



從InSAR時間序列到 地面運動服務系統（GMS）

農村發展與水土保持署
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Outlines

1. **Origin of InSAR time series**
2. **Algorithms:** InSAR, DInSAR, PS-InSAR, MTInSAR, SABS-InSAR etc.
3. **The rise of Ground Motion Services**
4. **The status of Taiwan**

Origin of DInSAR



Massonnet D, Rossi M, Carmona C, et al (1993)
The displacement field of the Landers earthquake mapped by radar interferometry. *Nature* 364:138–142. <https://doi.org/10.1038/364138a0>

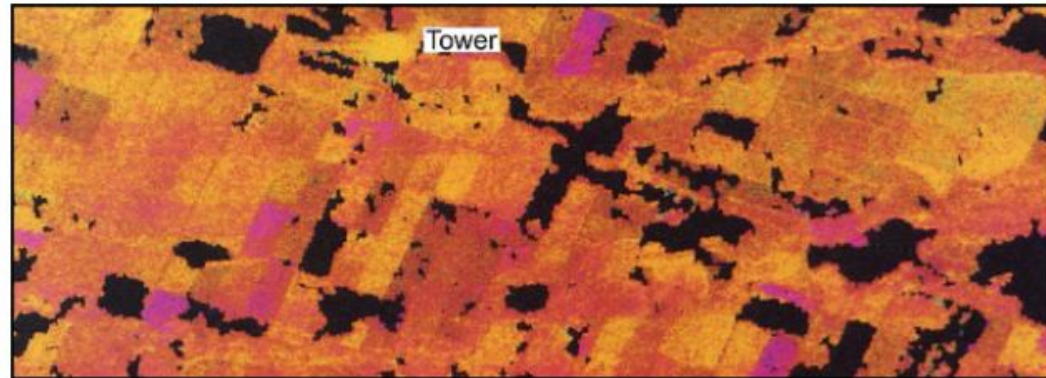
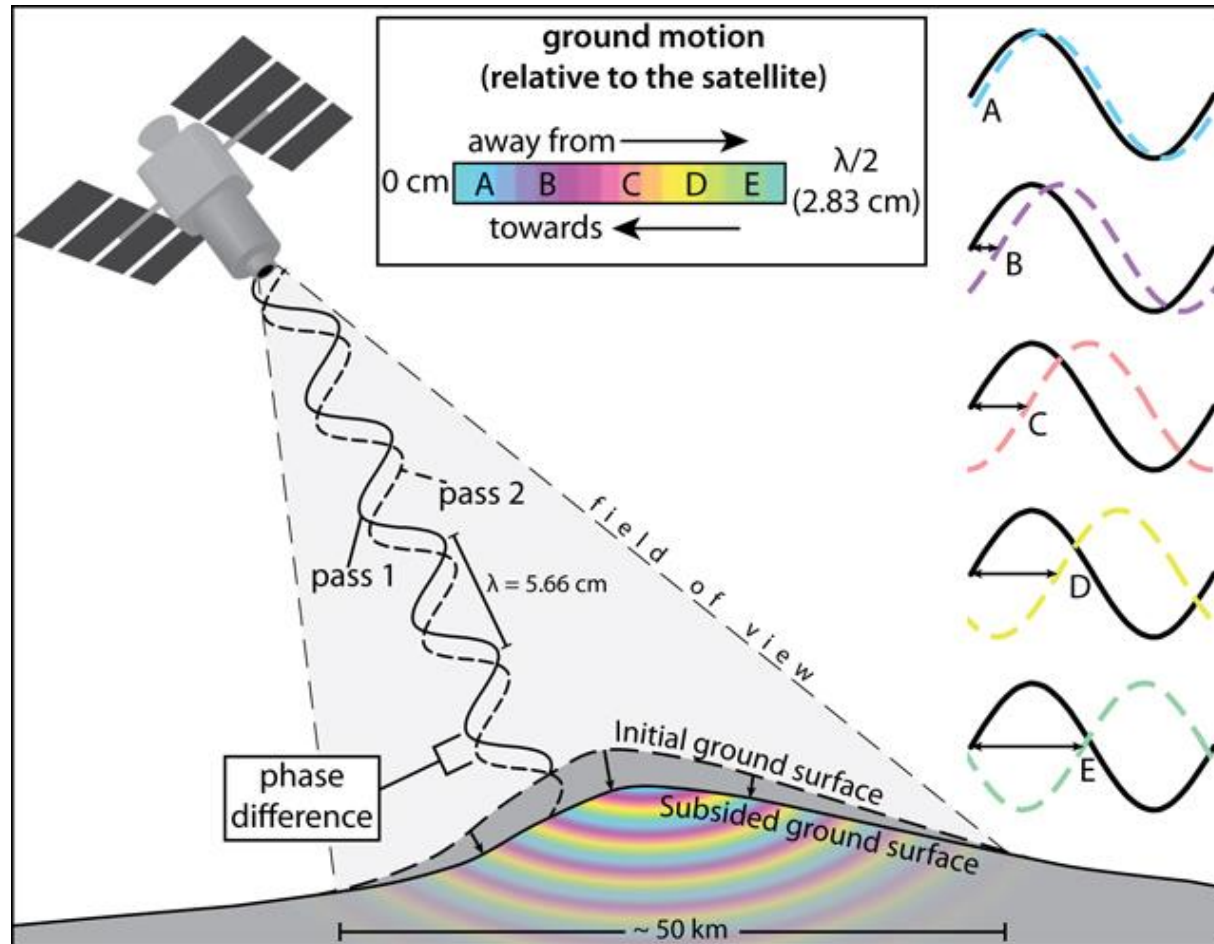


Figure 4 A portion of the original deformation map from the first proof-of-concept experiment for spaceborne InSAR using imagery obtained by the SeaSAT mission (Gabriel et al., 1989). Colored patches delineated by field boundaries indicate possible swelling/compaction of the fields due to moisture changes. The image is approximately 15 km across.

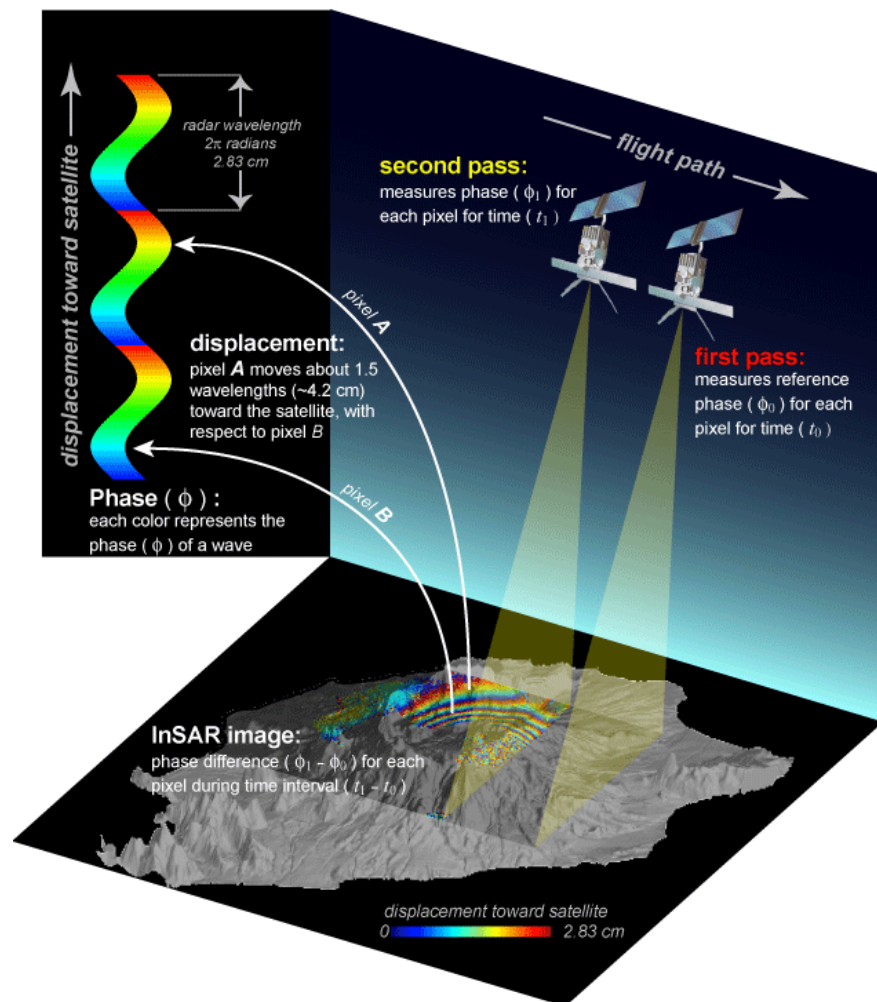
Gabriel AK, Goldstein RM, Zebker HA (1989) Mapping small elevation changes over large areas: Differential radar interferometry. *Journal of Geophysical Research: Solid Earth* 94:9183–9191. <https://doi.org/10.1029/JB094iB07p09183>

DInSAR

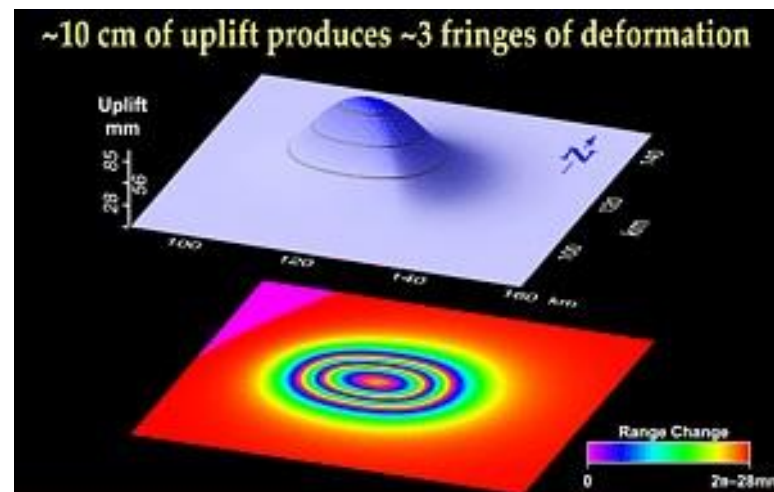


1. 相近視角的SAR影像
2. 利用相位差
3. 移除地形效應

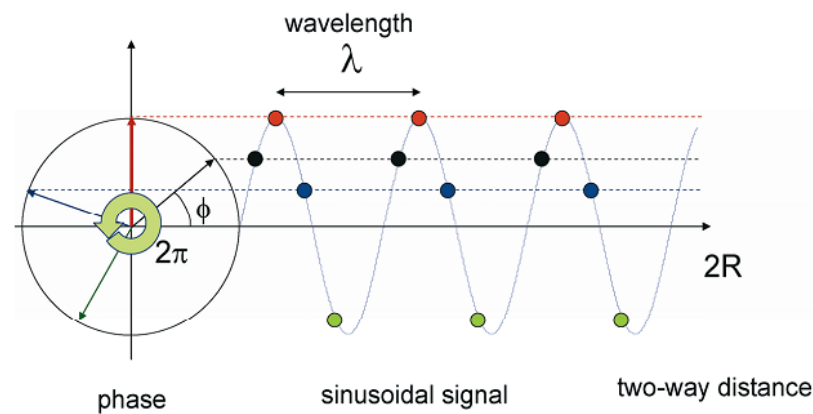
<https://insar.space/insar-technology/>



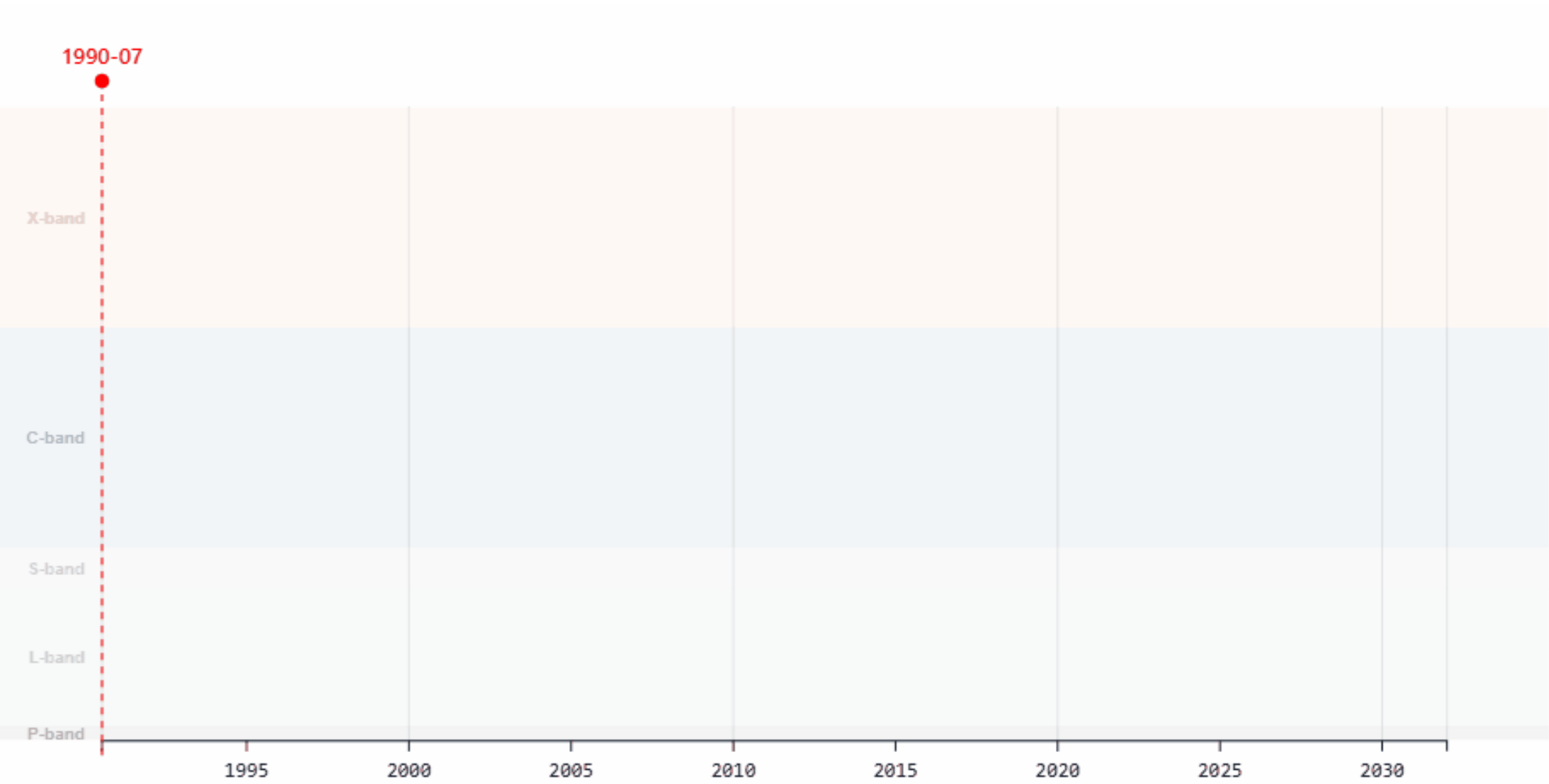
(Tim Masterlark, UW-Madison Ph.D.almunus)



Interferogram (lower) showing modeled uplift of 10 cm; Illustration by G. Bawden, USGS

