A First Glimpse on the Interferometry and Multi-Temporal Capability of the Chinese GaoFen-3A/B/C Constellation

Yuxiao QIN*, Mengge Wang
School of Electronics and Information
Northwestern Polytechnical University
Xi'an, China

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

中国航天 中国空间技术研究院
China Academy of Space Technology

NSOAS
National Satellite Ocean Application Service

AIR 中国科学院空天信息创新研究院
Aerospace Information Research Institute,Chinese Academy of Sciences

CONTENTS

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

Part 1

Background

Part 2

Process

Part 3

Results

Part 4

Next Steps

/01 Background

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

1. Background

GaoFen-3 (GF-3)

- First Chinese civilian high resolution, multi polarization SAR satellite
- Belongs to the **CHEOS** (China High Resolution Earth Observation System) project

2016 — GaoFen-3 launched, 8yrs design lifetime, C-band, 755km altitude, 29d revisit time

2022 — GaoFen-3B and GaoFen-3C launched on Nov 2021 and Apr 2022, commissioning phase completed 2023

2023 — GF-3 functioning well, distributed more than 2.2m images, covering 3.56b km² of earth surface, 37 times the size of China

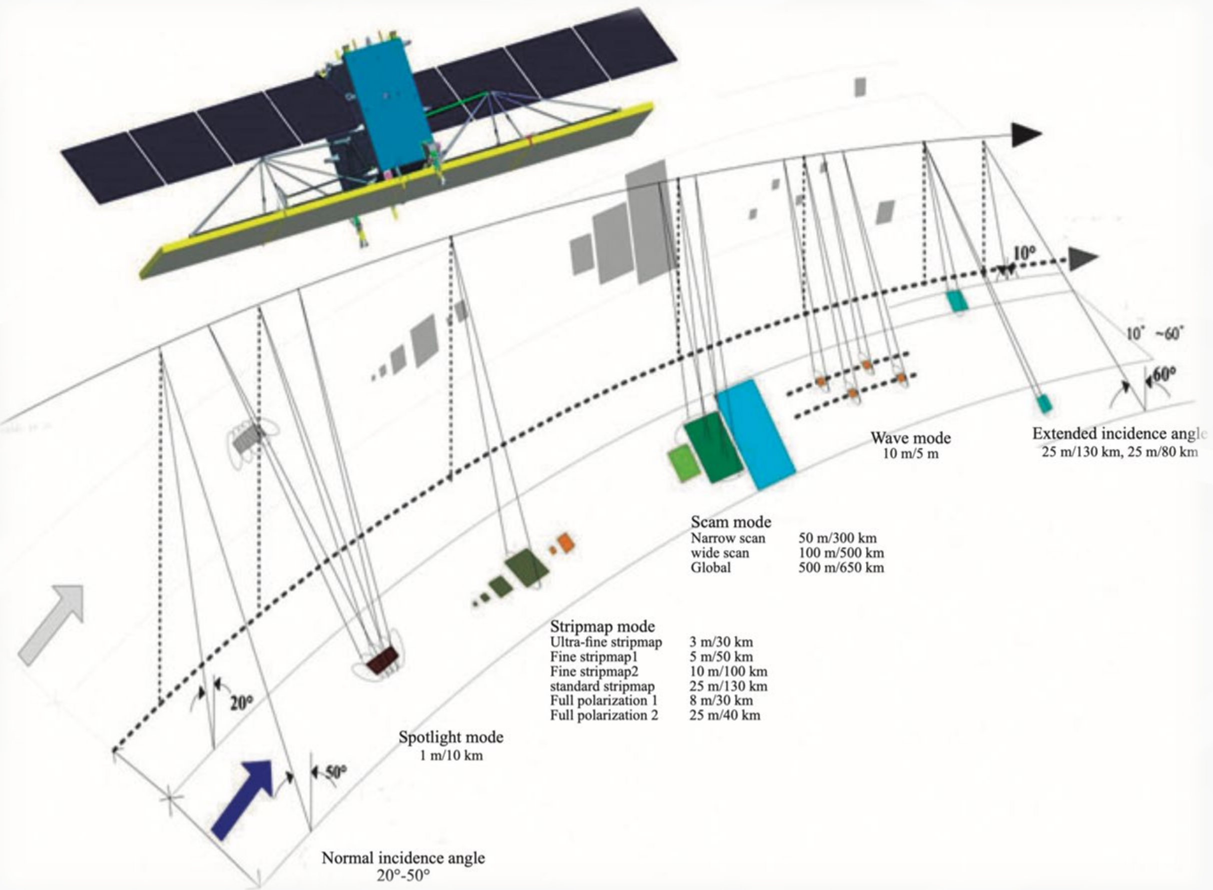
1. Background

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

Item	GF-3	Sentinel-1	Radarsat-2
Orbit	Sun-synchronous orbit	Sun-synchronous orbit	Sun-synchronous orbit
Orbit altitude	755 km	693 km	798 km
Band	C	C	C
Satellite weight	2779 kg	2300 kg	2300 kg
Peak power	1.5 kW	4700 W	1.27 kW
Incidence angle	10° - 60°	20° - 45°	20°- 60°
Antenna area	15 m×1.5 m	12.3 m×0.84 m	15 m×1.37 m
Signal bandwidth	0-240 MHz	0 - 100 MHz	0 - 100 MHz
Polarization	Single/Dual/Full	Single/Dual	Single/Dual/Full
Antenna system	Waveguide slot	Waveguide crack	Microstrip
Angle of elevation	±20°	±11°	±20°
Imaging mode	12	4	10
Resolution	1-500 m	5 - 20 m	1-100 m
Swath	10-650 km	20-400 km	20-500 km
Life	8 years	7.25 years	7.25 years

Comparison with typical C-band SAR satellites

1. Background



Imaging mode		Resolution (m)	Swath (km)	Incident Angle (°)	Polarization
Spotlight		1	10×10	20 - 50	Single
Ultra-fine stripmap		3	30	20 - 50	Single
Fine stripmap 1		5	50	19 - 50	Dual
Fine stripmap 2		10	100	19 - 50	Dual
Standard stripmap		25	130	17 - 50	Dual
Narrow scan		50	300	17 - 50	Dual
Wide scan		100	500	17 - 50	Dual
Full polarization 1		8	30	20 - 41	Full
