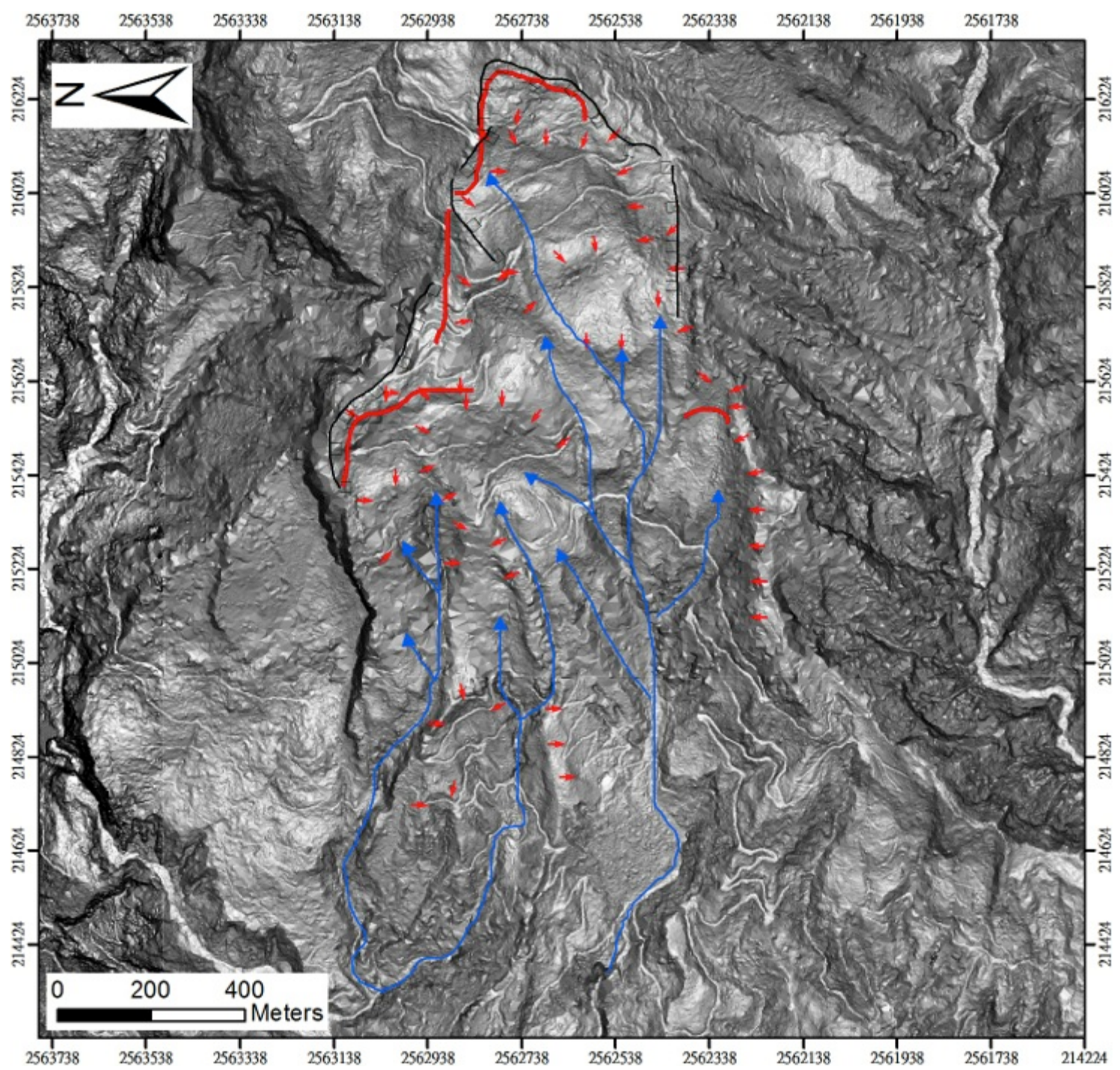
- ✓ 航空照片
- ✓ 光學衛星影像
- ✓ 數值地形
- ✓ 光達高精度數值地形模型
- ✓ 雷達衛星影像
- ✓ 單頻GPS監測