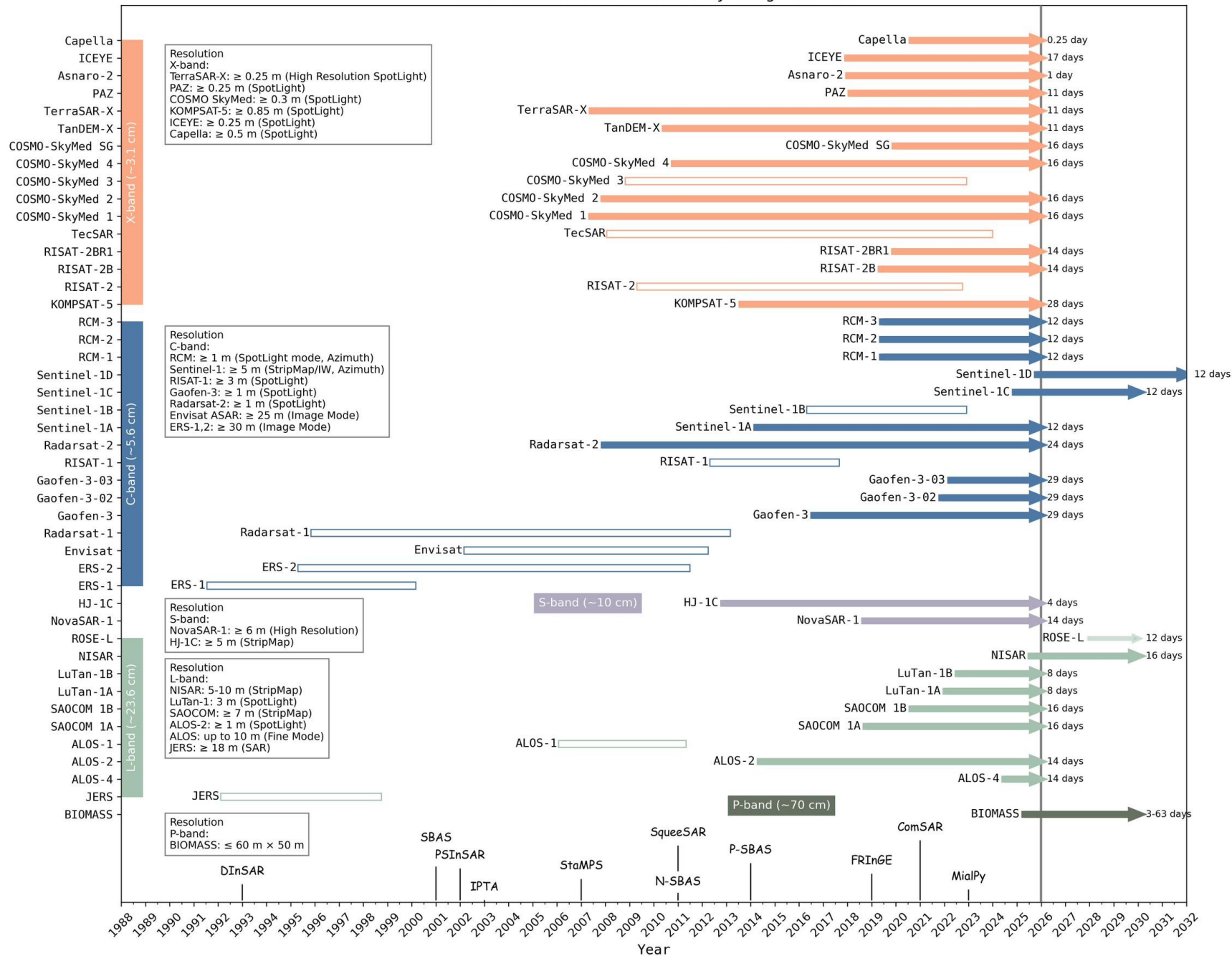


$$\phi = \frac{2\pi}{\lambda} 2R = \frac{4\pi}{\lambda} R$$





Radar Satellites Timeline by Geng-Pei Lin



Persistent Scatterer InSAR (Hopper et al, 2007)

If a pixel is dominated by only one stable scatterer that is brighter than the background scatterers, the variance in the phase of the returning signal due to the change of the background scatterers will be reduced and may be small enough for extracting the underlying deformation signal.

Physically, these stable scatterers might be a tree trunk or a single large rock among the vegetation.

$$\phi_{x,i} = \phi_{def,x,i} + \phi_{\alpha,x,i} + \phi_{orb,x,i} + \phi_{\varepsilon,x,i} + n_{x,i}$$

$\phi_{x,i}$: interferometric phase

$\phi_{def,x,i}$: surface displacement

$\phi_{\alpha,x,i}$: atmospheric effect

$\phi_{orb,x,i}$: orbit effect

$\phi_{\varepsilon,x,i}$: DEM residual effect

$n_{x,i}$: noise

Component	Spatial Properties	Temporal Properties
Deformation	Low frequency	Low frequency
Atmosphere	Low frequency	High frequency
Orbital errors	Low frequency	High frequency
Look angle error	High frequency	Correlated with baseline
Scatterer noise	High frequency	High frequency

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$\phi_{x,i}$: interferometric phase

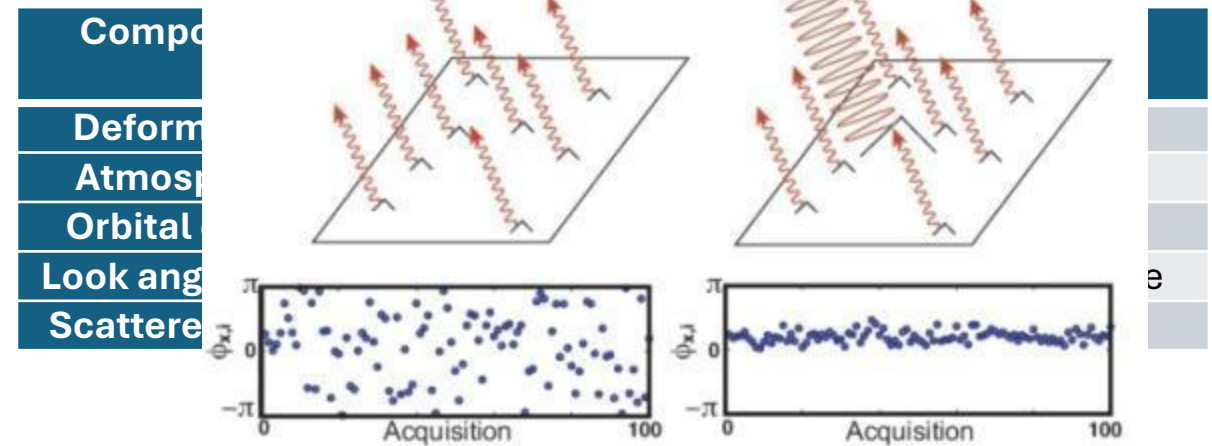
$\phi_{def,x,i}$: surface displacement

$\phi_{\alpha,x,i}$: atmospheric effect

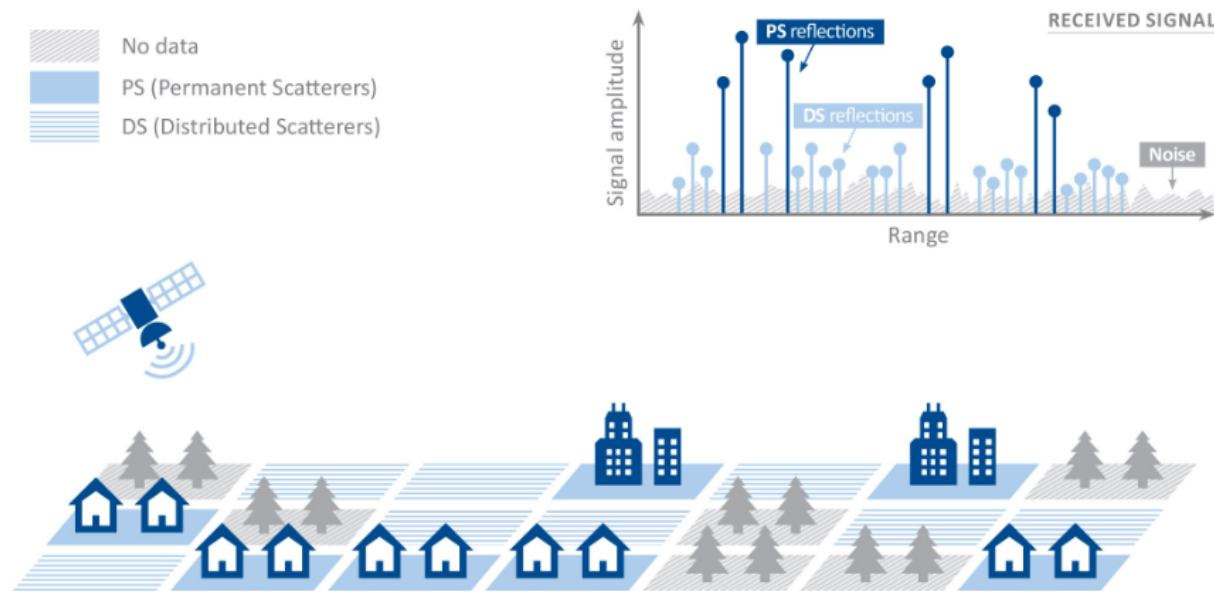
$\phi_{orb,x,i}$: orbit effect

$\phi_{\varepsilon,x,i}$: DEM residual effect

$n_{x,i}$: noise



Algorithms: PS + DS + more



SqueeSAR[®] is the only algorithm that we offer to clients, providing a significantly increased coverage of ground points, especially over non-urban areas. As it was standard with the previous PSInSAR[™] algorithm, SqueeSAR[®] continues to identify PS but it also exploits spatially distributed scatterers (DS). Whilst PS usually correspond to man-made objects, DS are typically identified from homogeneous ground, scattered outcrops, debris flows, non-cultivated lands and desert areas.

<https://site.tre-altamira.com/insar/>

Long-wavelength atmospheric delay

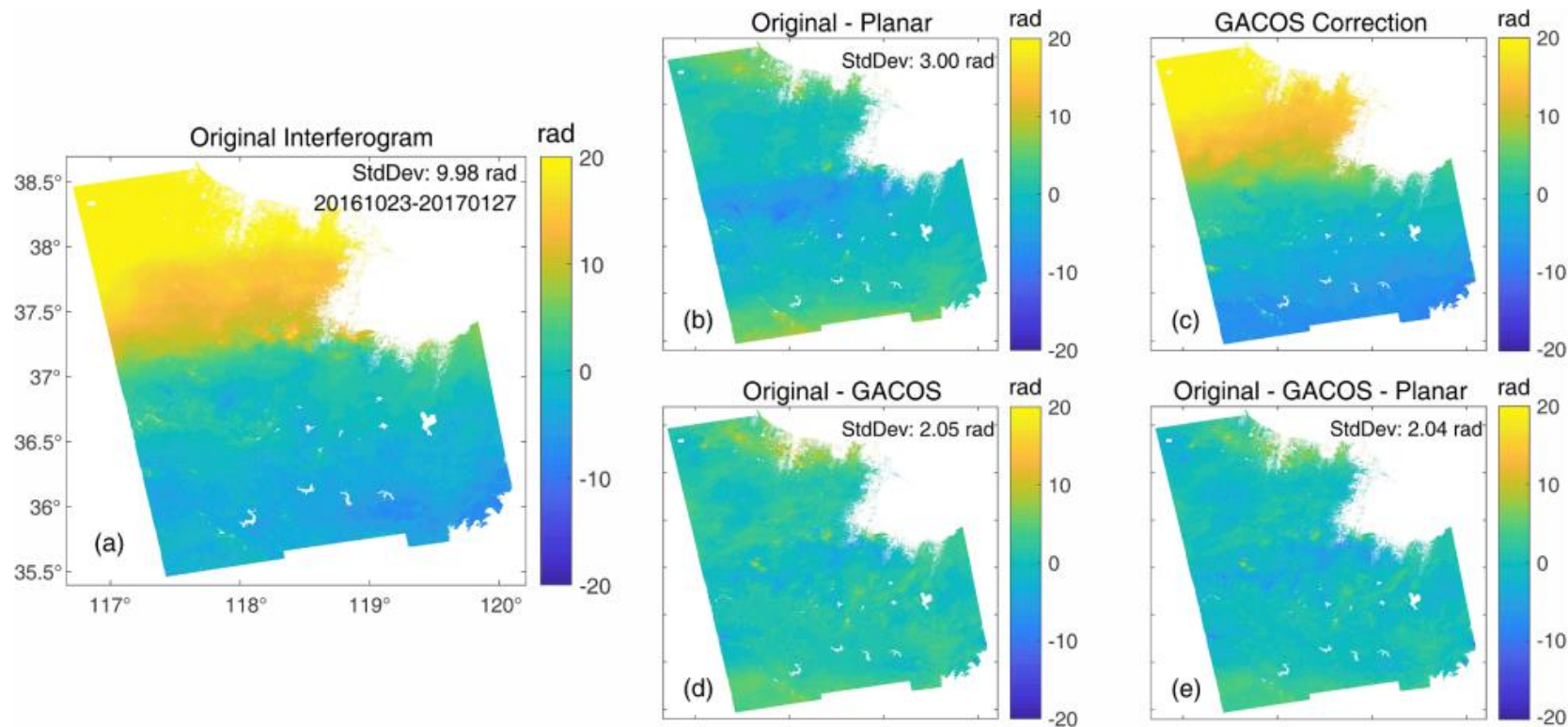
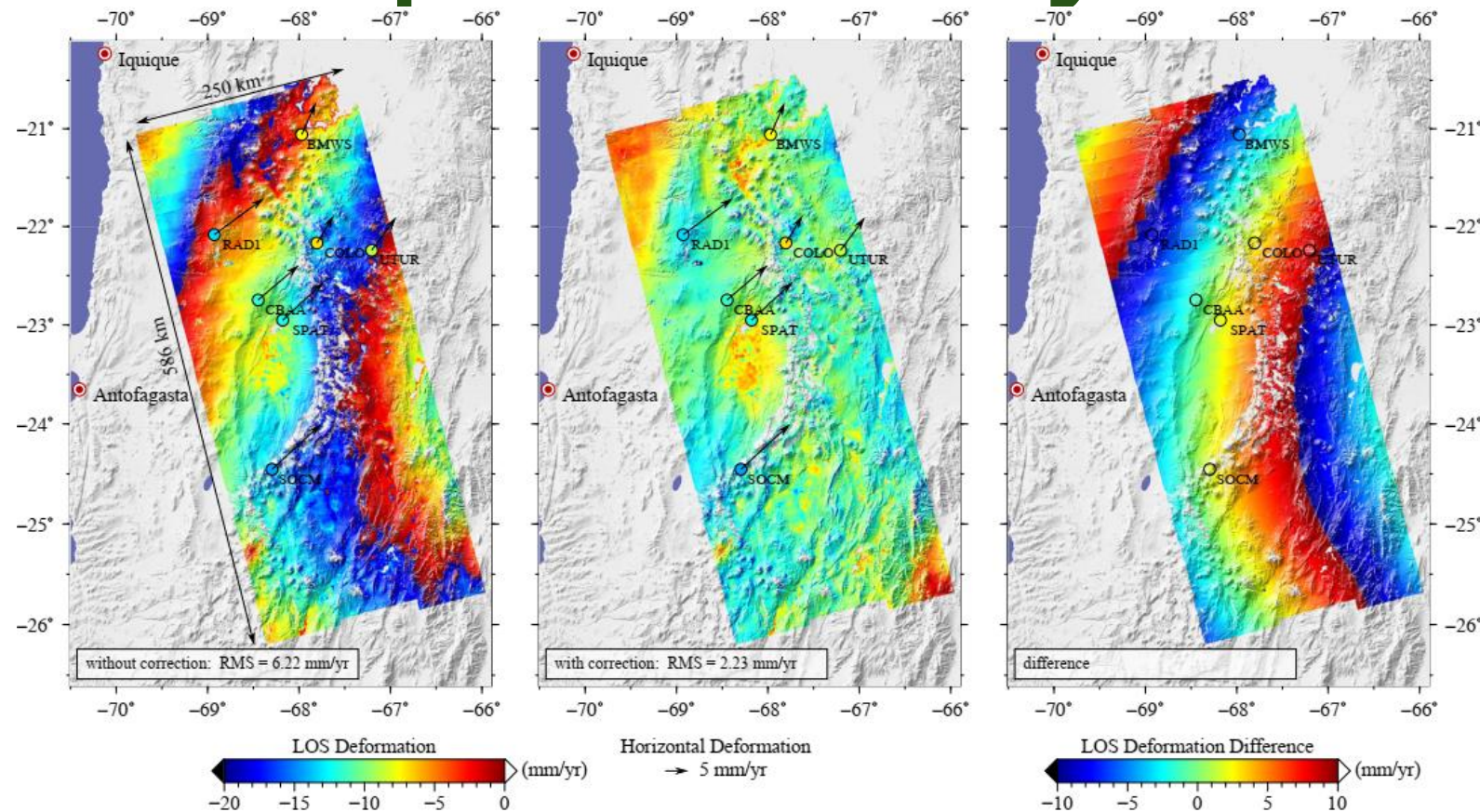


Fig. 3. Example of the interferogram 20161023–20170127 before (a) and after correction (b, d, e). (c) is the GACOS correction.