Full polarization 2		25	40	20 - 38	Full
Wave		10	5×5	20 - 41	Full
Global		500	650	17 - 53	Dual
Extended incidence angle	Low	25	130	10 - 20	Dual
	High	25	80	50 - 60	Dual

1. Background

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

Main user	Observation target and application
Maritime	Sea wave, sea surface wind field, internal wave, frontal surface, shallow sea topography, sea surface oil spill, sea ice, green tide, coastal zone and sea surface targets
Disaster reduction	Flood submerged area, debris flow, landslide, ice or snow, extent of sea ice, drought scope, buildings, temporary housing, traffic, agricultural and land use, flood control facilities
Water conservancy	Characteristics of river basin systems, surface water distribution, flood range, soil moisture content, land use and vegetation coverage. Surface water indicators, lakes, reservoirs (dams), rivers, wetlands, glaciers, snow, other important water sources, irrigation areas, groundwater remote sensing monitoring indicators, karst, phreatic water, springs, geological landforms, etc.
Meteorology	High resolution regional surface soil moisture monitoring, rainstorm triggered landslides and debris flow and other geological disaster prediction and warning

Main users of GF-3

1. Background

Main user	Observation target and application
Maritime	Sea wave, sea surface wind field, internal wave, frontal surface, shallow sea topography, sea surface oil spill, sea ice, green tide, coastal zone and sea surface targets
Disaster reduction	Flood submerged area, debris flow, landslide, ice or snow, extent of sea ice, drought scope, buildings, temporary housing, traffic, agricultural and land use, flood control facilities
Water conservancy	Characteristics of river basin systems, surface water distribution, flood range, soil moisture content, land use and vegetation coverage. Surface water indicators, lakes, reservoirs (dams), rivers, wetlands, glaciers, snow, other important water sources, irrigation areas, groundwater remote sensing monitoring indicators, karst, phreatic water, springs, geological landforms, etc.
Meteorology	High resolution regional surface soil moisture monitoring, rainstorm triggered landslides and debris flow and other geological disaster prediction and warning

Main users of GF-3

InSAR is not among the top priority of GF-3. But now we want to do InSAR with GF-3A/B/C!