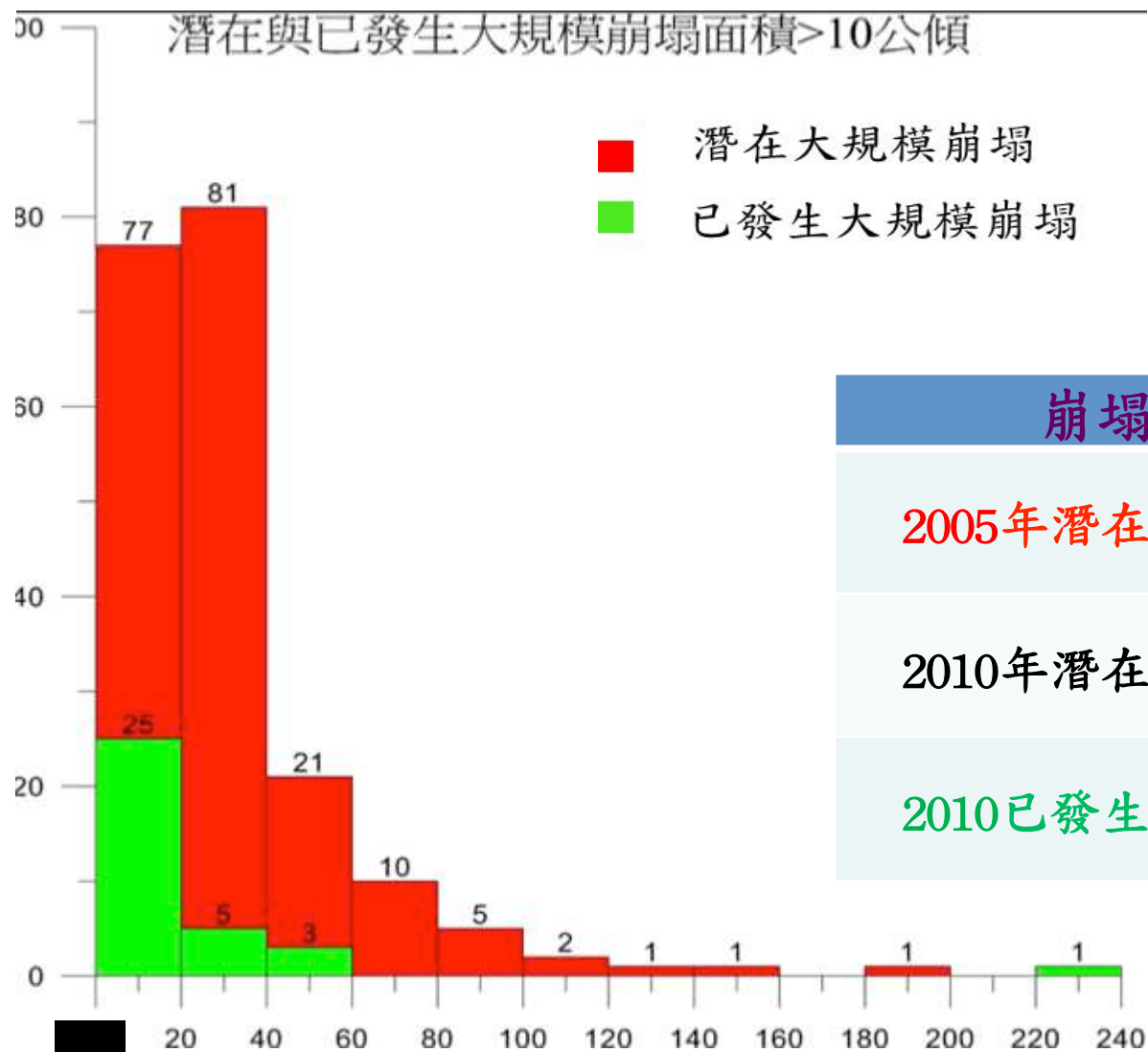
✓ 大規模崩塌是可以預判的





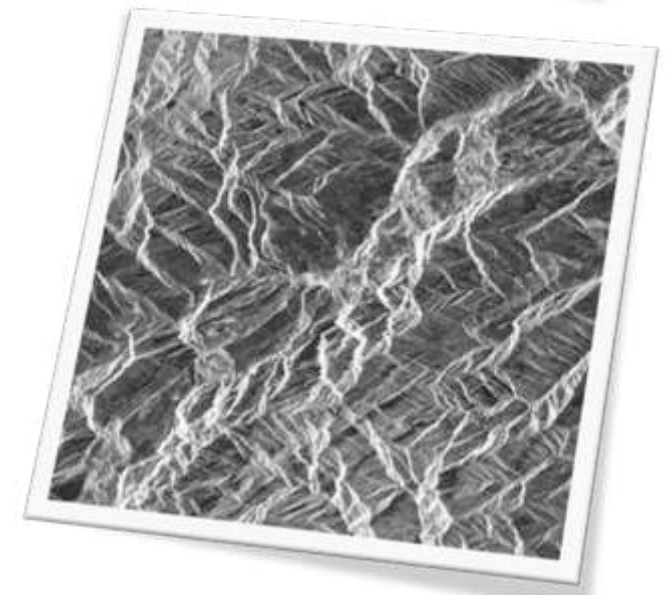
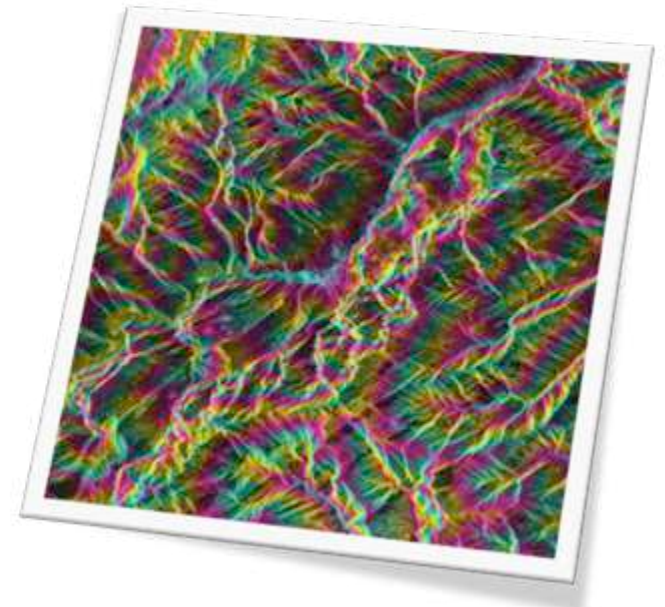
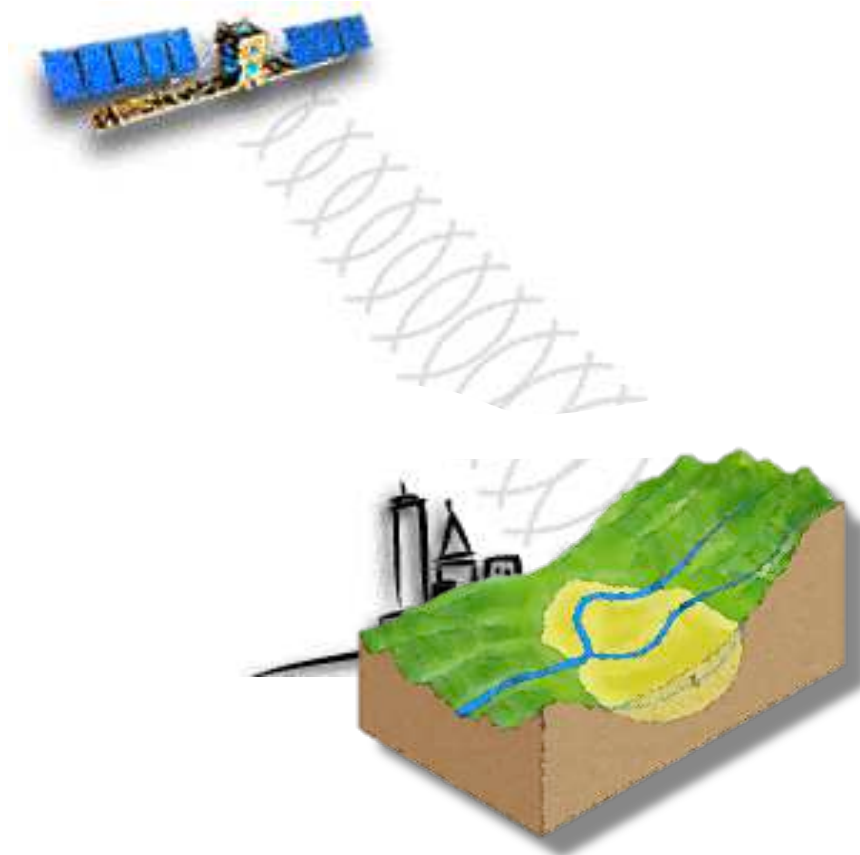


空載光達應用於大規模崩塌判釋



崩塌類型	崩塌數量
2005年潛在大規模崩塌	261
2010年潛在大規模崩塌	208
2010已發生大規模崩塌	53

Interferometric Synthetic Aperture Radar

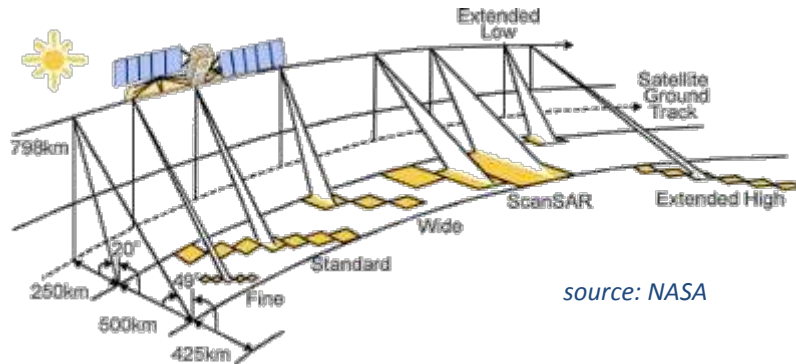


- All-day and all-weather
- Large scale and spatial continuity
- High precision and no need of ground instruments

How satellite radar interferometry works?

Image Product Options: 35 possibilities

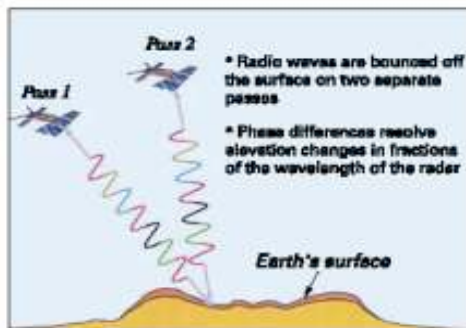
- ❖ Positions – cross-track viewing incidence angles



source: NASA

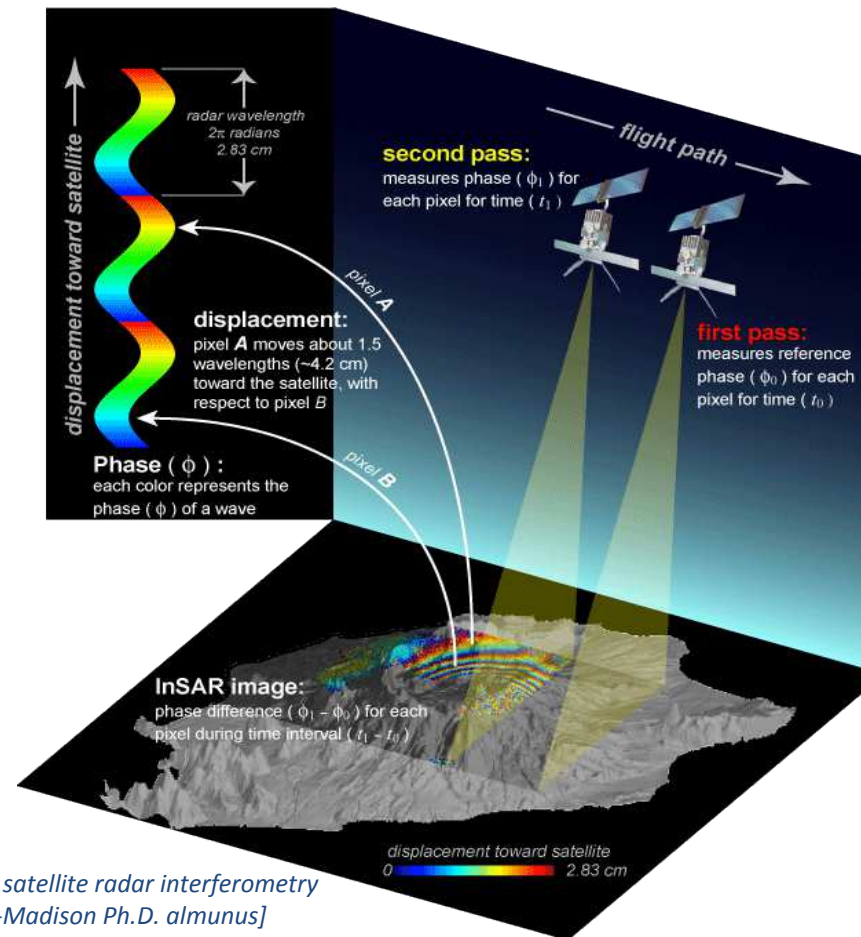
Return signal from satellite holds the key