- GACOS
(Yu et al., 2018)
- Limited performance for region smaller than 75 km (Murray et al., 2019).

Ionospheric delay



- Ionospheric delay accumulated as long wavelength pattern.
- Take more bursts to form reliable computation.

Fig. 17. Same as Fig. 15. Track A149 in northern Chile (low-latitudes). Note that the data in the first and third panels at bottom are wrapped before plotting.

(Liang et al., 2019)

Ocean Tidal Loading

- Largest M2 (Lunar semi-diurnal tide) tidal deformation only 2.7 mm at FALI station in PingTung (Yeh et al., 2011).
- Assuming constant or simple trend surface in SW Taiwan.

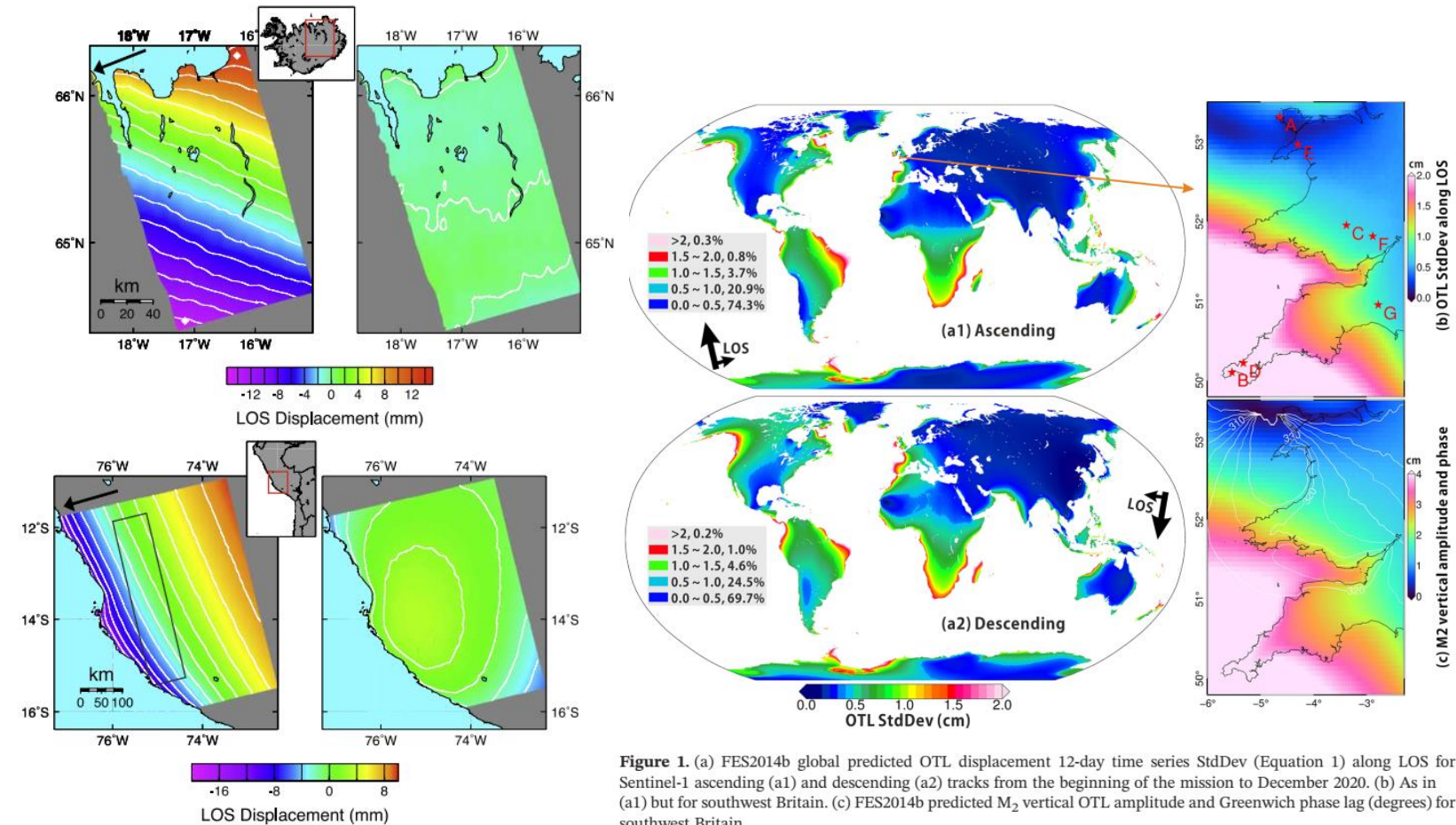


Figure 1. (a) FES2014b global predicted OTL displacement 12-day time series StdDev (Equation 1) along LOS for Sentinel-1 ascending (a1) and descending (a2) tracks from the beginning of the mission to December 2020. (b) As in (a1) but for southwest Britain. (c) FES2014b predicted M₂ vertical OTL amplitude and Greenwich phase lag (degrees) for southwest Britain.

(DiCaprio & Simons, 2008)

(Yu et al., 2020)

Solid Earth Tides

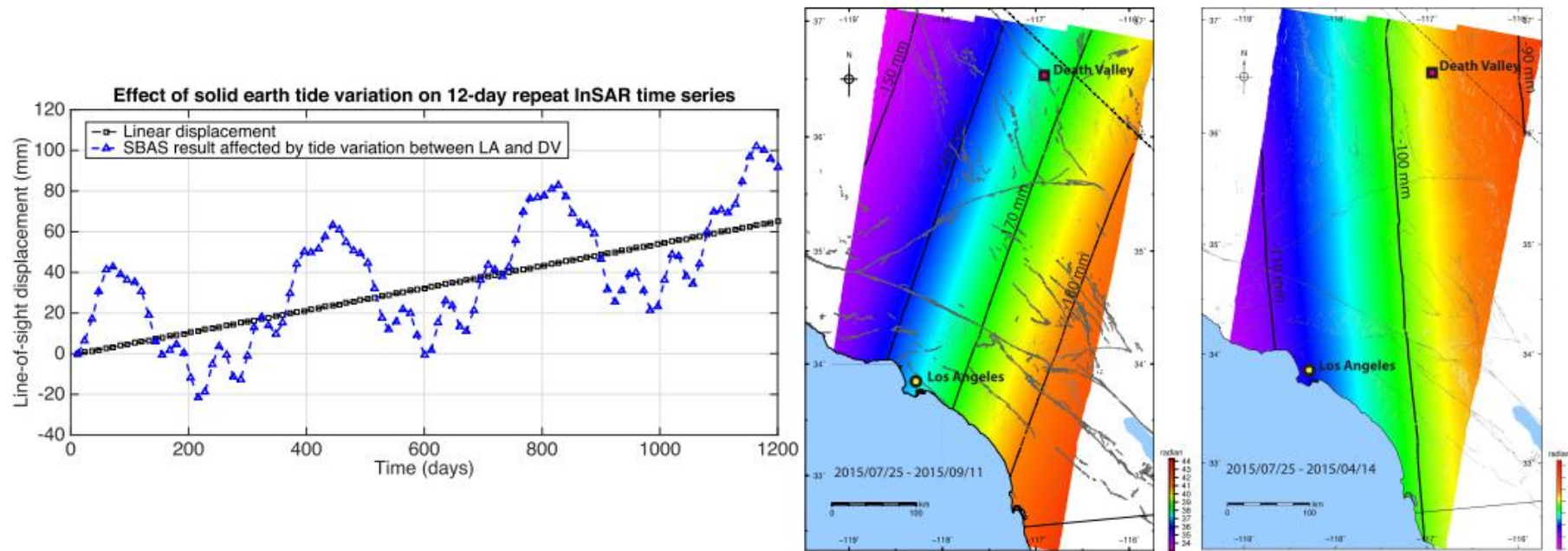
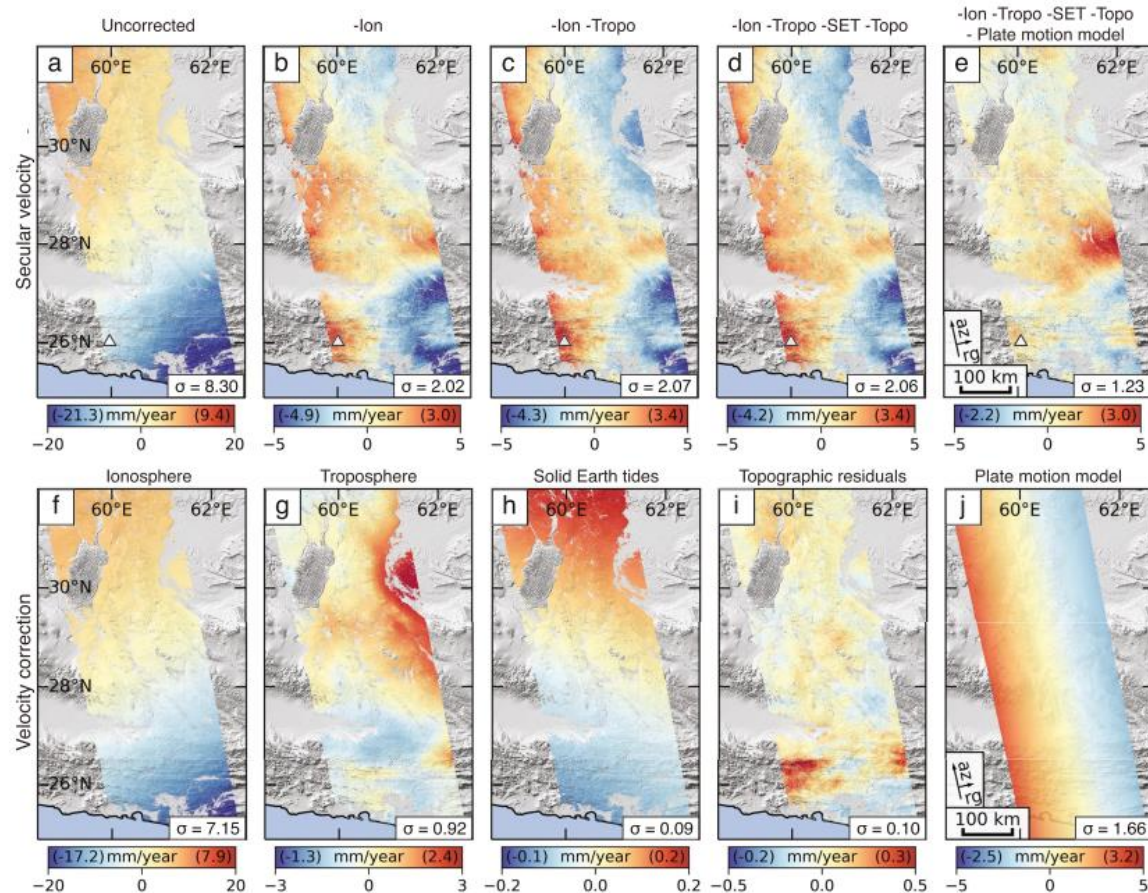


Fig. 3. (Left) SBAS time series from 3-year of InSAR acquisitions at 12-day sampling and a 60-day window for interferogram formation. This represents the difference in tidal displacement between Los Angeles and Death Valley (300 km) as a function of time. Black curve: assumed underlying linear trend. Blue curve: recovery when the solid earth tide is not corrected. (Middle and Right) Solid earth tide phase/displacement for two Sentinel-1 TOPS interferograms (July 25, 2015–September 11, 2015 and July 25, 2015–April 14, 2015).

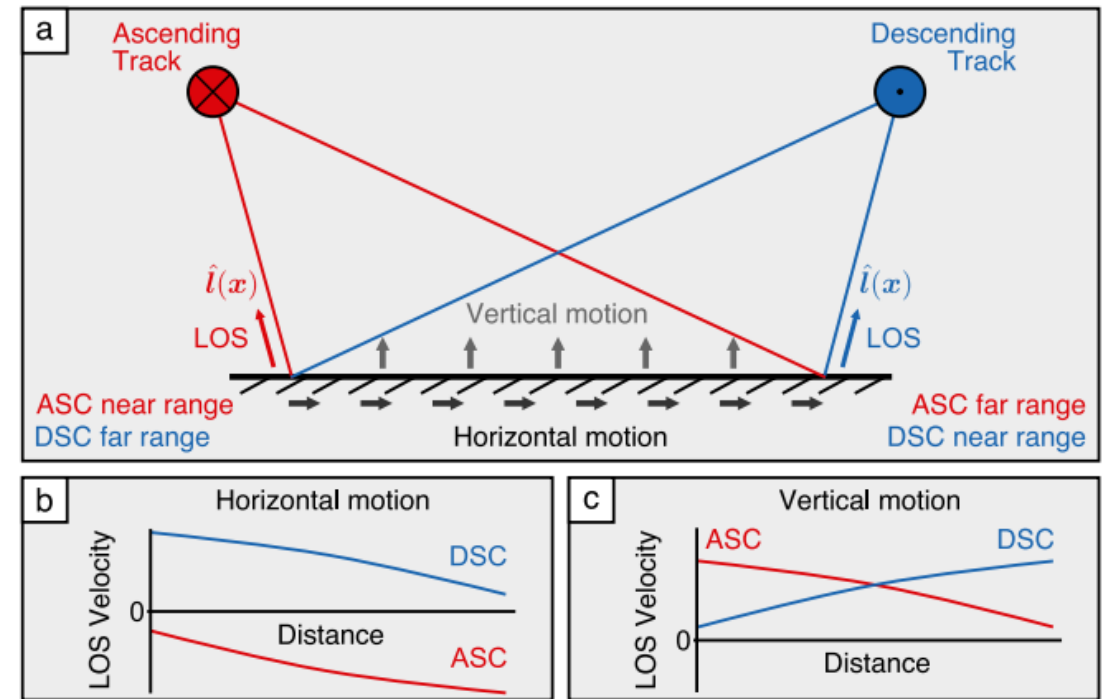
- Absolute tides:
~ 10 mm
- Relative Tide:
Along-range
and along-track,
~ 30 mm.