1. Background

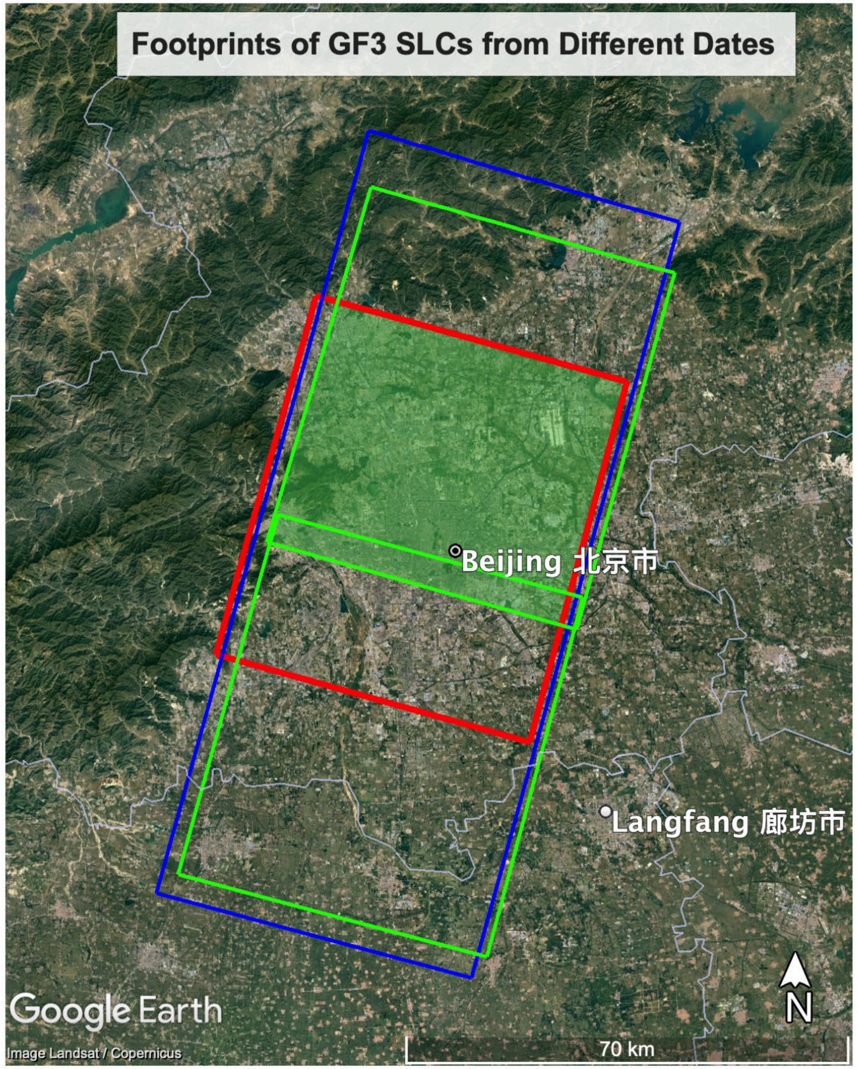
We want to …

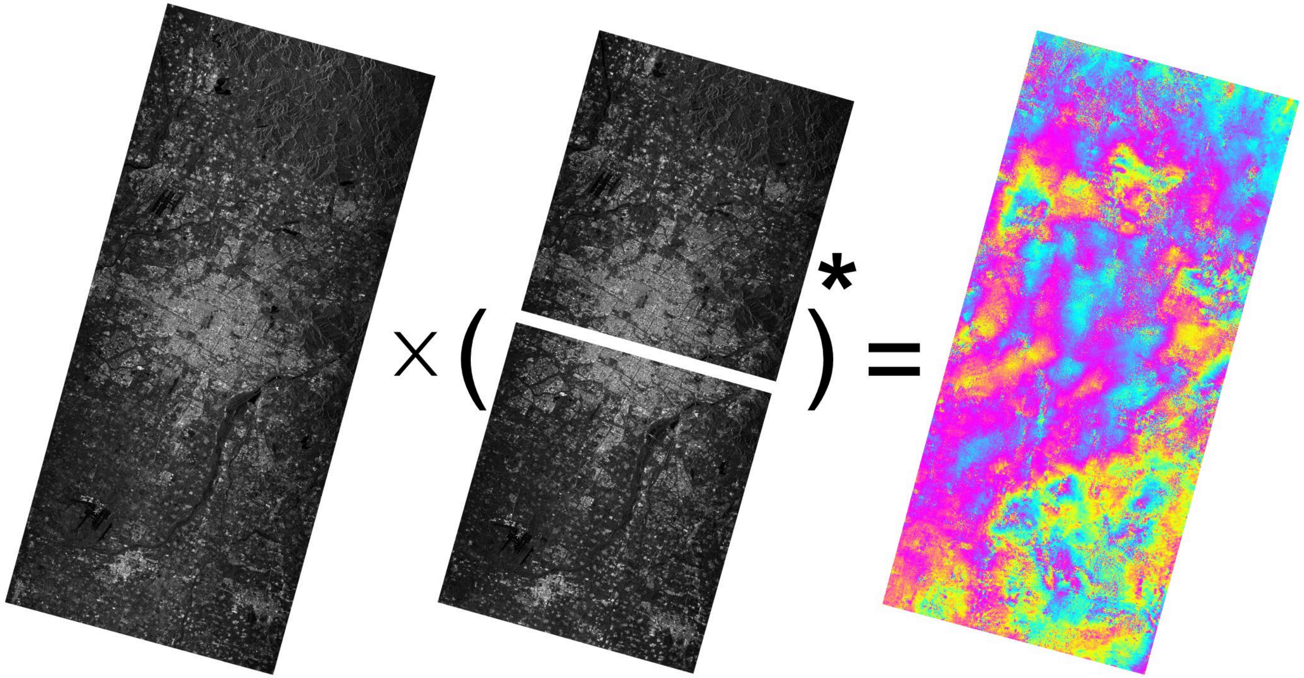
- Understand the interferometry & multi-temporal InSAR capability of GF-3;
- Evaluate what parameters should be if the current configuration is not good enough;
- Set up optimized configurations for a deep InSAR stack for the GF-3A/B/C constellation.