- ❖ strength or amplitude of the return signal
- ❖ round trip distance from the satellite to the ground and back again



Multipass interferometric SAR (InSAR)

SAR interferometry needs at least (i) two radars or (ii) radar imaging from two places

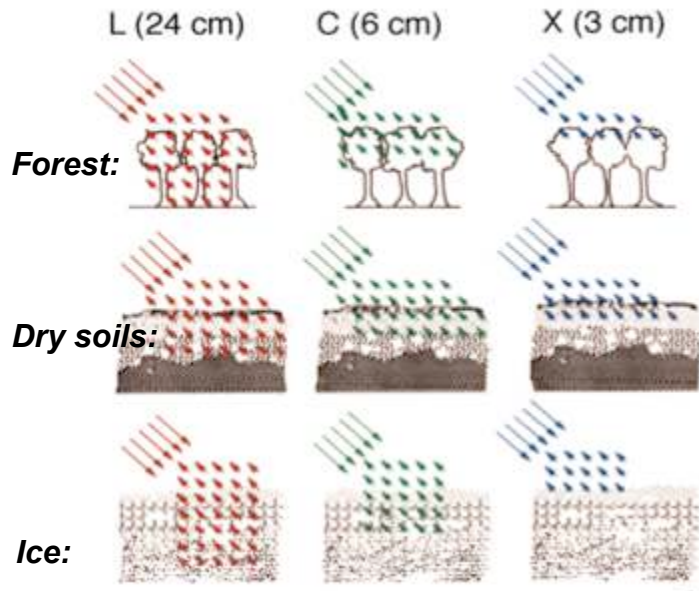


Sketch of measuring volcanic activity by satellite radar interferometry
[Image courtesy of Tim Masterlark, UW-Madison Ph.D. alumnus]

How to choose the Synthetic Aperture Radar ?

Frequency (wavelength)

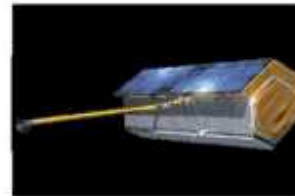
- ❖ Light interacts most strongly with objects on the sizes of the wavelength
- ❖ Wavelengths a measure of surface and subsurface scale sizes
- ❖ **L-band** greatly improves correlation



Paul A Rosen
(Jet Propulsion Laboratory, California Institute of Technology)



SIR-C
NASA / JPL (USA)
April 1994 (10 days)
October 1994 (10 days)
L, C-Band (Quad)



TerraSAR-X
DLR / EADS - ASTRIUM / Infoterra GmbH
June 2007
X-Band (Sngl / Twin / Quad ?)

Pottier and Ferro, 2008
(University of Rennes1, IETR-UMR CNRS)



ENVISAT / ASAR
ESA (EU)
2002
C-Band (Sngl / Twin)

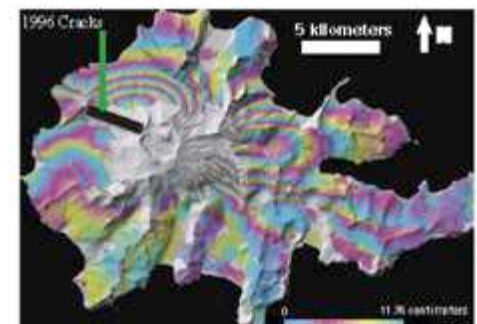
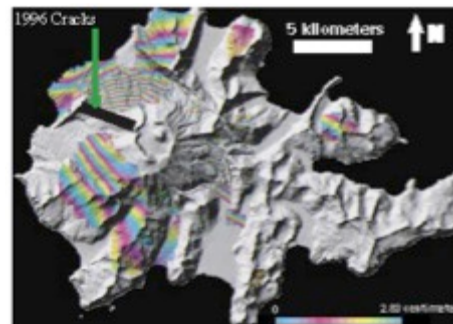


ALOS / PALSAR
JAXA (J)
January 2006
L-Band (Sngl / Twin / Quad)



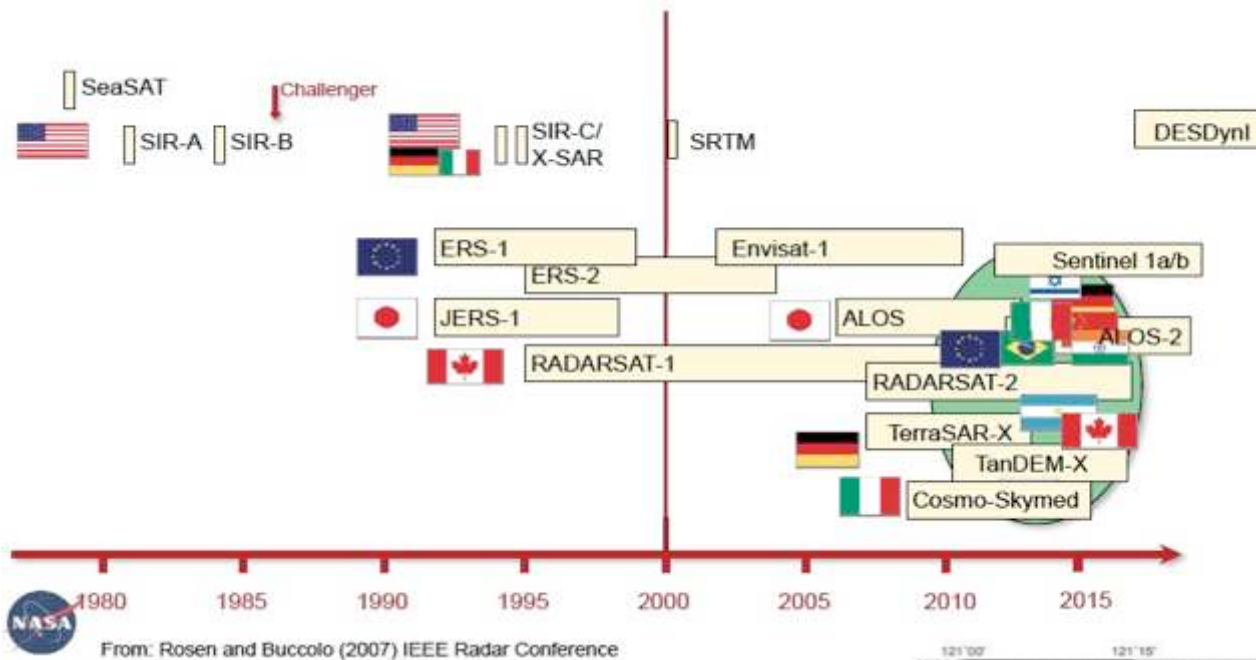
RADARSAT 2
CSA / MDA (CA)
December 2007
C-Band (Quad)

ERS/Radarsat (C-band) vs JERS/ALOS (L-band)