(Xu & Sandwell, 2020)

Plate Motion

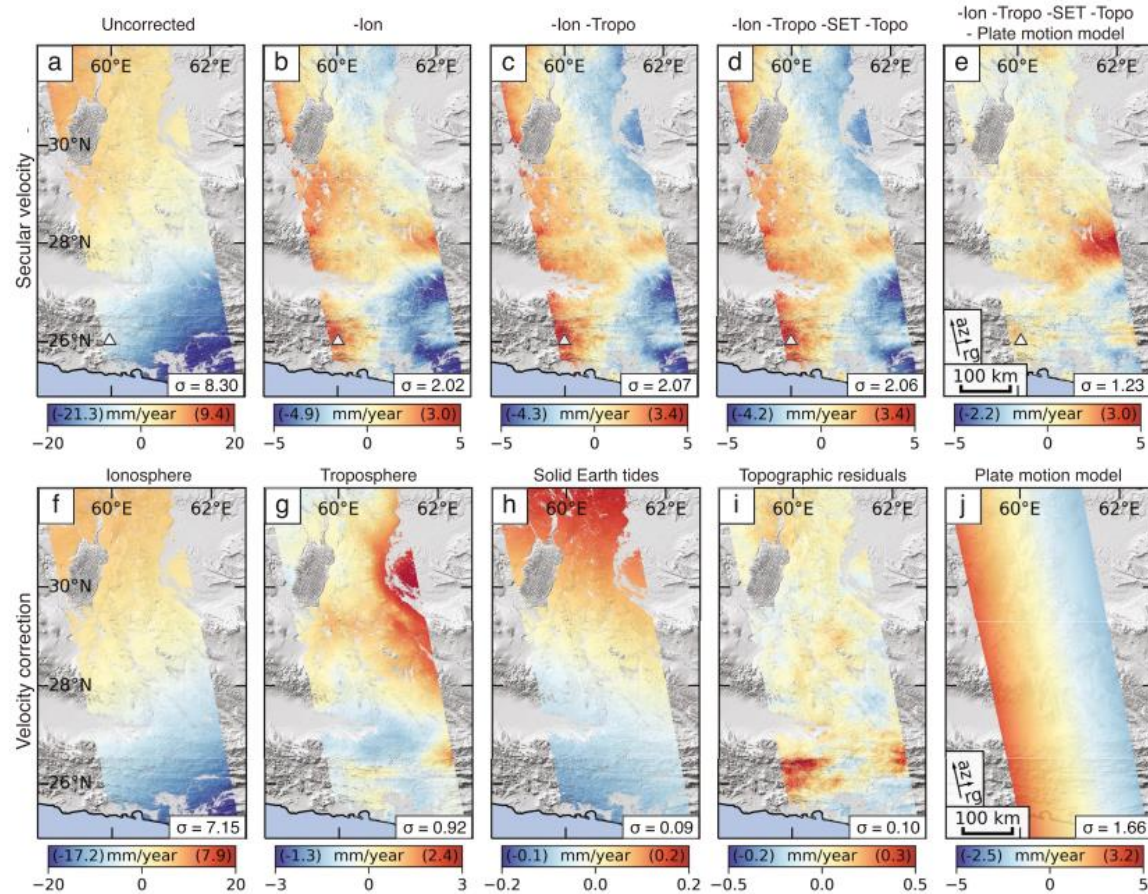


(Stephenson et al., 2022)

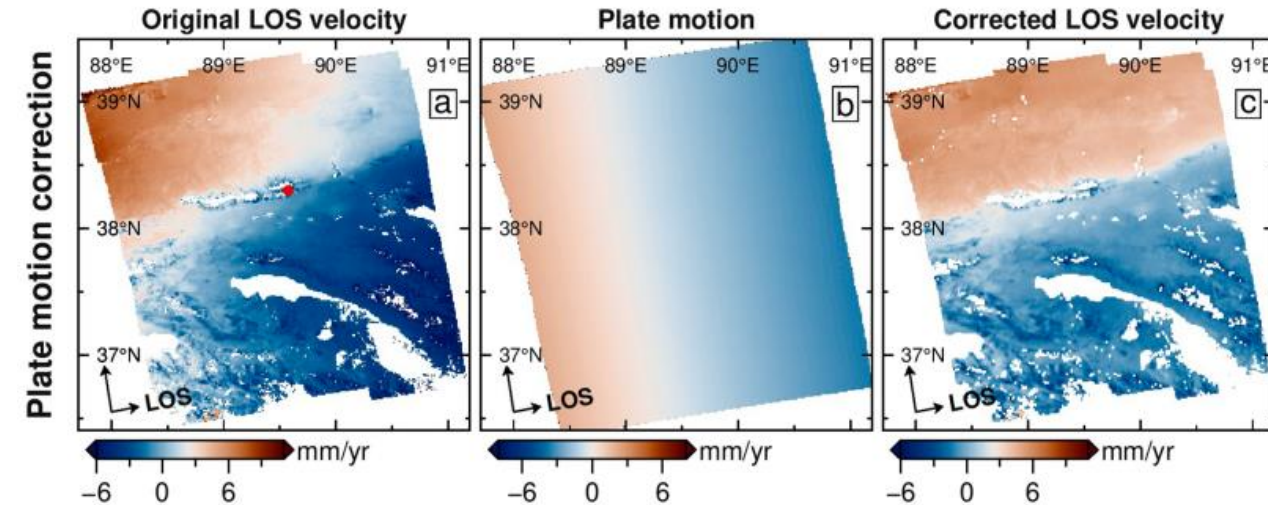


- Along-range
- With Sentinel-1's 250 km width, resulting 1 to 5 mm/yr in velocity field (Wang et al., 2024).

Plate Motion



(Stephenson et al., 2022)



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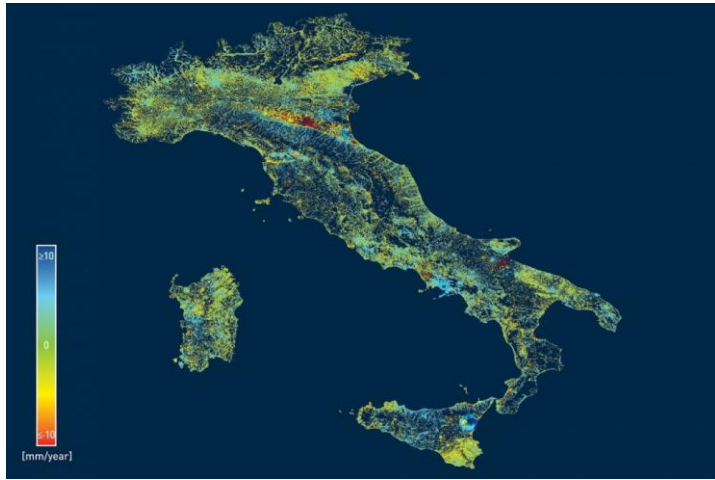


The rise of Ground Motion Services

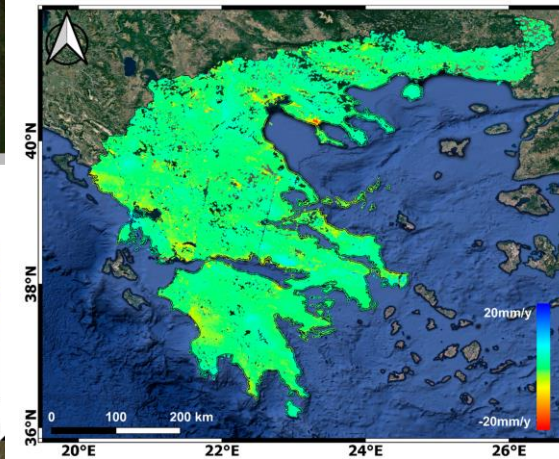
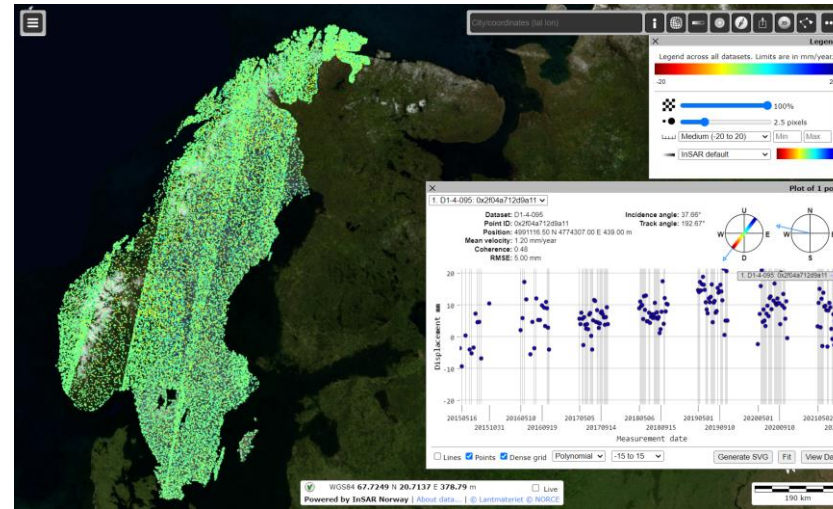
- 1. InSAR Norway leads the first dance (2018)**
- 2. But Italy was already on the way (2008).**
- 3. ALL GMS and EGMS**
- 4. US and Japan**
- 5. Taiwan**



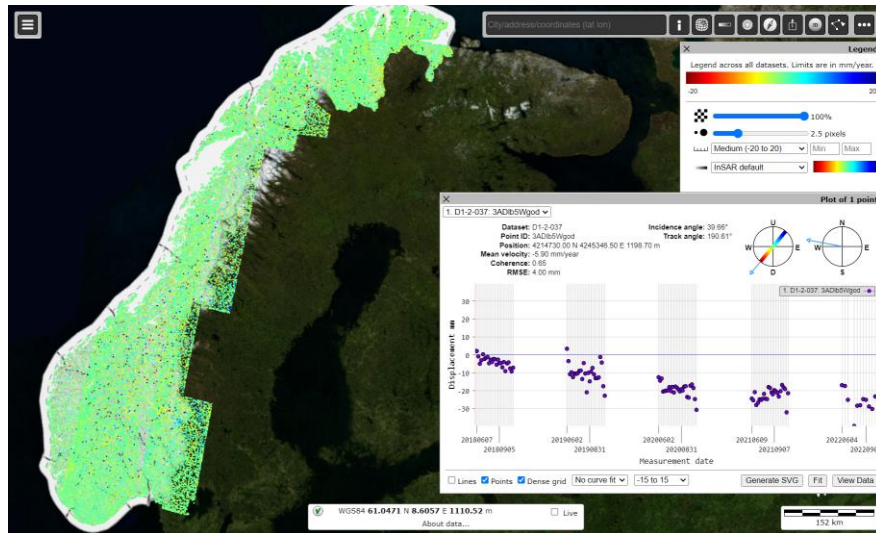
2017: Italian InSAR nationwide monitoring (TRE)



2020: InSAR Sweden, InSAR Greece.

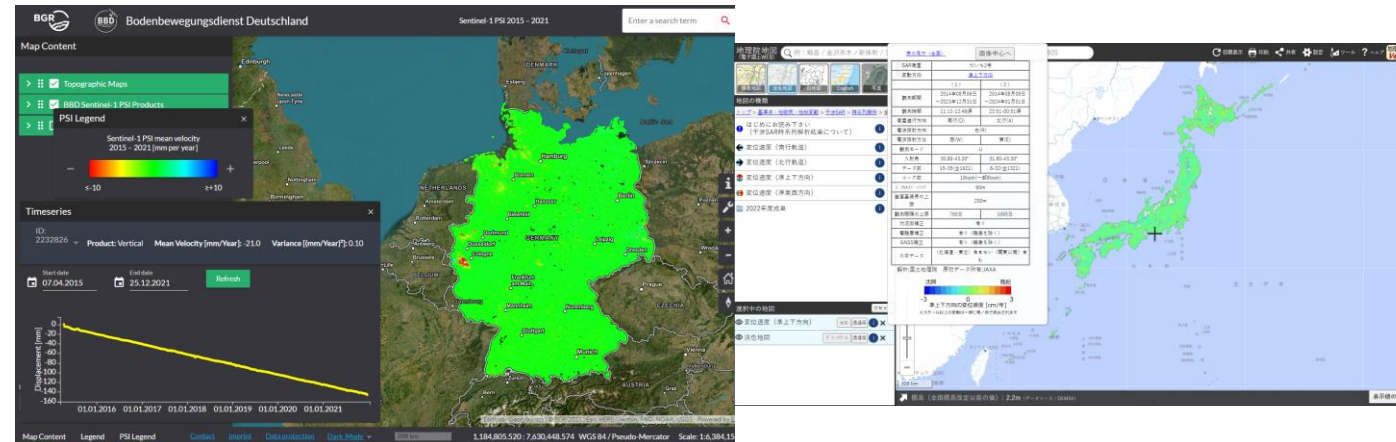


2018: InSAR Norway



2021: Germany's BBD Sentinel-1 PSI Products

2021: Japan's GSI Maps with Sentinel-1, ALOS1, ALOS2 InSAR.

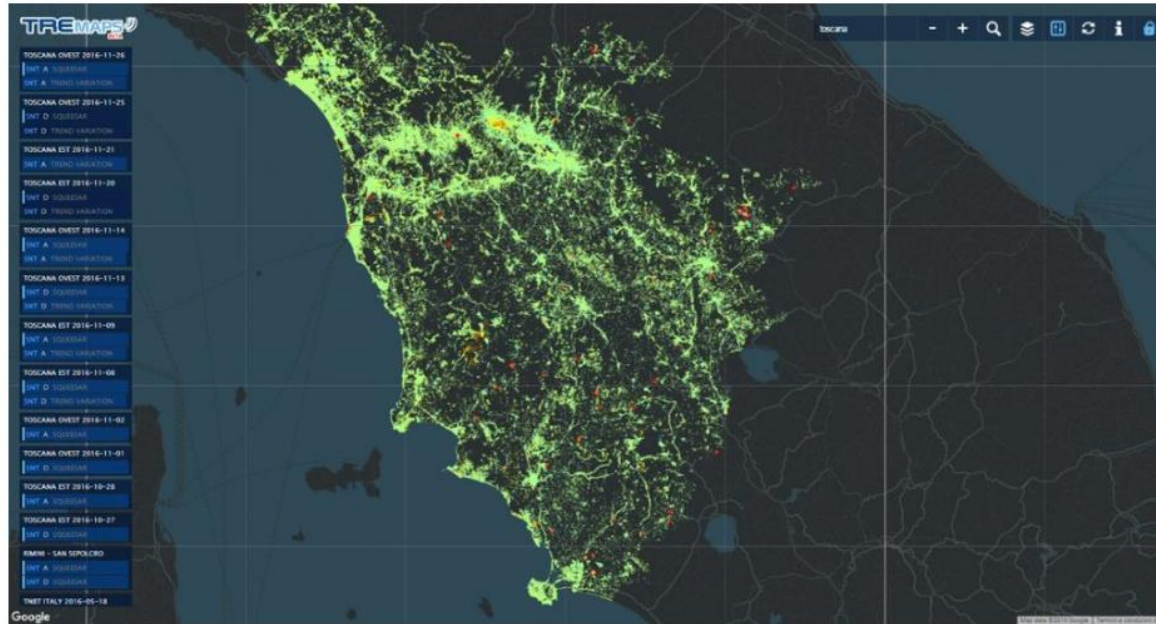




先行者：義大利的環境遙測特別計畫 (PST-A)

- 2008開始整合ERS, Envisat 及 COSMO-SkyMed 數據。
- 早期主要供政府內部使用，非完全開放下載。
- 衍生出區域級服務（如 Tuscany, Veneto），提供近即時監測與異常點偵測。
- 應用：滑坡目錄更新、基礎設施監測

and national scale. Up-to-date displacement information is routinely provided to clients relying on our advanced satellite InSAR technique (SqueeSAR®), our broad computing capacity and free access to timely Sentinel-1 images.