/02 Process

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

2. Process





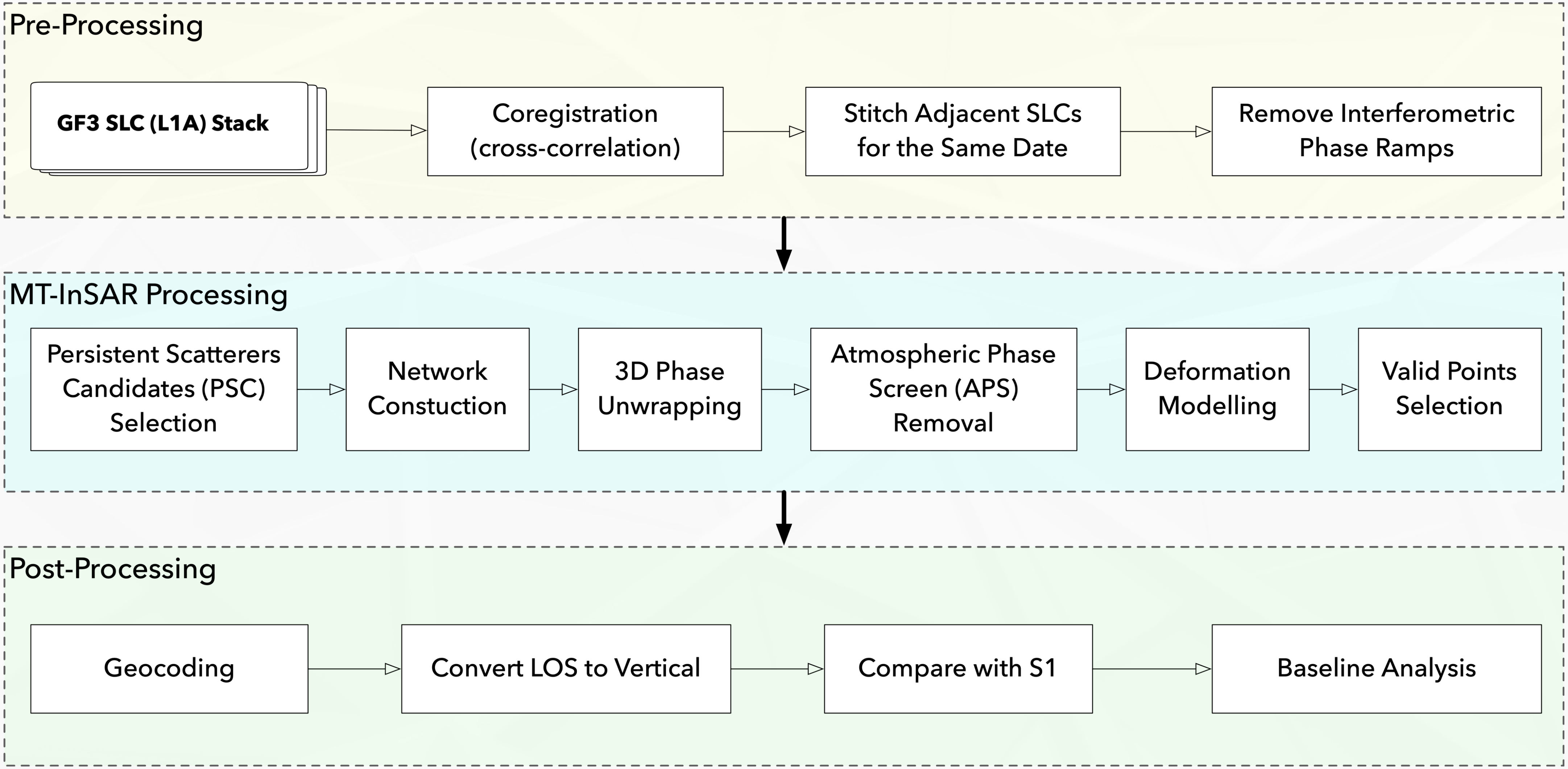
2020/04/12

2020/11/01

Interferogram with larger coverage after stitching

- footprint on 2020/04/12 (blue outline)
- footprint on 2021/01/27 (red outline)
- footprint of 2 adjacent SLCs on 2020/11/01 (green outline)
- common overlap area ***without*** stitching 2 adjacent SLCs (light green fill)