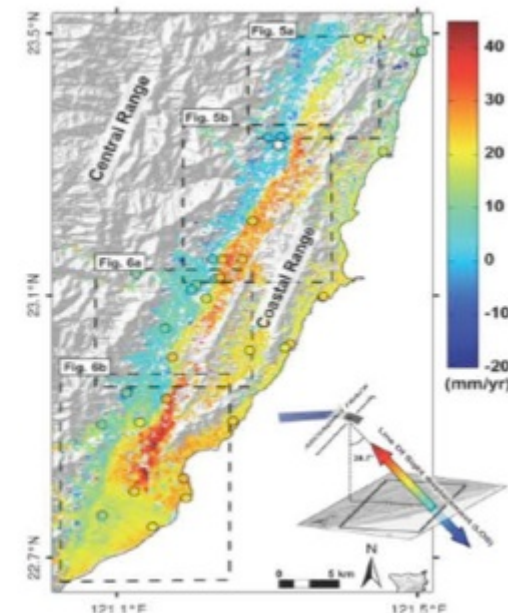
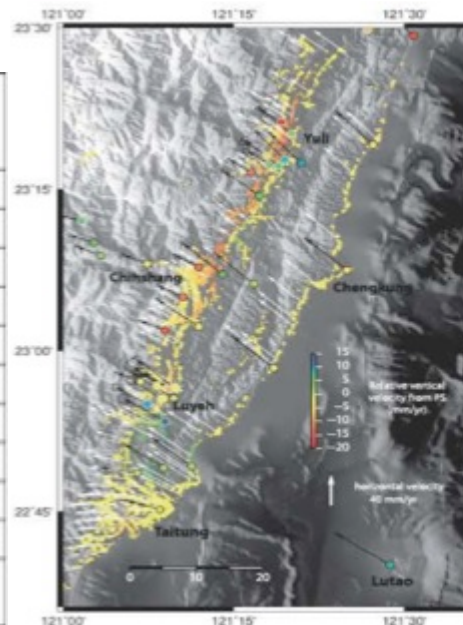
Interferogram showing deformation of Akutan Island (October 1994 to June 1997), draped over shaded-relief map of the island (Lu et al., 2005)

Compare ERS-1 and ALOS in Taiwan



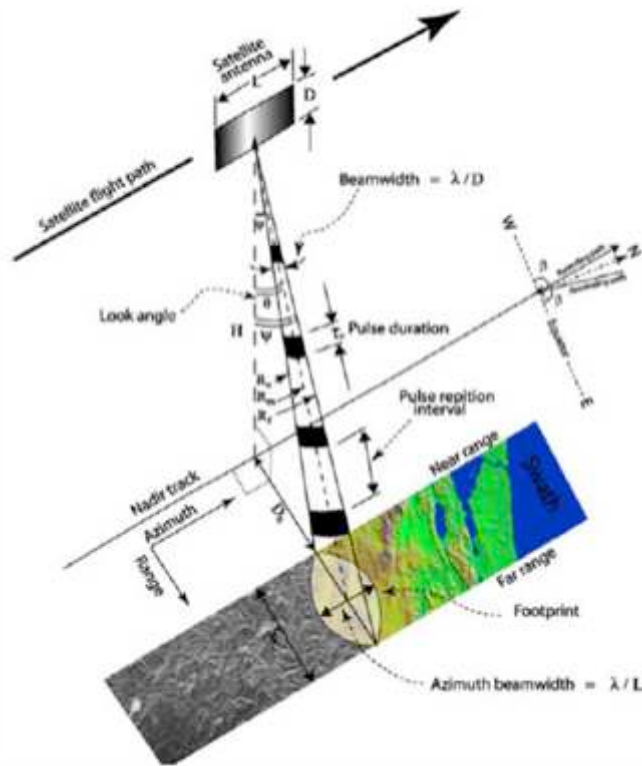
Peyrtet et al (2011)與 Champenois et al (2012)分別選用**ERS-1**及**ALOS**衛星，觀測臺灣東部花東縱谷之活動構造，發現使用ALOS衛星影像的**L波段**(23.5公分)與使用ERS衛星影像的**C波段**(6公分)相比，在山區衛星雷達解算資料較佳。

衛星SAR系統	發射年份	軌道高度(km)	波段/波長(cm)	側視角(度)	重複週期(天)	地面解析度(m)	影像幅寬(km)
ALMAZ-1	1987	300	S/10	21~65	3	15~30	30~45
ERS1	1992	790	C/6.5	23	35	25	100
ERS2	1995	790	C/6.5	23	35	25	100
JERS-1	1992	568	L/23.5	38	44	25	80
RADARSAT-1	1995	590	C/5.6	23~65	24	8~30	50~500
ENVISAT	2002	800	C/5.6	15~45	35	25~100	100~405
ALOS	2006	700	L/23.5	8~60	46	10~100	20~350
RADARSAT-2	2007	798	C/5.6	10~49	23	3~100	~25~500
TerraSAR-X	2007	514	X/3.1	20~45	11	1~16	10~100
TanDEM-X	2010	514	X/3.1	20~45	11	1~16	10~100
COSMO-SkyMed(四星座)	2007~2010	620	X/3.1	20~60	4~16	1~100	10~200



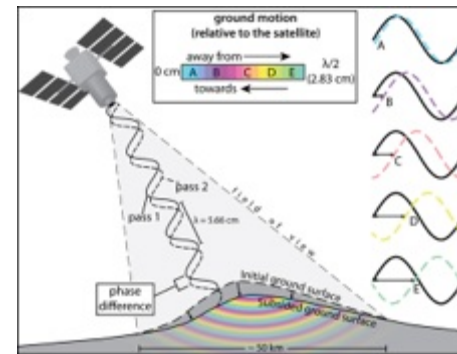
Definition of the SAR techniques

❖ **SAR**合成孔徑雷達(Synthetic Aperture Radar)：以固定天線感測器向地表發射電磁波，藉由接收物體所反射回波之強度(Strength)、振幅(Amplitude)和距離(distance)等資訊，配合都卜勒偏移原理(Doppler Shift)進行幾何修正，得到地表三維資訊。

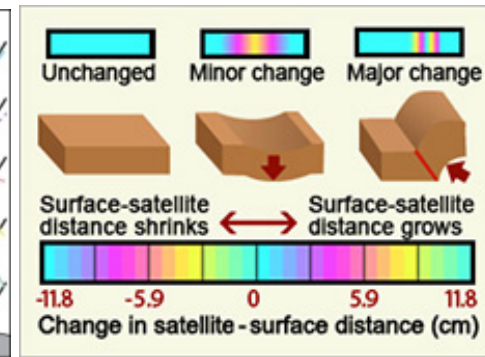


Paolo trivero and Walter Biamino (2010) *Observing marine pollution with Synthetic Aperture Radar*, ISBN 978-953-7619-97-8

❖ **InSAR**干涉合成孔徑雷達(Interferometric SAR)：利用兩張不同時間同一地區之SAR影像，回復影像對之間的相位差(Unwrapping) 取得數值高程地形模型(DEM)或是干涉圖(Interferogram)。



Mauna Loa (2012) *Bulletin of the Global Volcanism Network*, vol. 37, no. 5



Masayuki Yamanaka (2011) *Saving Lives With Satellites*. JAXA.

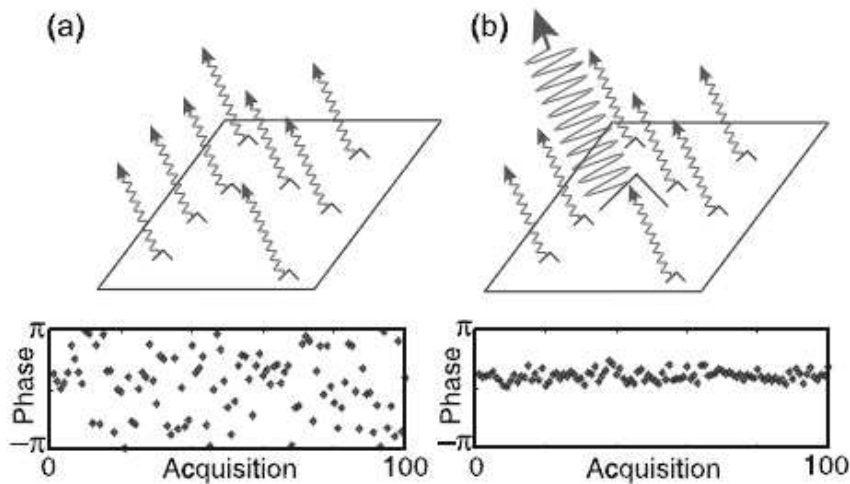
❖ **D-InSAR**差分干涉合成孔徑雷達(Differential InSAR)：同一地區兩幅不同時期干涉圖，利用差分處理將地形效應去除後，得到地表變形量。

❖ **PS-InSAR**永久散射體差分干涉雷達(Persistent Scatterers InSAR)：根據不同時間序列之SAR影像，萃取地表反射性、同調性良好的散射點(Persistent Scatterer, PS)，提供高相關性且長時間穩定之相位資訊。

What is difference between PS and TCP-InSAR?