SqueeSAR® analysis over Tuscany (IT) using Sentinel-1 imagery.

[Environment](#)[Environmental stability](#)[Esa](#)[Europe](#)[European Ground Motion Service](#)[European program](#)[Failure analysis](#)[Flooding](#)[France](#)[Geohazard](#)[Geothermal](#)[Germany](#)[Ground deformation](#)[Ground displacement](#)[Ground monitoring](#)[Ground motion](#)[Ground stability](#)[Ground surface](#)[Hampton Roads](#)[Heavy oil](#)[High resolution](#)[Himalaya](#)[Hydropower plant](#)[India](#)[Infrastructure](#)[InSAR](#)[InSAR data](#)[InSAR monitoring](#)[Instability](#)[International celebration](#)[Interreg](#)[IRIDE](#)[Italian region](#)[Landslide](#)[Large scale](#)[Linear infrastructure](#)

<https://site.tre-altamira.com/insar-nationwide-monitoring-the-italian-case/>

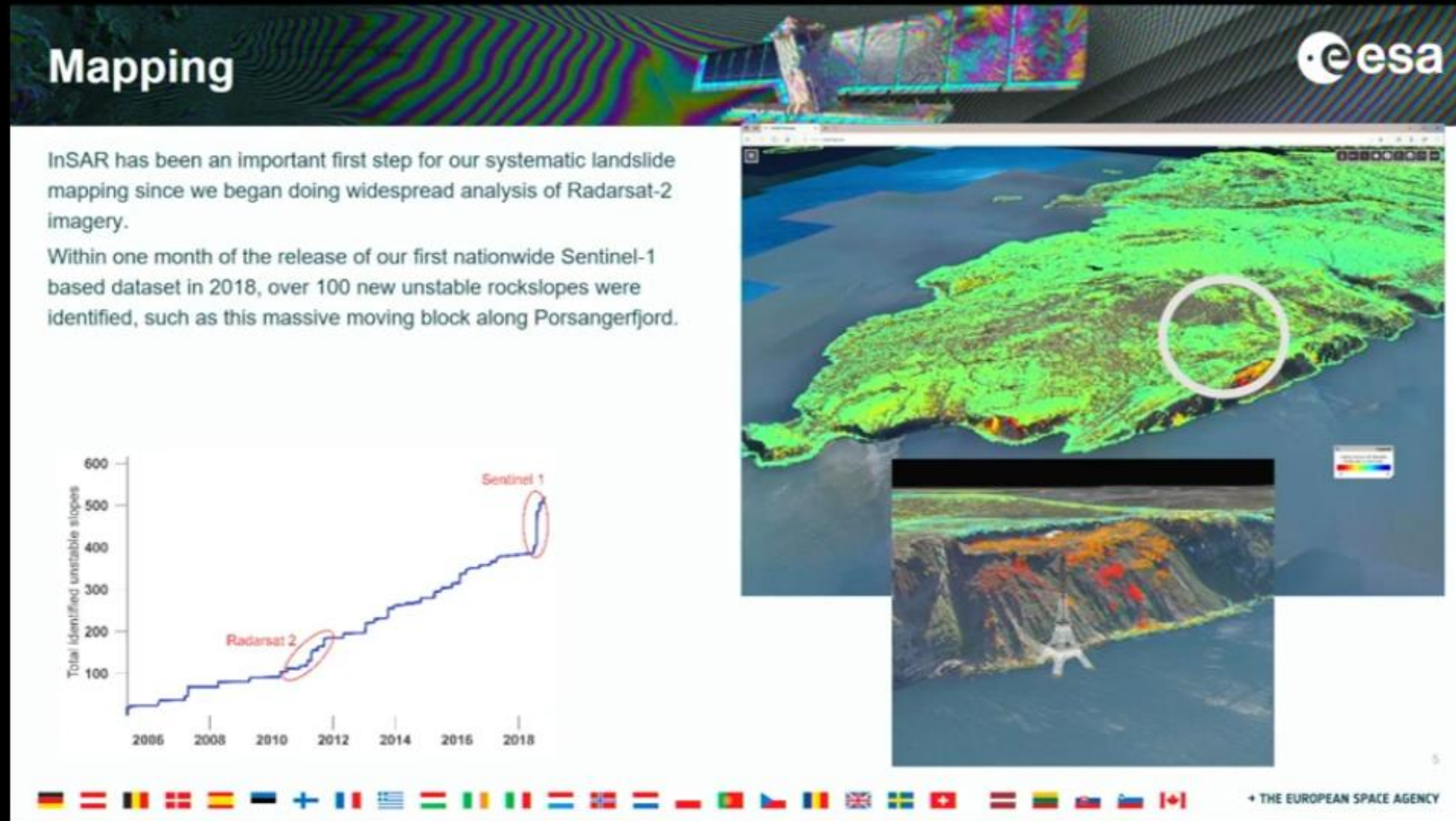


開放資料典範：InSAR Norway (挪威)

- 2018 年上線，首個對公眾完全免費開放的國家級服務。
- 技術特點：針對複雜地形與長積雪期優化（僅處理 6-10 月影像）。

全解析度處理，使用 PSI 技術。

- 更新滑坡與岩崩清冊 (Rockslides/Rock Glaciers)。發現超過 100 處新的潛在不穩定岩坡。
- 提供 WebGIS 瀏覽、單點時間序列下載及 API 介接。



<https://www.youtube.com/watch?v=fzb4uF0BmJc>

Corner reflectors – Operational landslide monitoring



At all high-risk sites, and numerous others, we have installed networks of corner reflectors that stand above the snow, to get InSAR data during the winter months.

More than 120 reflectors are now in use at over 25 locations.



• THE EUROPEAN SPACE AGENCY



<https://www.youtube.com/watch?v=fzb4uF0BmJc>

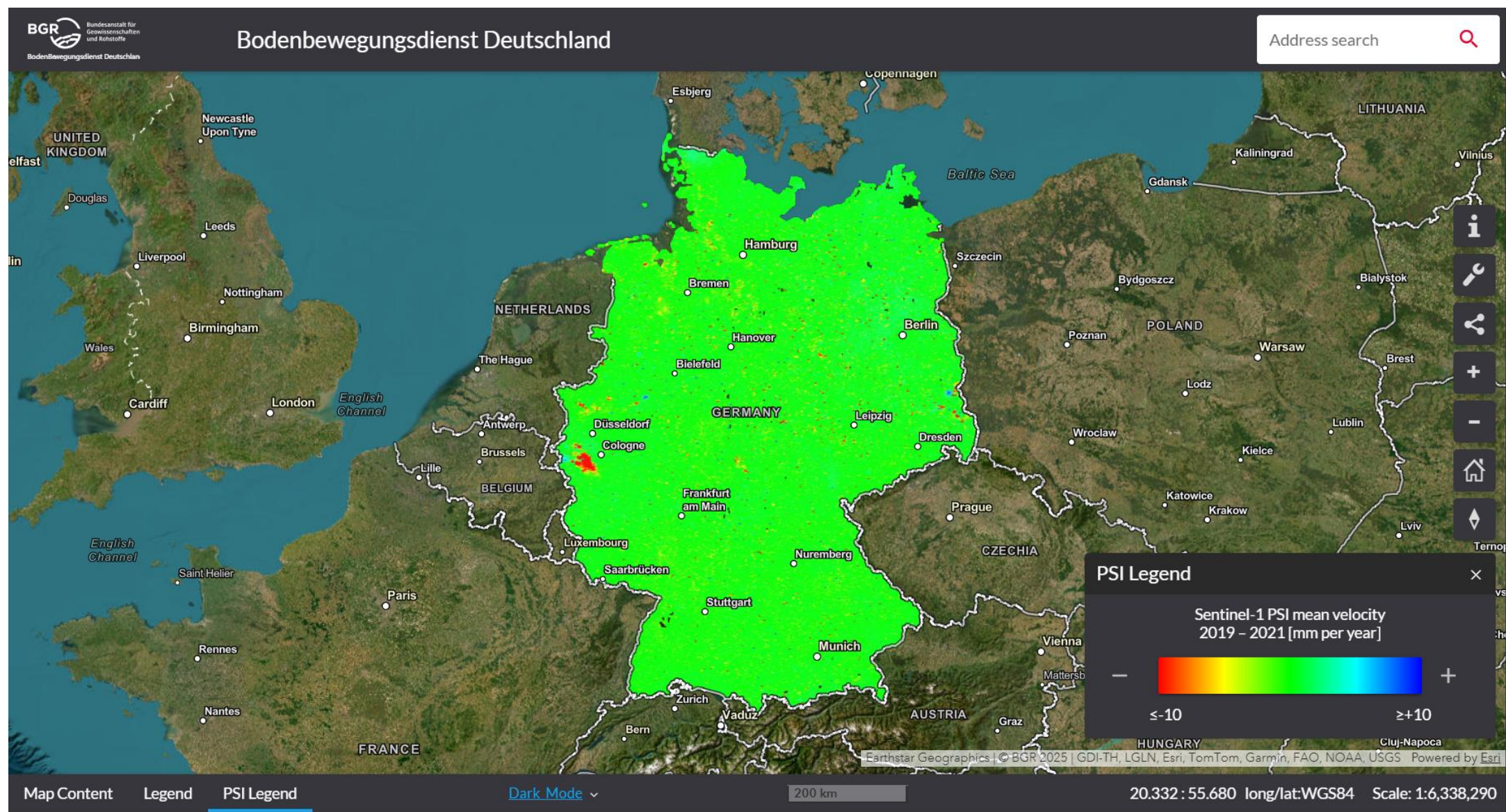


<https://www.youtube.com/watch?v=fzb4uF0BmJc>

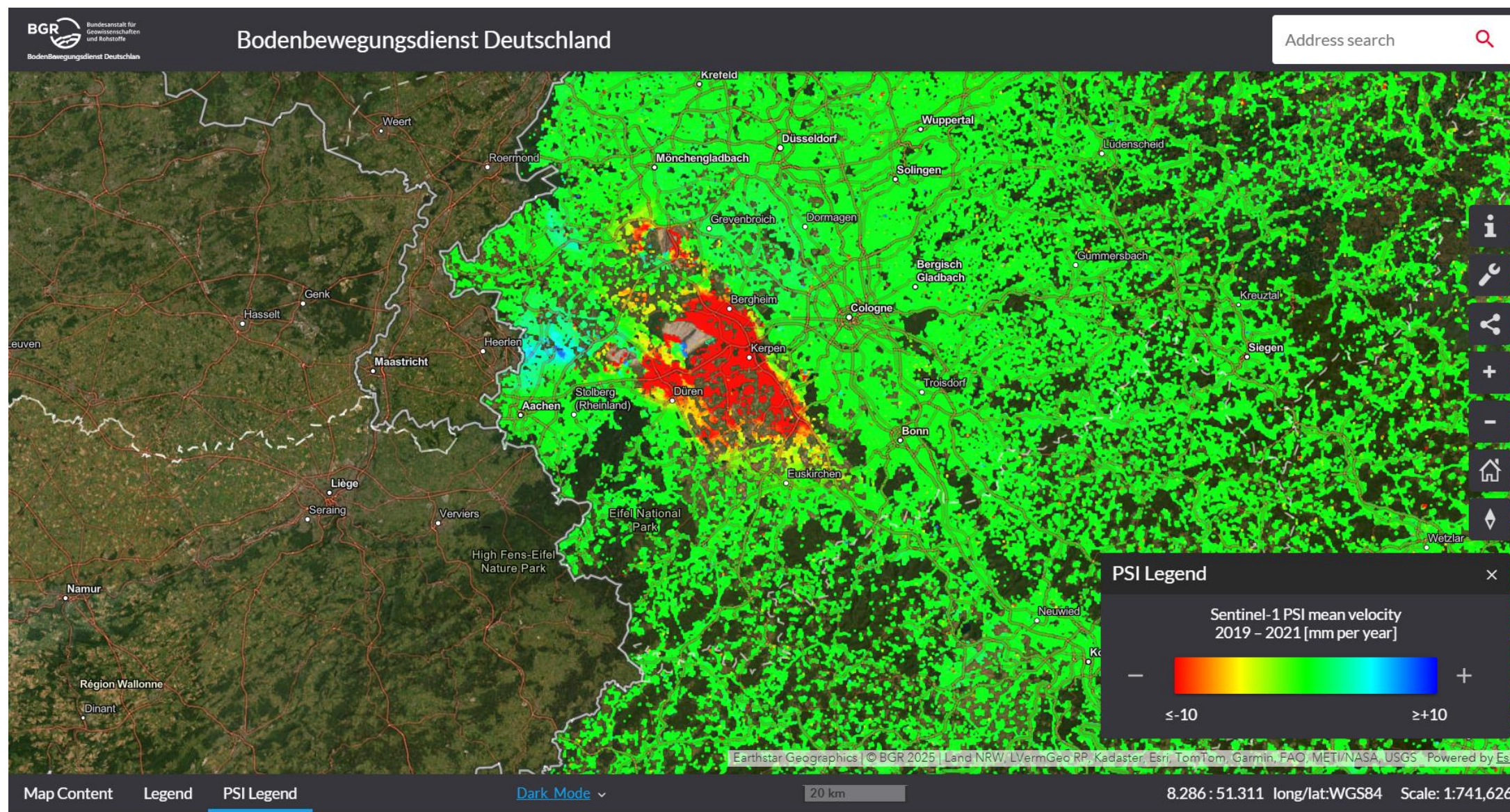


精確校正：德國地表運動服務 (BBD)

- 2019 年發布。
- 結合數值天氣預報模型減輕大氣效應。
- GNSS 校正：利用全國 SAPOS GNSS 網絡進行絕對速度校正，確保大地測量級的精度。
- 服務模式：免費開放，支援 400 平方公里內的數據下載。
- 採礦沈陷監測 (如 Hambach 礦區)、城市沈降。
- Spreckels V (2022) Status of the new German DIN standards project "InSAR - Radarinterferometry for the detection of ground movements"



<https://bodenbewegungsdienst.bgr.de/mapapps/resources/apps/bbd/index.html?lang=en>



<https://bodenbewegungsdienst.bgr.de/mapapps/resources/apps/bbd/index.html?lang=en>



基礎設施關注：荷蘭

- 2020上線，免費。
- 關注地表沉陷與水資源管理。
- 產品分級：Level 2 (測點)、Level 3 (網格化與物件化，如橋樑、堤防)。
- 嚴格的品質控制與 GNSS/水準測量驗證。
- Surface motion map 1.0
- Surface and object motion (SOM) map 2.0

Nieuw in deze update

Dekking omvat nu ook België en Luxemburg en loopt van oktober 2017 tot en met oktober 2022. De data uit de vorige versie is niet meer publiek toegankelijk. Voor vragen of opmerkingen kunt u [contact met ons opnemen](#).

Wat toont bodemdalingskaart 2.0?

We tonen de geschatte bewegingssnelheid van miljoenen InSAR meetpunten, waar in kleur de verzakking is aangegeven. De kleurenschaal kan worden ingesteld om meer detail te kunnen zien. Door op een meetpunt te klikken verschijnt het tijdsverloop van de verplaatsing van dat punt van oktober 2017 tot en met oktober 2022.

Welke kaartlagen zijn er?