- ❖ PS select pixels with stable scattering behavior over time, only focus on “good” pixels
- PS identify dense coherent points from each image pair only
 - Coherence @ 1 point
 - Need > 15-20 scenes

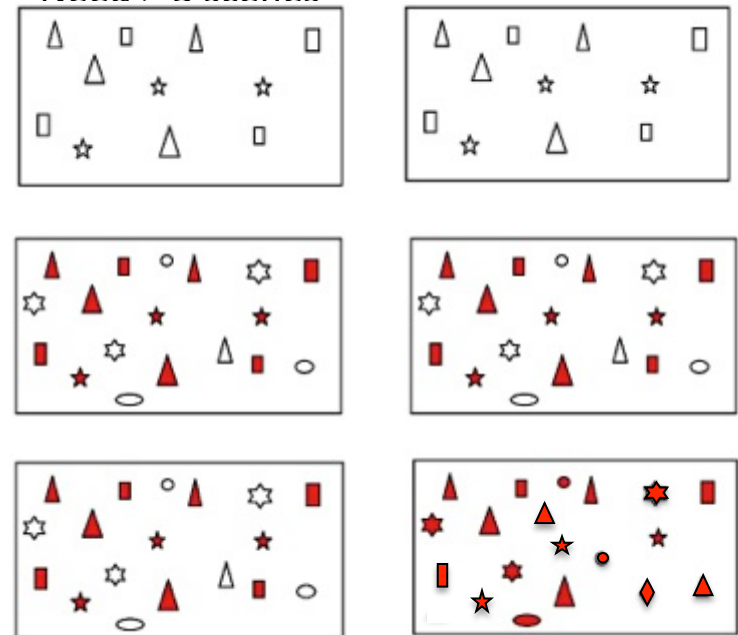
- ❖ TCP-InSAR approach is also adequate for retrieving deformation signal from a small set of SAR images.



StaMPS method (Hooper et al. 2004 and 2009)

- Coherence @ 1 point
- **PS selection** Need > 3 scenes

TCP selection

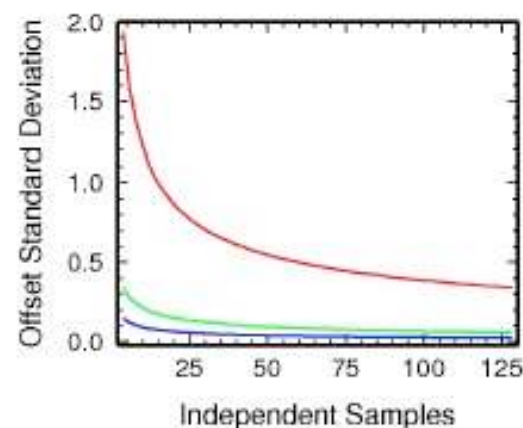
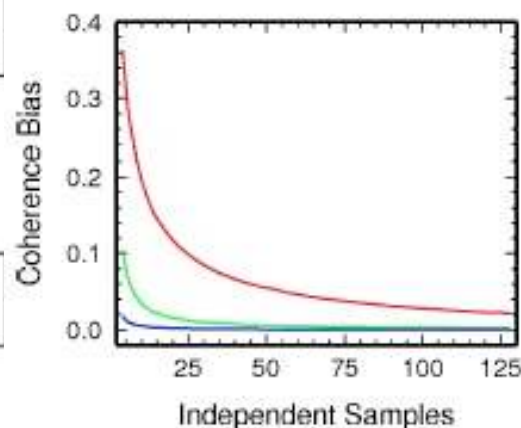
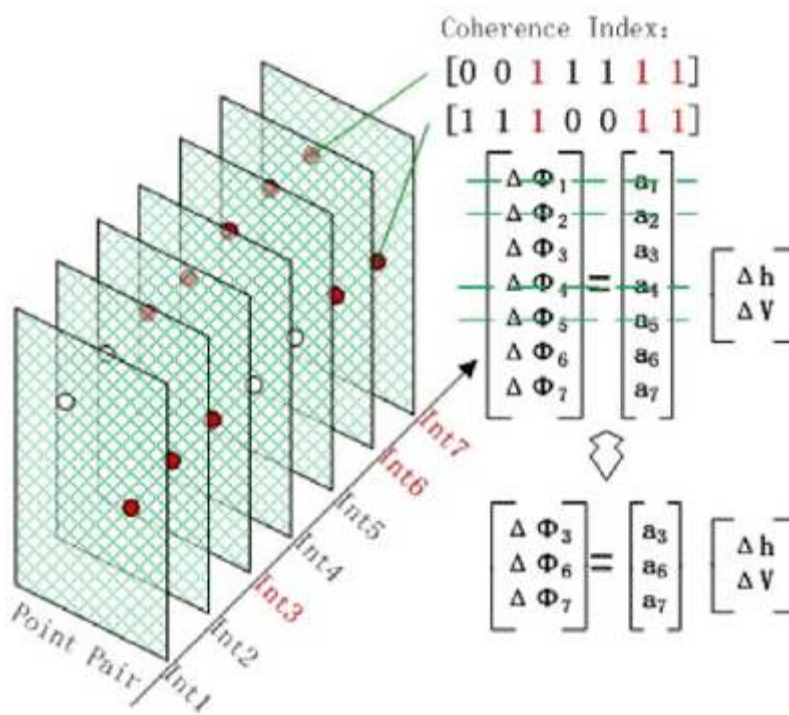


What is Temporarily Coherent Point-InSAR?

- Not necessary to keep coherent during the whole time span
- Including persistently coherent point and partially coherent point

• TCP 選取：

- 固定像素：改變罩窗產生之相關性偏差，相關性低，超成偏差量大。
- 偏移量估計：偏移量跟相關性一致，相關性低時，視窗尺寸改變所造成的相關性低，偏移量大，相關性高，偏移量不明顯。



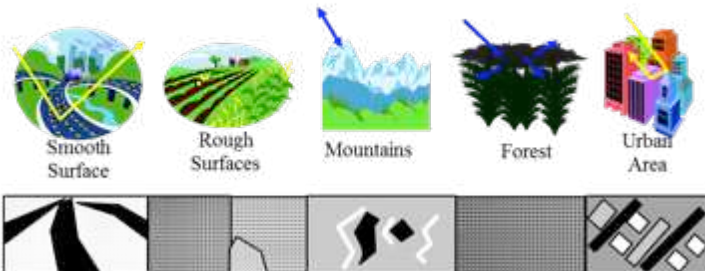
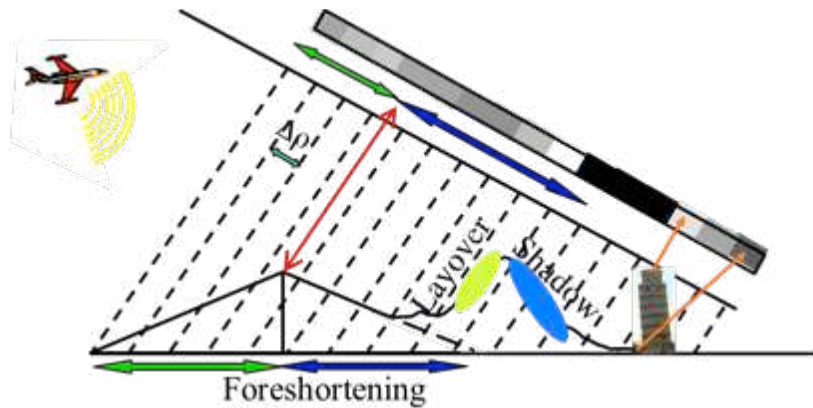
罩窗尺寸對象素相關性與偏移量計算影響 (Zhang, 2012)

- (a) 罩窗尺寸對象素相關性計算影響
- (b) 罩窗尺寸對像素偏移量影響

TCP (Temporarily Coherence Point) InSAR

What is a Temporarily Coherence Point?

- ✓ identify dense coherent points from one image pair only



Paul A Rosen 2011

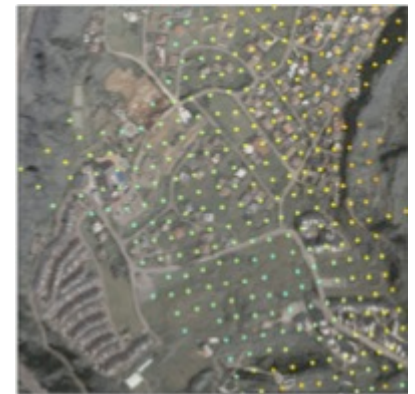
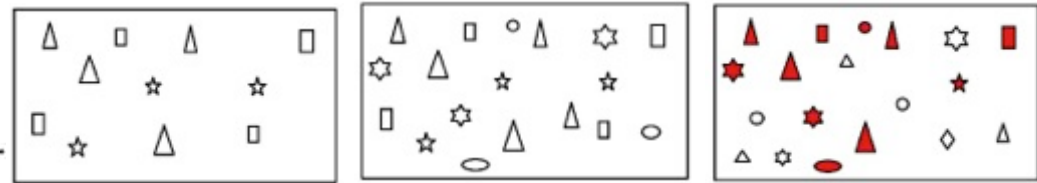
(Jet Propulsion Laboratory, California Institute of Technology)

- ✓ TCP-InSAR approach is also adequate for retrieving deformation signal from a small set of SAR images.

PS-InSAR



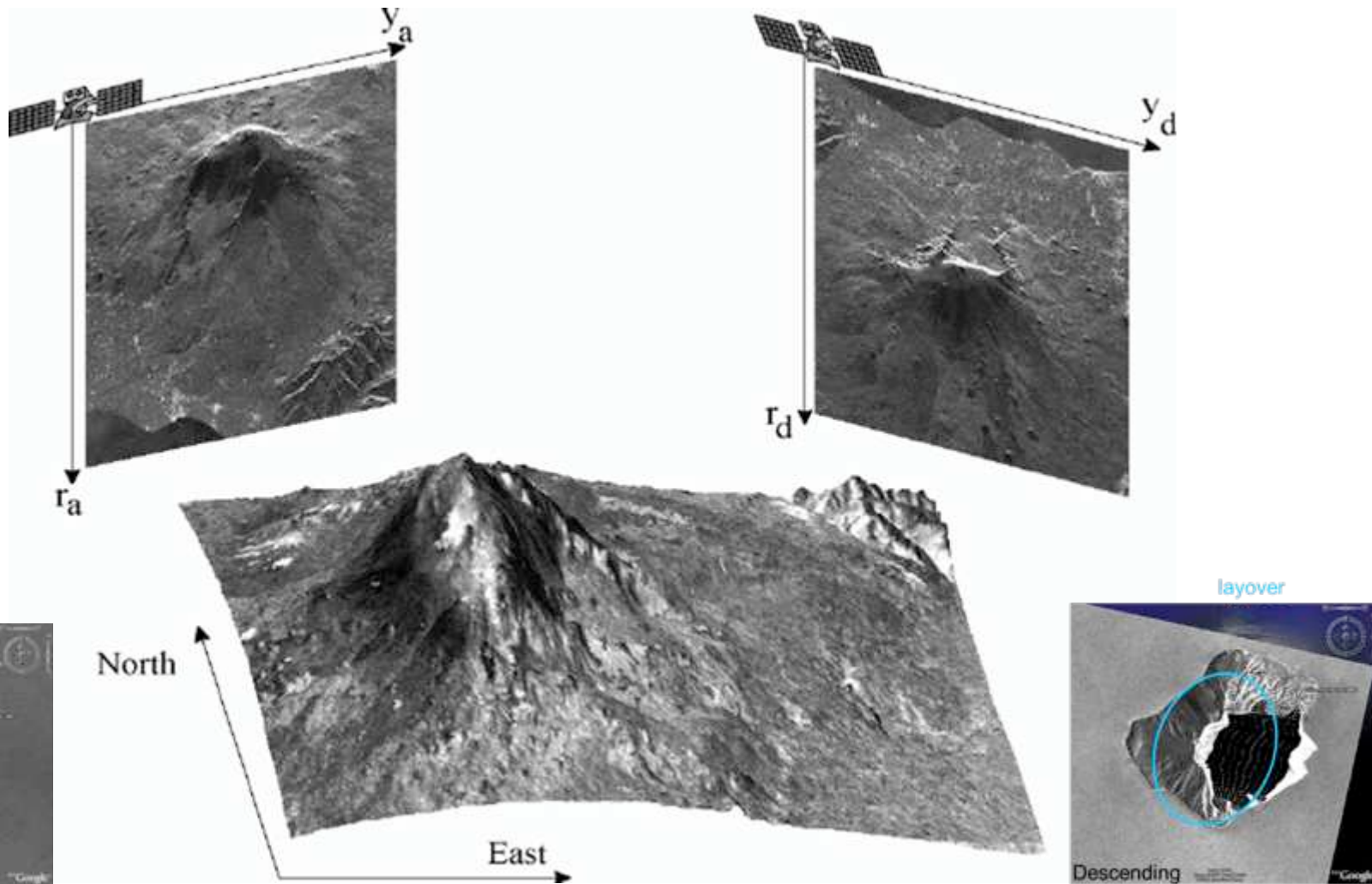
TCP-InSAR



How to choose satellite images?

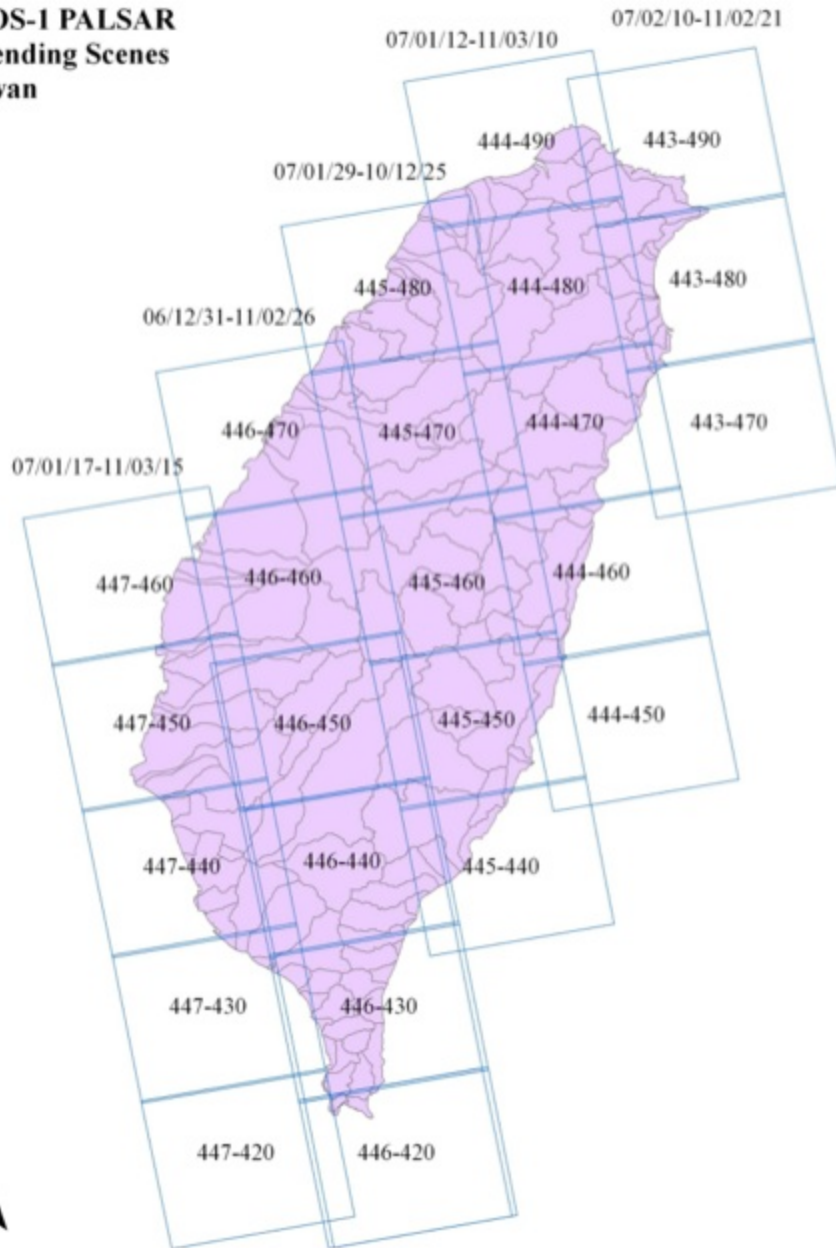
❖ Combine Ascending and descending orbits

The combination of the motion of the satellite and the motion of the earth makes it possible to look at the same area of interest from two opposite acquisition geometries.