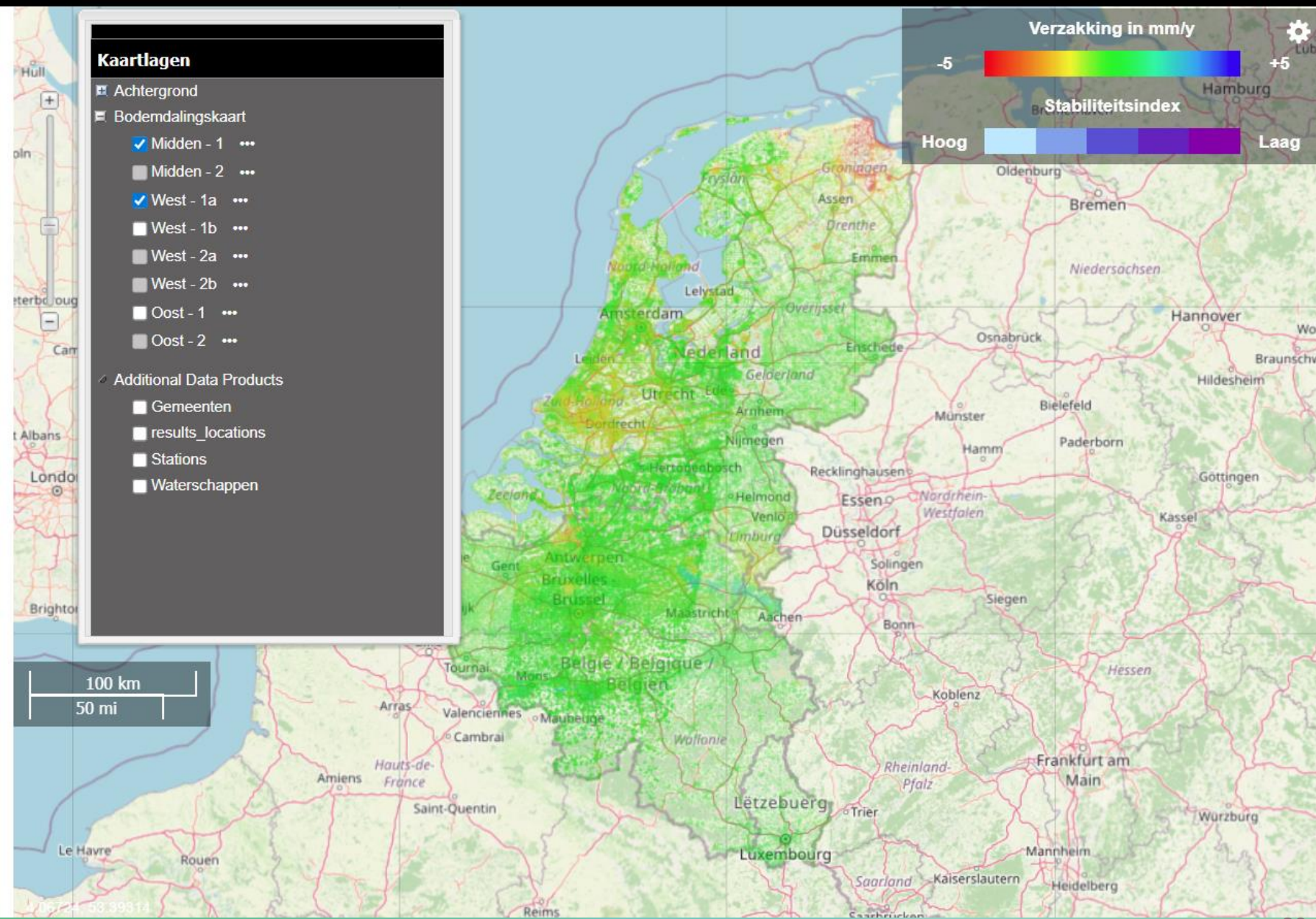
De satellietradar bekijkt Nederland vanuit zes verschillende posities in de ruimte. De bijbehorende kaartlagen heten West, Midden en Oost. Door de verschillende posities van de satelliet worden steeds andere meetpunten gevonden. Hierdoor kan er mogelijk ook tegenspraak ontstaan.

Hoe is de kaart gemaakt?

SkyGeo heeft de kaart geproduceerd door complexe radargegevens van satellieten te verwerken. De InSAR gegevens in de bodemdalingskaart zijn *schattingen* van verplaatsing waarbij verschillende aannames zijn gedaan.

JA IK MELD ME AAN VOOR TOEGANG TOT EEN
INSAR KAART MET MEER FEATURES EN DATA VOOR
CIVIEL TECHNISCH WERK

Voor toepassingen in de civieltechnische praktijk kun je na aanmelden verder inzoomen en meer recente data zien, in een betere viewer. We stemmen de InSAR verwerkingswijze altijd af op de toepassing en op beschikbare andere gegevens. Dat was in deze



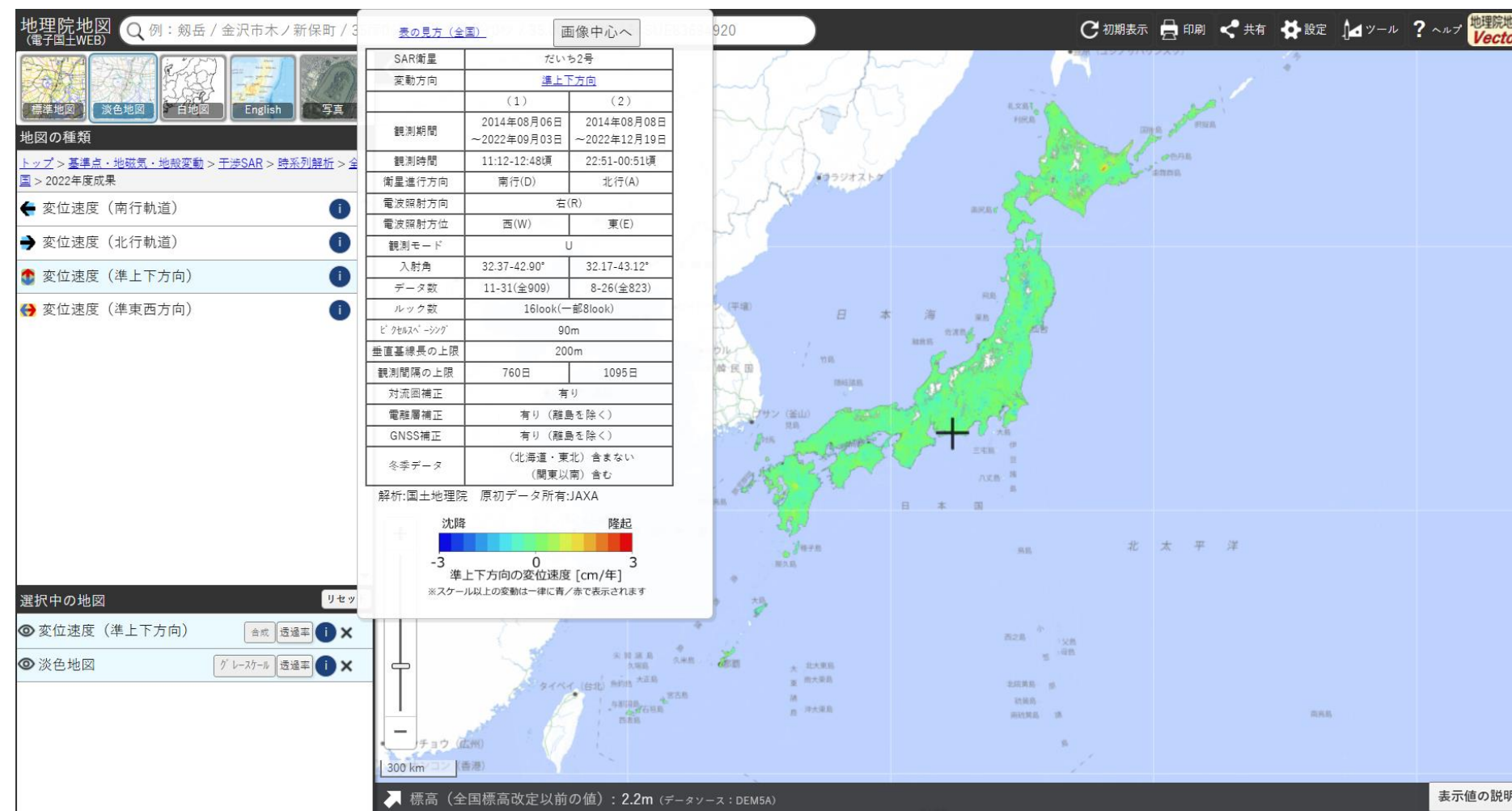


基礎設施關注：丹麥

- 結合商業SqueeSAR 技術 (PSI + DSI)。
- 經GNSS校正
- PS + DS的異常值熱點偵測
- 提供垂直與水平分量分解產品，並校正冰後回彈模型。



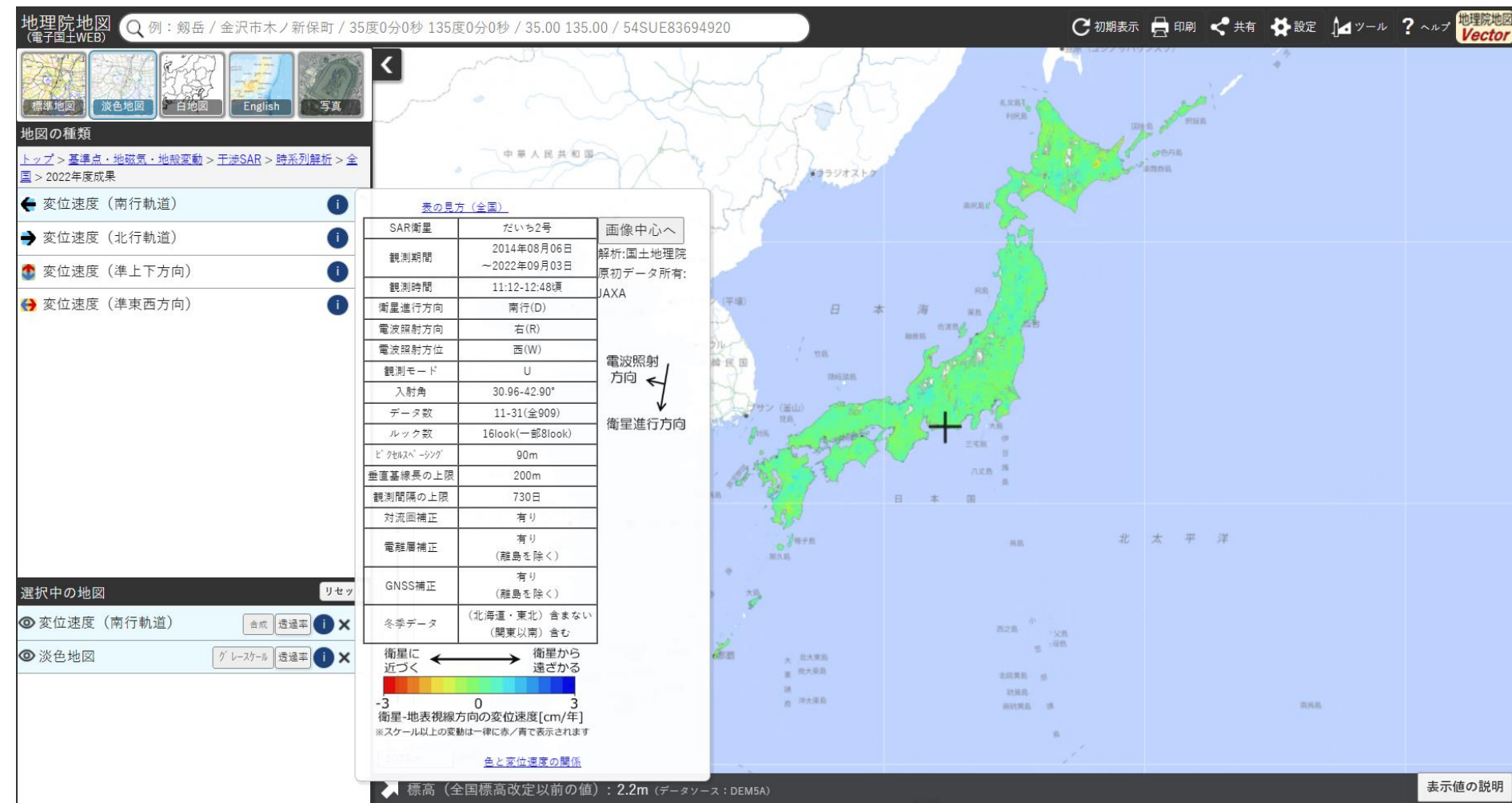
日本國土地地理院 GSI Map



- ALOS-2
- GNSS



日本國土地地理院 GSI Map



- ALOS-2
- GNSS



美國 ARIA-OPERA project



Jet Propulsion Laboratory
California Institute of Technology

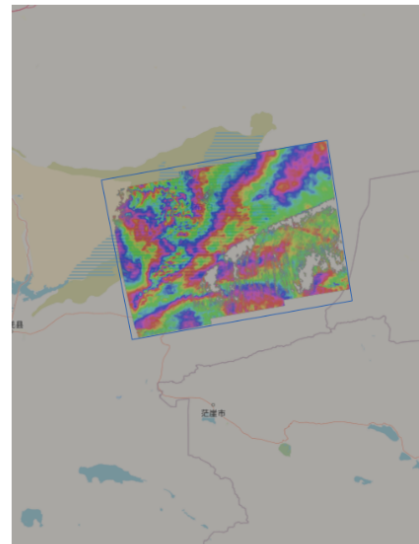
Home About Products Media Publications

Overview

Below is a schematic showing what Level 2 (L2) and Level 3 (L3) data sets are available. Available products are in [blue](#), and clicking on them will take you to additional information about the product specifications and background.

Product	Science Products		Urgent Response Products
	InSAR	GPS	SAR
Level 2	Standard Displacement Products	PS Time-Series	
Level 3	Time Series		Damage Proxy Maps (DPM)
	Coseismic	GPS Coseismic Offsets	Flood Proxy Maps (FPM)

Science Data Products



InSAR standard data products are currently searchable and downloadable through the ARIA Product Search website.

Urgent Response Products



- NISAR
- Sentinel-1
- On ASF now.



美國 ARIA-OPERA project

The screenshot displays the EarthData ASF Data Search Vertex web application. The top navigation bar includes the EarthData logo, a search bar, and links for Feedback, On Demand, Downloads, Help, English, and Sign In. The search filters are set to Geographic Search, Dataset OPERA-S1, and Area of Interest POLYGON((-492.3833 15. ...). The map view shows the United States with a blue polygon highlighting a region in the Pacific Northwest. The bottom panel shows a list of search results, including OPERA_L2_RTC-S... v1.0 and OPERA_L2_RTC-S... v1.0, with details for each scene and file.