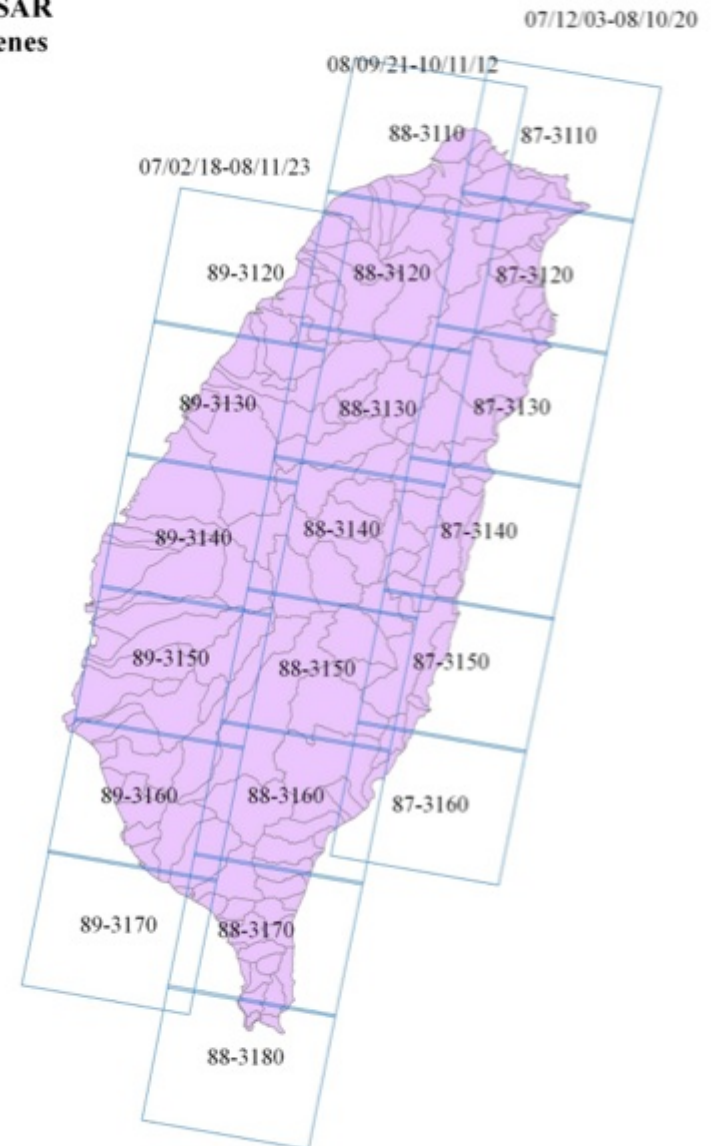


Ascending and Receding Scenes ?

**ALOS-1 PALSAR
Ascending Scenes
Taiwan**



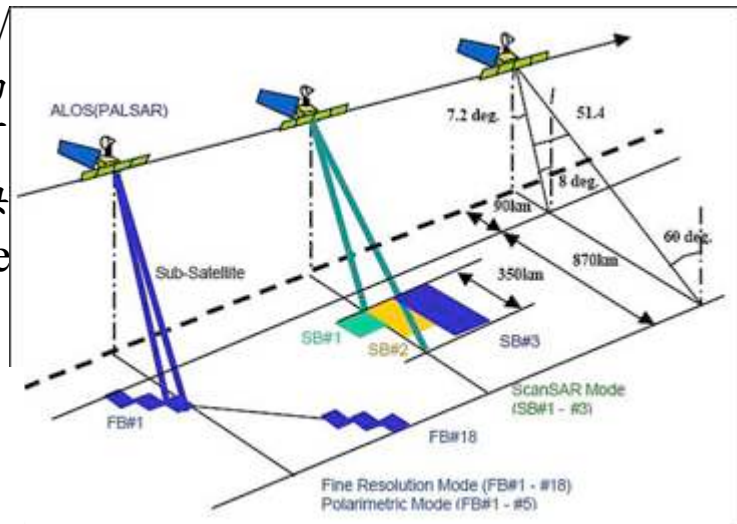
**ALOS-1 PALSAR
Decending Scenes
Taiwan**



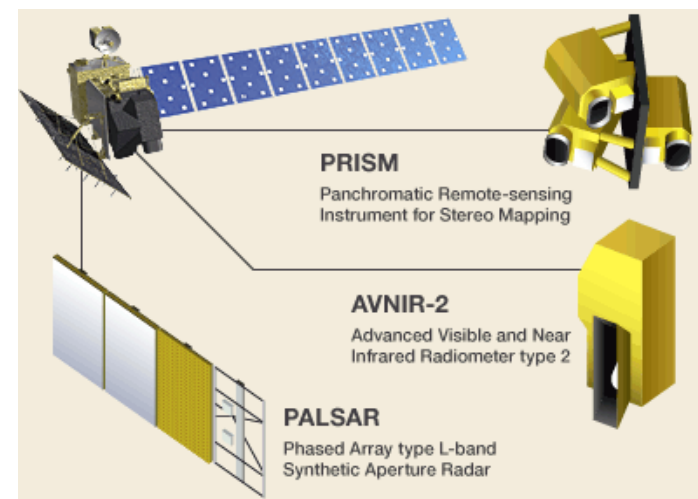
ALOS/PALSA satellite images

本研究選用衛星雷達影像規格，為日本ALOS/PALSAR感測器之**Fine模式**，衛星雷達建置原則為涵蓋計畫範圍，每一圖幅影像選用包括上升以及下降軌道，所使用PALSAR雷達衛星影像將統一轉換為Single Look Complex(SLC)的Fine Beam Single (FBS)檔案格式。

PALSAR Characteristic				
Phased Array type L-band Synthetic Aperture Radar				
Mode	Fine		ScanSAR	Polarimetric (Experimental mode)*1
Center Frequency	1270 MHz(L-band)			
Chirp Bandwidth	28MHz	14MHz	14MHz,28MHz	14MHz
Polarization	HH or VV	HH+HV or VV+VH	HH or VV	HH+HV+VH+VV
Incident angle	8 to 60deg. 8 to 60deg.		18 to 43deg.	8 to 30deg.
Range Resolution	7 to 44m	14 to 88m	100m (multi look)	24 to 89m
Observation Swath	40 to 70km	40 to 70km	250 to 350km	20 to 65km
Bit Length	5 bits	5 bits	5 bits	3 or 5bits
Data rate	240Mbps	240Mbps	120Mbps,240Mbps	240Mbps
NE sigma zero *2	< -23dB (Swath Width 70km)		< -25dB	< -29dB
	< -25dB (Swath Width 60km)			
S/A *2,*3	> 16dB (Swath Width 70km)		> 21dB	> 19dB
	> 21dB (Swath Width 60km)			
Radiometric accuracy	scene: 1dB / orbit: 1.5 dB			

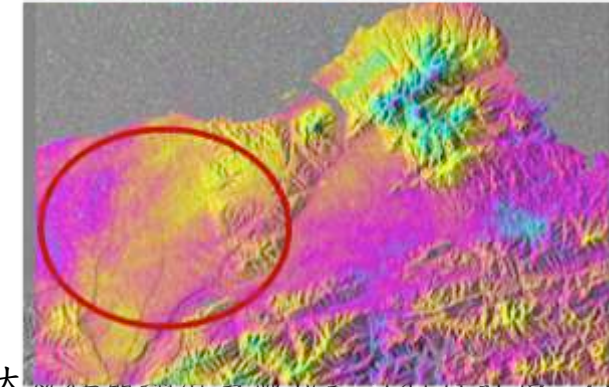
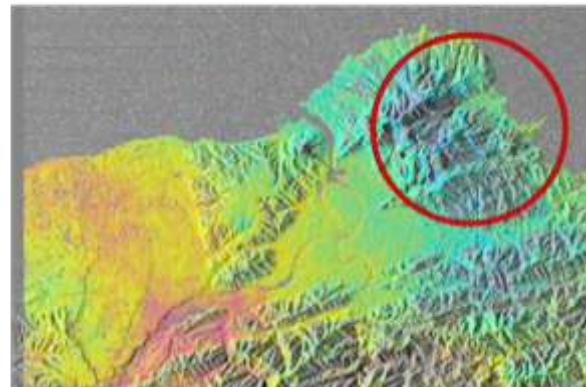
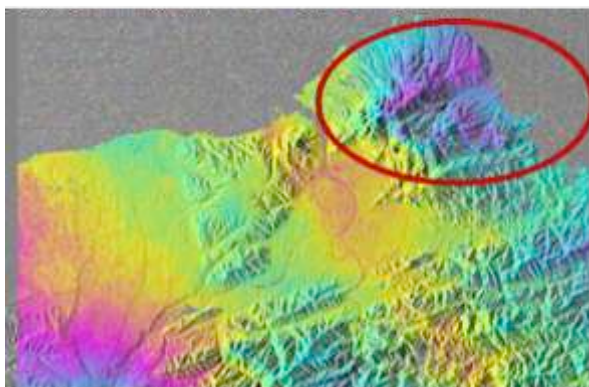
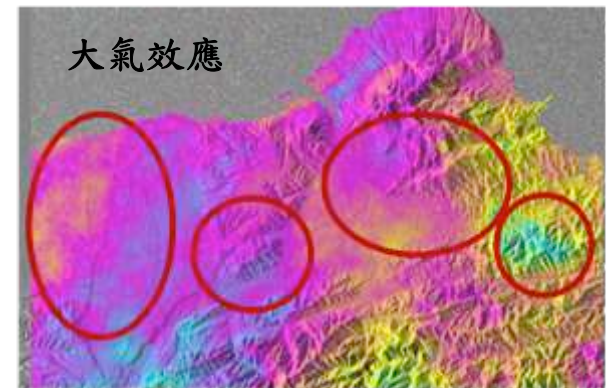
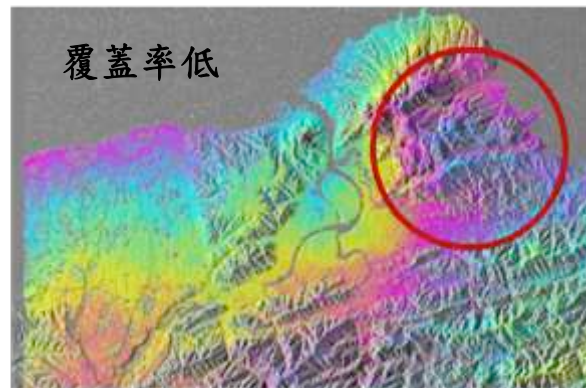
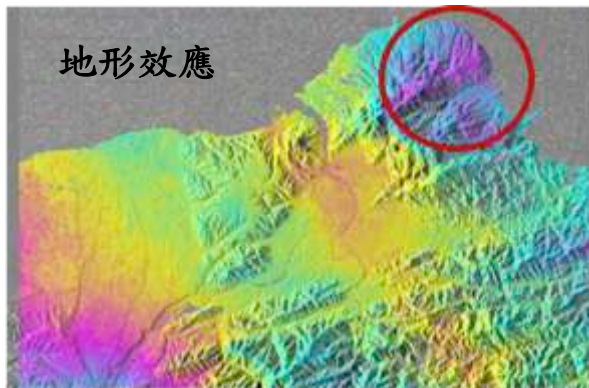


ALOS/PALSAR感測器飛航拍攝方式，(引自中央大學太空及遙測研究中心網頁，ALOS衛星簡介)



ALOS/PALSA satellite images

- ✓ **大氣效應(Atmospheric artefacts)**：雖然雷達訊號可有效穿透雲霧，但仍有部份訊號會被水汽折射或是吸收造成回波雜訊或是相位偏移，在氣候空間變化劇烈的地區會引致觀測與解算結果中相當的誤差量。
- ✓ **軌道誤差(orbital error)**：雷達訊號解算主要基於觀測衛星與地面的相對空間關係，衛星軌道的定位精度會直接影響解算成果的準確度。
- ✓ **地形效應(geometric distortion)**：由於雷達系統採用側向觀測的設計，因此所拍攝的影像會因為和地形起伏的相對位置關係而發生扭曲或是部份地區被遮蔽而無法順利觀測的情況。



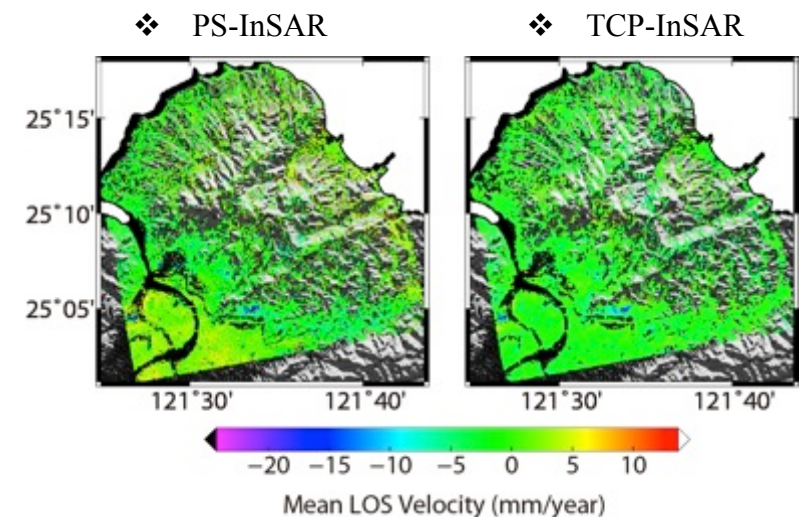
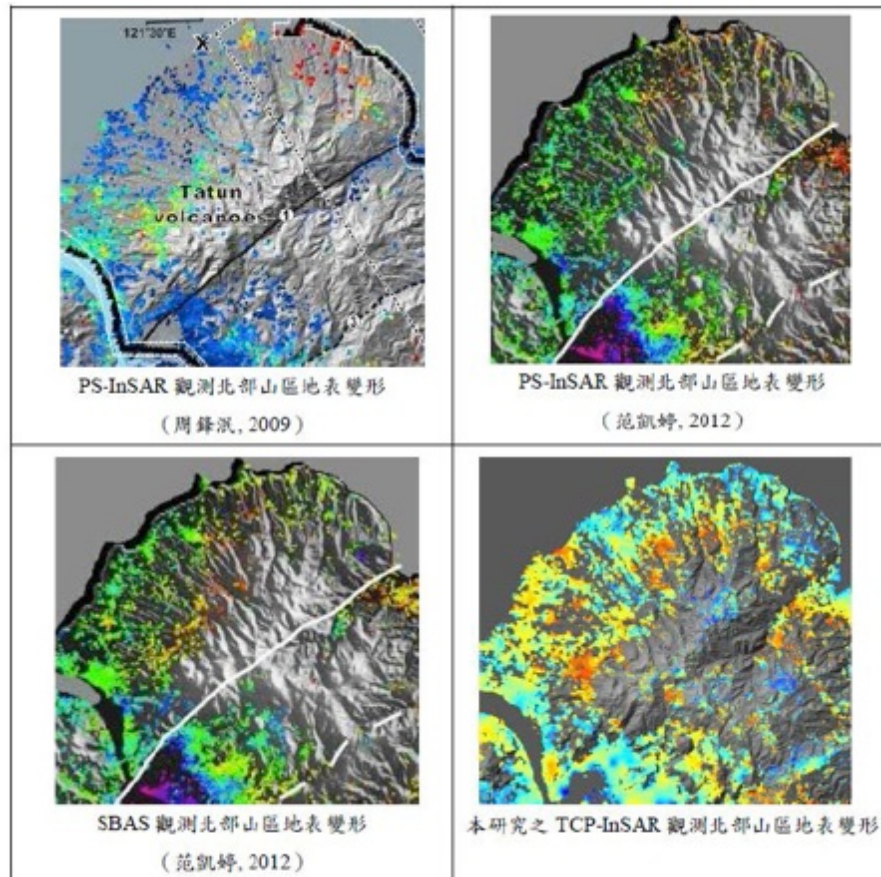
TCP (Temporarily Coherence Point) InSAR

What is a Temporarily Coherence Point?

- ✓ identify dense coherent points from one image pair only

- ✓ TCP-InSAR approach is also adequate for retrieving deformation signal from a small set of SAR images.

本團隊所使用TCP-InSAR技術，比較前人研究在陽明山地區的結果，地表變形點位分布明顯優於其他方法論，平均點位密度更可達到**335點/平方公里**。



	StaMPS/MTI	DORIS based TCP-InSAR
Number of PS	30636	326310
Average PS density (PS/ km ²)	32	335