Search Type: Geographic Search | Dataset: OPERA-S1 | Area of Interest: WKT POLYGON((-492.3833 15. ... | Filters: ... | SEARCH | 250 of 12,035,626 Files

Map View | Zoom | Layers | Area Of Interest | Opacity | 100% | lat 47.6844° lon -82.5387° | 500 km

250 Scenes | Zoom | Queue | Scene Detail | 5 Files

250 (1000 additional) of 12,035,626 Files

OPERA_L2_RTC-S... v1.0
February 2, 2026, 14:01:35Z

OPERA_L2_RTC-S... v1.0
February 2, 2026, 14:01:34Z

OPERA_L2_RTC-S1_T144-308041-IW3_20260202T140135Z_20260202T201843Z_S1A_30_v1.0
OPERA-S1 • C-Band

SEARCH: Baseline SBAS Source Data

HDF5 | VV GeoTIFF



國家 / 地區	服務名稱	政府主管機關	執行單位 / 民間公司	啟動 / 發布時間	使用的衛星資料	備註
歐洲 (EU)	歐洲地表運動服務 (EGMS)	歐洲環境署 (EEA)	ORIGINAL聯盟 (包含 e-GEOS, TRE Altamira, NORCE, GAF)	2021	Sentinel-1	涵蓋哥白尼計畫參與國，提供三級產品，由多國技術團隊聯合執行。
義大利	環境遙感特別計畫 (PST-A)	義大利環境部 (Ministry of the Environment)	e-GEOS、CNR-IREA (國家研究委員會) 等	2008	ERS-1/2, Envisat, COSMO-SkyMed	全球首個國家級服務，早期主要供政府內部使用，結合了歷史數據與高解析度X波段數據。
挪威	InSAR Norway	挪威地質調查局 (NGU)、水資源與能源局 (NVE)、挪威太空中心 (NSC)	NORCE (挪威研究中心)、PPO.labs	2018	Sentinel-1, Radarsat-2	全球首個向公眾完全免費開放的國家級服務，Radarsat-2 用於部分歷史或特定高風險區分析。
德國	德國地表運動服務 (BBD)	聯邦地質與自然資源研究所 (BGR)	德國航太中心 (DLR)	2019	Sentinel-1	結合數值天氣模型與GNSS校正，資料處理外包給國家航太研究機構。
丹麥	丹麥地表運動監測服務	資料供應與效率局 (SDFE)	TRE Altamira (義大利私人遙測公司)	2018	Sentinel-1	由政府發包給民間公司處理，提供垂直與水平分量產品。
荷蘭	荷蘭地表運動服務 (Bodemdalingskaart)	荷蘭大地測量與地理資訊中心 (NGC)	SkyGeo、Sensor 等私人公司	2020	Sentinel-1	關注軟土沉降，透過公開招標由民間企業提供技術服務。
希臘	InSAR Greece	雅典國家天文台 (NOA)	BEYOND 地球觀測研究中心	2020	Sentinel-1	屬科研計畫成果，利用平行運算處理大量數據。
瑞典	InSAR Sweden	瑞典國家太空局 (SNSA)、瑞典測繪地籍局 (Lantmäteriet)	挪威地質調查局 (NGU)、NORCE、PPO.labs	2023	Sentinel-1	採跨國合作模式，由挪威團隊協助建置，並結合角反射器校準。
匈牙利	InSAR.Hungary	Lechner Non-profit Ltd (國有企業)	衛星大地觀測站 (SGO)	2023	Sentinel-1	由政府下轄的測繪研發機構執行，整合GNSS速度場模型。
羅馬尼亞	羅馬尼亞地表形變監測	目前無官方主管機關，屬私營計畫	TERRASIGNA (私人遙測公司)	2021	Sentinel-1	目前為商業/私營性質，填補國家級服務空白，非官方公共服務。
美國	OPERA 地表位移產品 (DISP)	NASA、USGS (響應聯邦SNWG需求)	NASA 噴氣推進實驗室 (JPL)	2023	Sentinel-1, NISAR	由國家級實驗室主導開發，整合現有C波段與未來L波段衛星數據。
日本	全國InSAR監測計畫	國土地理院 (GSI)	JAXA (提供衛星數據與技術支援)	2014	ALOS, ALOS-2, Sentinel-1	利用日本自主的L波段衛星優勢穿透植被，並結合Sentinel-1進行長時序分析。
中國	全國InSAR地表形變監測	中國科學院、中國地質調查局 (CGS)	中科院空天信息創新研究院 (AIR) 等	2020	Sentinel-1, 高分系列 (Gaofen)	基於超算系統進行科研與工程應用，雖然擁有自主高分衛星，但全境製圖仍大量使用Sentinel-1數據。

GMS的問題

Q1: 這些 InSAR 資料平台不定期更新，那它能用於「即時」災害預警嗎？

Q2: 這些 GMS 系統看起來很昂貴，它們的商業價值或對一般大眾的益處是什麼？

Q3: 既然已經有高精度的 GNSS (GPS)，為什麼還需要發展國家級的 InSAR GMS？兩者有何不同？

Q4: InSAR 可以達到毫米級精度，但為什麼在山區或植被茂密的地方地圖上會出現「空白」？

GMS的問題

Q1: 這些 InSAR 資料平台不定期更新，那它能用於「即時」災害預警嗎？

A: 目前不能，以數天間隔的監測

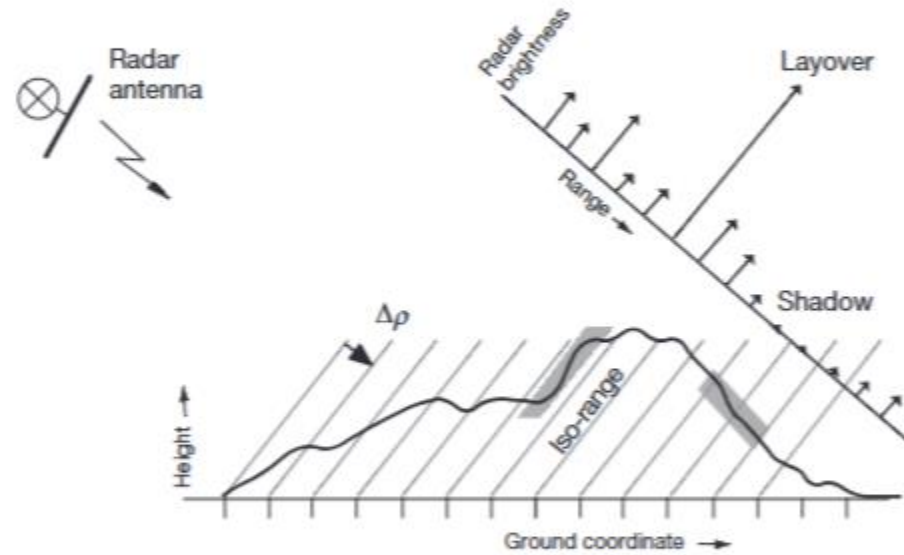
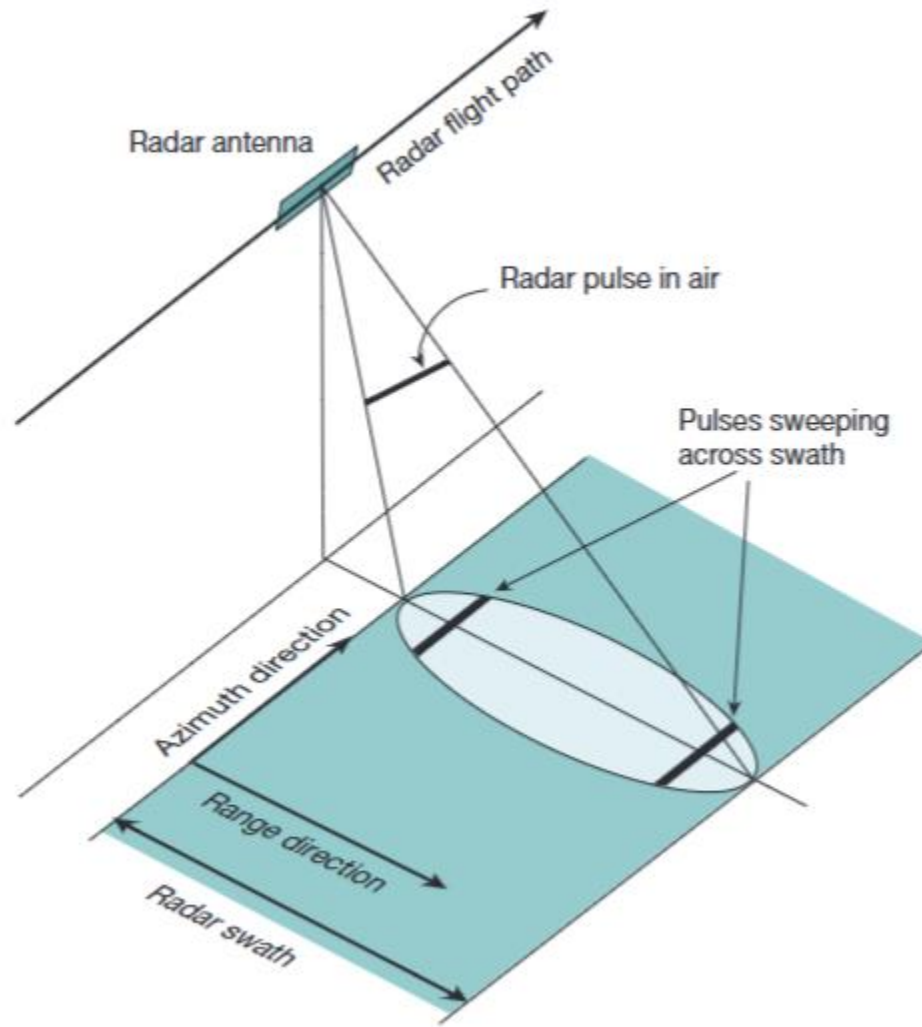
Q2: 這些 GMS 系統看起來很昂貴，它們的商業價值或對一般大眾的益處是什麼？

A: 人人都可以掌握周圍的地表變化，防災與建設

Q3: 既然已經有高精度的 GNSS (GPS)，為什麼還需要發展國家級的 InSAR GMS？兩者有何不同？

A: GNSS密度不夠，InSAR沒有獨立的三分量

Q4: InSAR 可以達到毫米級精度，但為什麼在山區或植被茂密的地方地圖上會出現「空白」？





全球坡地InSAR監測潛力快速評估指標：SIDX



傳統現地測量有侷限
成本高且具危險性，只能監測已知場址的有限範圍；InSAR可提供安全、廣域監測成果。

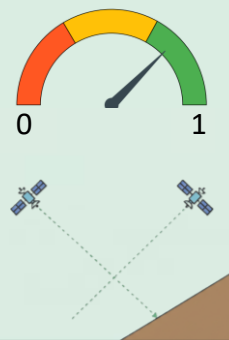
WHY 為何需要SIDX?



InSAR的「事前評估」
投入大量時間和計算資源前，先評估InSAR監測成效，並作為事後檢核依據。



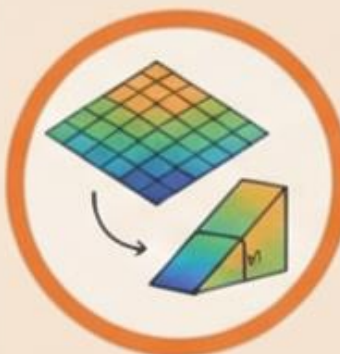
WHAT 什麼是SIDX(坡地變形InSAR敏感度指數)?



InSAR Landslide Sensitivity Index (SIDX)
一個介於0至1的數化指標，用於評估InSAR技術對於坡地順著坡向位移時的敏感度。

結合雷達衛星幾何與地形幾何資訊
結合衛星運作的有效方位與入射角，以及地形的位態和鄰近地形的影響，綜合計算而得。

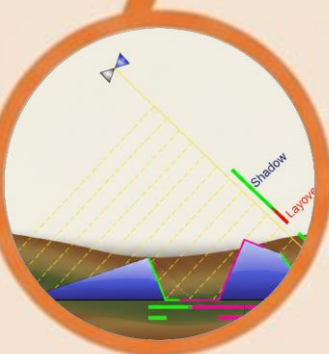
HOW 如何計算?



1. 分析坡地幾何
使用數值高程模型 (DEM) 計算每個格點的坡度與坡向。



2. 結合雷達星測量幾何
考量Sentinel-1衛星的軌道參數和入射角。



3. 考量鄰近地形效應
排除周圍地形造成的陰影與疊置。

WHERE 什麼地方適用?



全球91%的易致災坡地均有機會監測
結合衛星運作的有效方位與入射角，以及地形的位態和鄰近地形的影響，綜合計算而得。



WHO & WHEN 誰需要? 何時用?



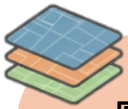
目標使用者
山崩專家與坡地工程師
協助專業人員進行監測規劃和衛星資料分析



使用時機
InSAR專案的規劃階段，與成果の後期檢核分析。



SIDX 圖層說明與注意事項



圖層說明：

坡地變形InSAR敏感度指數 (InSAR Landslide Sensitivity Index, SIDX) 係利用數位地形模型 (DEM) 之坡向 (α) 與坡度 (β) , 和 SAR衛星測量幾何之Line-Of-Sight (LOS) 的入射角 (θ) 與有效方位 ($\gamma'(\phi)$) 組合而成的函數：

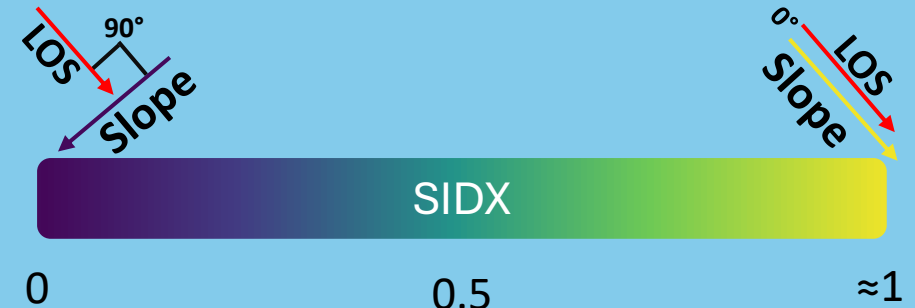
$$s(\alpha, \beta, \theta, \phi) = |\sin(\beta) \cos(\theta) + \sin(\theta) \sin(\alpha - \gamma'(\phi)) \cos(\beta)|$$

其物理意義為坡向上的單位向量於LOS單位向量的投影，可用於預判InSAR測量幾何是否對特定的坡面單元具有敏感性。



本圖層來自van Natijne et al. (2022) , 係以歐洲太空總署 (ESA) 的Copernicus任務資料計算獲得。

衛星參數	ESA Copernicus Sentinel-1
數值高程模型	ESA Copernicus DEM GLO-30 (30m)
BigGIS中對應臺灣的圖層	
1	Sentinel-1 升軌軌道69 (30m解析度)
2	Sentinel-1 降軌軌道105 (30m解析度)
3	Sentinel-1 升降軌最大值 (30m解析度)



使用說明：

SIDX介於0至1之間，數值愈小代表衛星LOS測量對坡向運動愈不敏感，亦即InSAR於此坡面無法取得好的成果，因為坡向位移能投影至LOS的分量極小。數值愈接近1則相反，代表LOS方向的測量能獲得更多的坡向位移貢獻。

注意事項：

SIDX僅利用衛星與地形形貌間的測量幾何關係，並未考慮到地表植被或裸露，以及人工建物的影響。

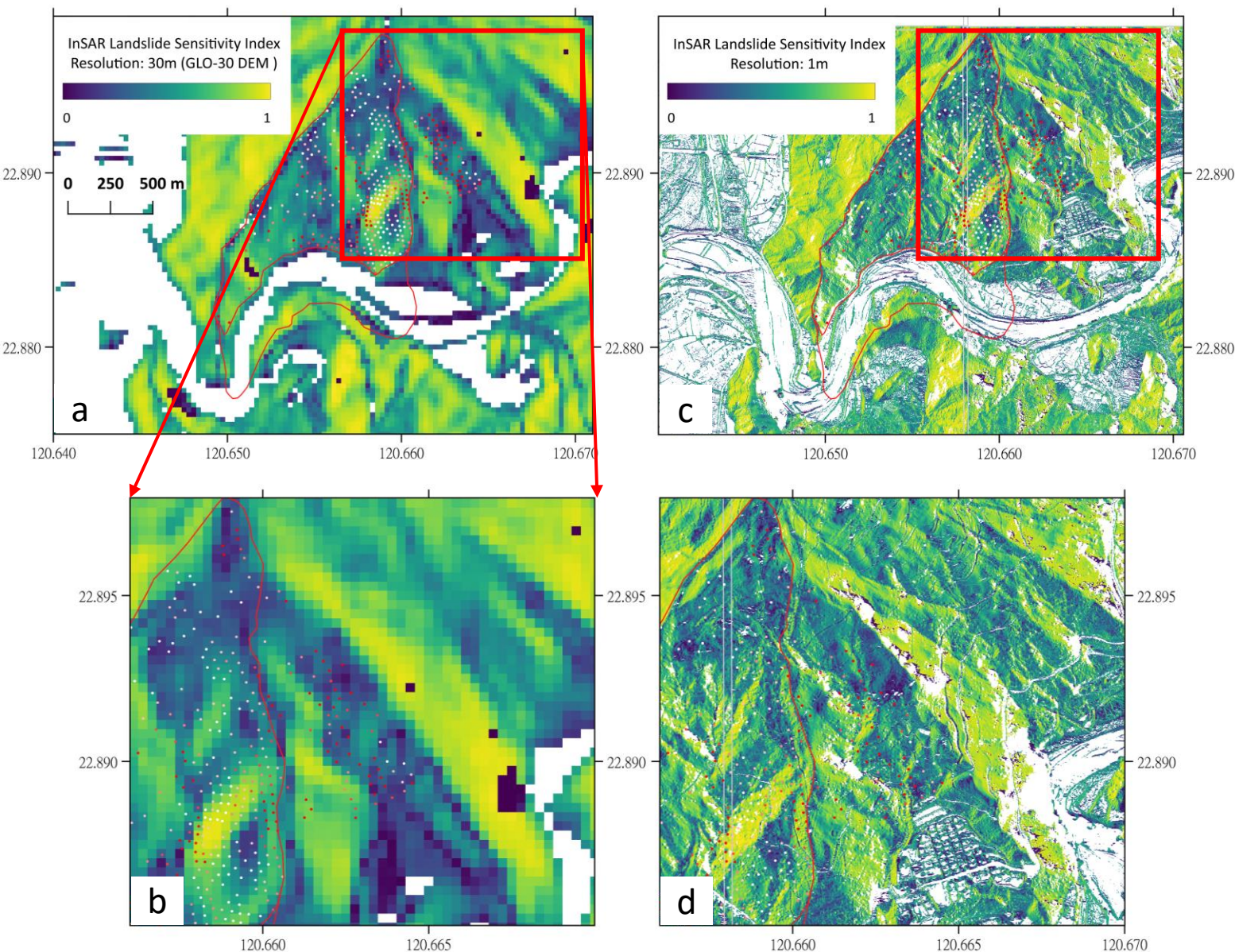
原始資料：

https://data.4tu.nl/articles/_/14095777

參考文獻：

van Natijne AL, Bogaard TA, van Leijen FJ, et al (2022) World-wide InSAR sensitivity index for landslide deformation tracking. International Journal of Applied Earth Observation and Geoinformation 111:102829.
<https://doi.org/10.1016/j.jag.2022.102829>

高解析度DEM製作SIDX可獲得更接近真實的評估成果



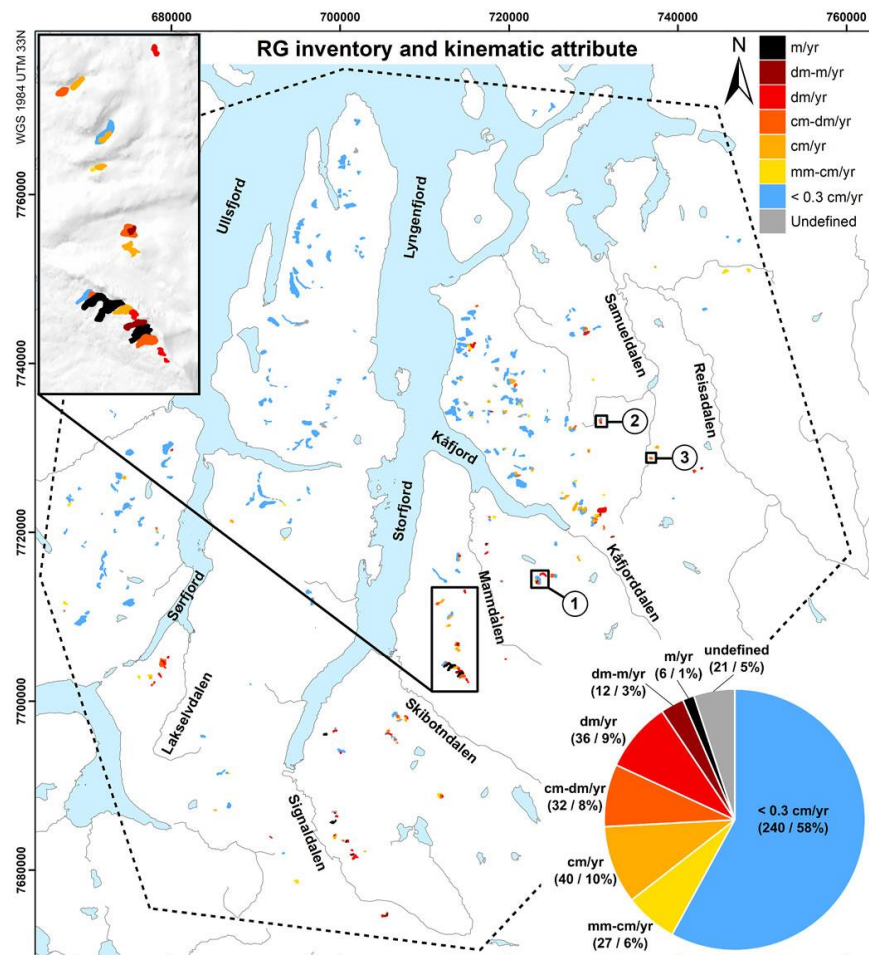
為什麼要用高解析度DEM計算SIDX？

儘管30m全球尺度DEM已能有效計算出可用的InSAR敏感度指數，但當關注的坡體位移量與變形尺度更細緻時，30m解析度會因為解析度較粗，低估了每個網格內的地形變化，而忽略了坡面上更小尺度的地形凹凸，也可能在SAR影像的數公尺級像素範圍內，提供穩定回波。

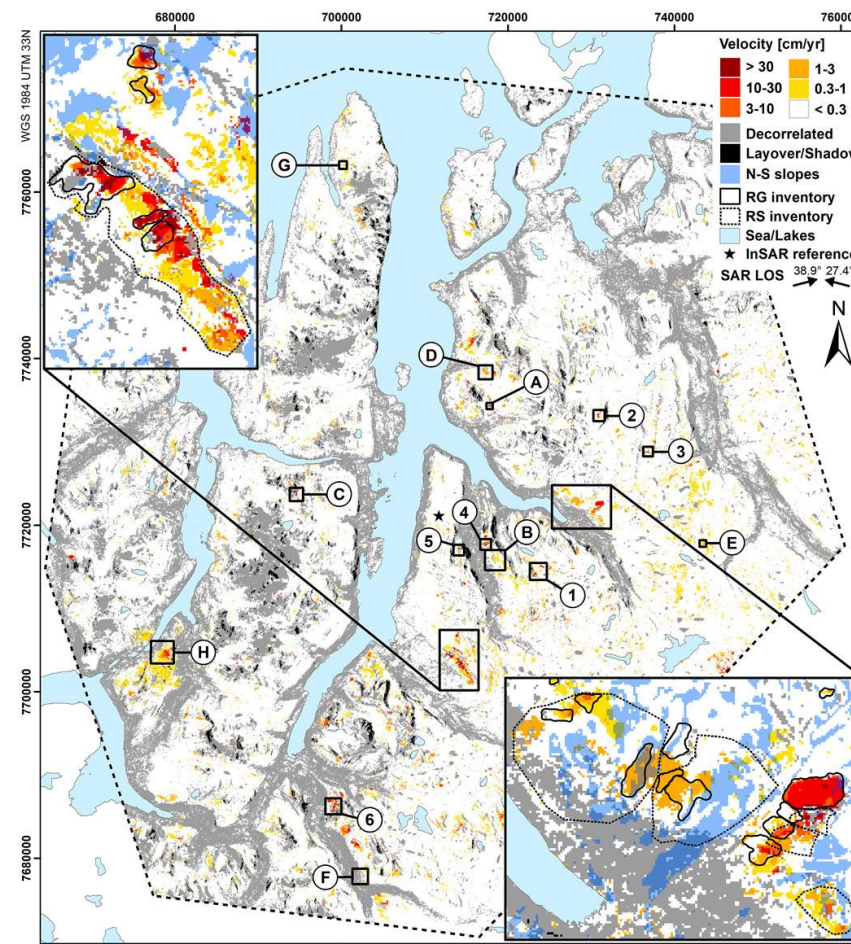
左圖以編號高市LL009（茂林）的大規模崩塌潛勢區為例：30m解析度DEM下（圖a與b），原先被視為低敏感度的區域（深藍色），在1m高解析度DEM下（圖c與d），可以發現存在更細微的地形變化，使得該區域仍有一部分具有InSAR偵測坡體位移的高敏感度；故實際上這個位置是可以產出合適的InSAR反射點。

圖中彩色點為本署委辦計畫獲得的MT-InSAR產品。

• GMS 與坡地災害



挪威的岩石冰川 (RG) 目錄

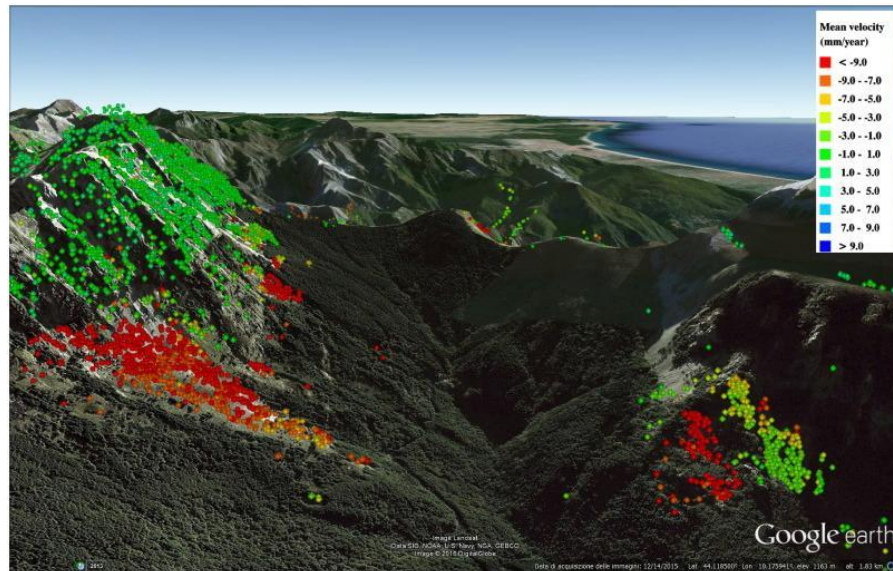


Classified InSAR results

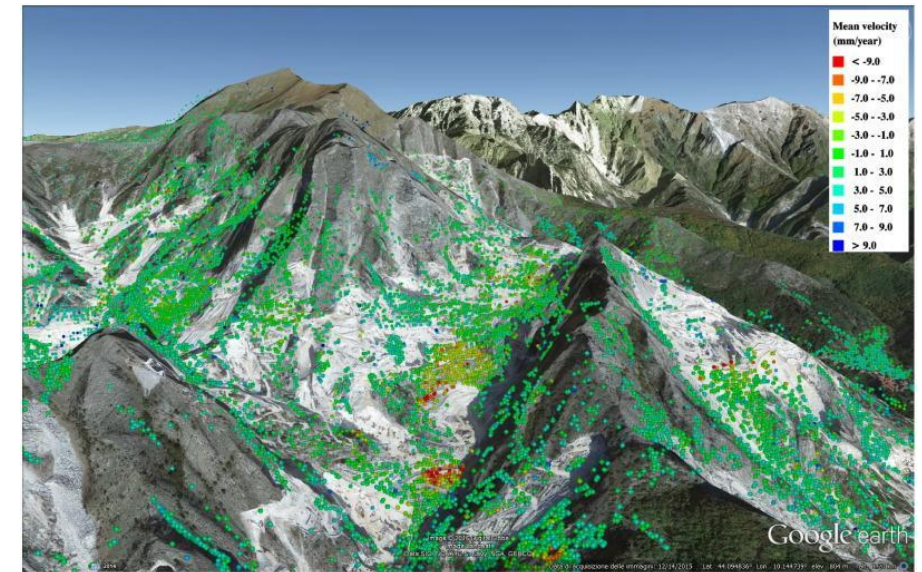
透過 InSAR 分析，研究人員成功更新了現有的岩石冰川 (RG) 和岩崩 (RS) 清冊。在研究區域內，新發現了 54 個岩石冰川和 20 個岩崩，這些地貌隨後被納入數據庫中。

(Rouyet et al. 2021)

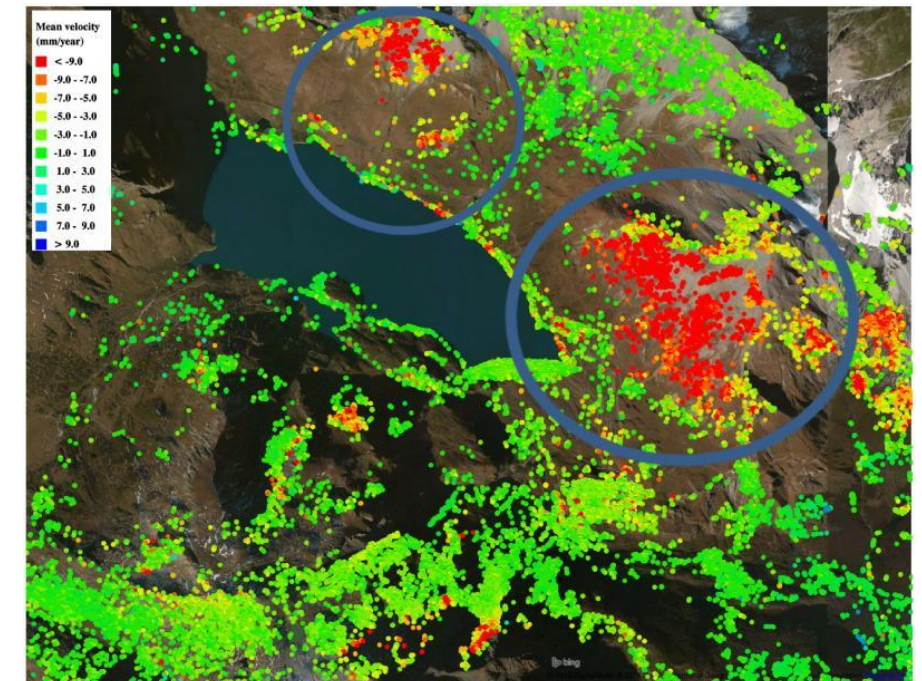
• GMS 與坡地災害



COSMO-SkyMed HIMAGE descending (2011-2014)



COSMO-SkyMed HIMAGE descending (2011-2014)



COSMO-SkyMed HIMAGE descending (2011-2014)

Costantini M, Ferretti A, Minati F, et al (2017) Analysis of surface deformations over the whole Italian territory by interferometric processing of ERS, Envisat and COSMO-SkyMed radar data. Remote Sensing of Environment 202:250–275. <https://doi.org/10.1016/j.rse.2017.07.017>



GMS in Taiwan

1. 數個民間公司已提供平台服務，規模與整合度有限。
2. 政府部門與學界已展開合作。
3. 尚未有開放且免費的平台。



參考文獻

1. Crosetto M, Solari L, Mróz M, et al (2020) The Evolution of Wide-Area DInSAR: From Regional and National Services to the European Ground Motion Service. Remote Sensing 12:2043. <https://doi.org/10.3390/rs12122043>