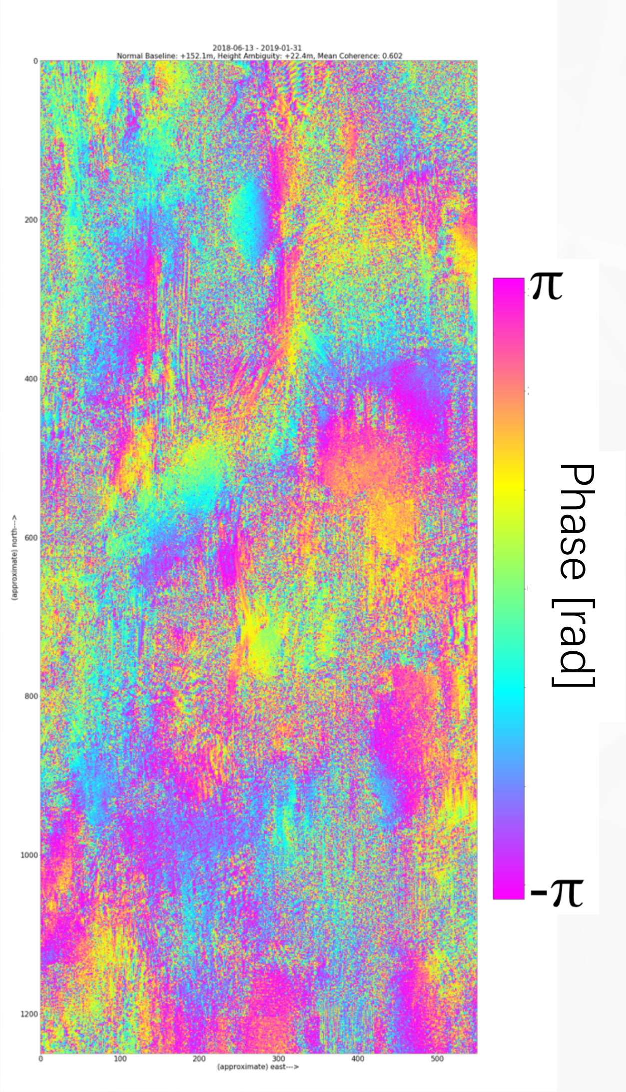
2. Process

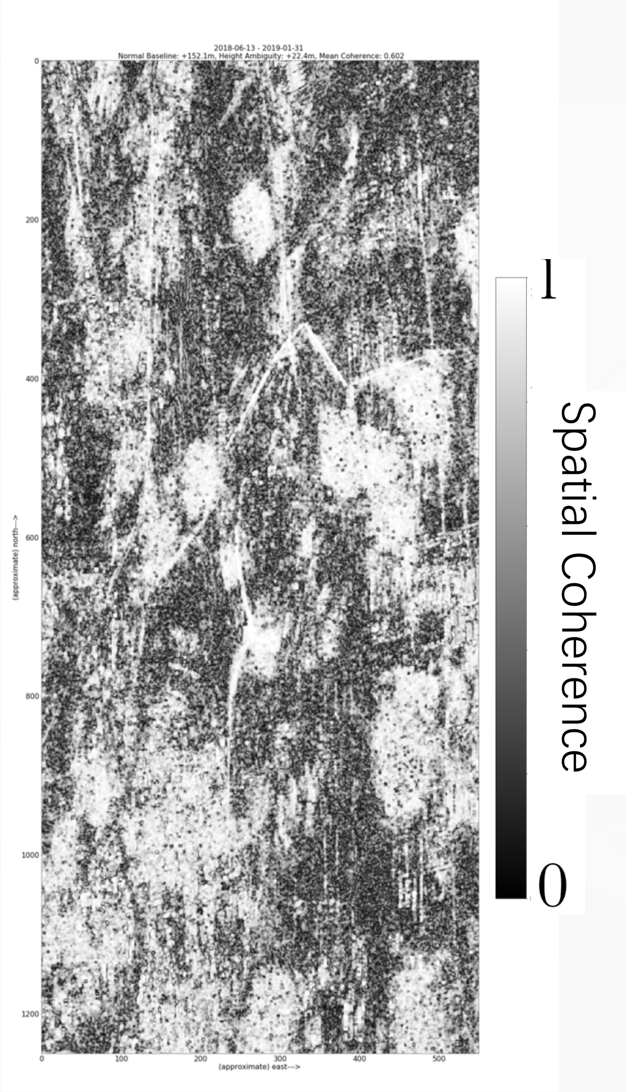

Pre-Processing
GF3 SLC (L1A) Stack
Coregistration (cross-correlation)
Stitch Adjacent SLCs for the Same Date
Remove Interferometric Phase Ramps
MT-InSAR Processing
Persistent Scatterers Candidates (PSC) Selection
Network Constuction
3D Phase Unwrapping
Atmospheric Phase Screen (APS) Removal
Deformation Modelling
Valid Points Selection
Post-Processing
Geocoding
Convert LOS to Vertical
Compare with S1
Baseline Analysis

/03 Results

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

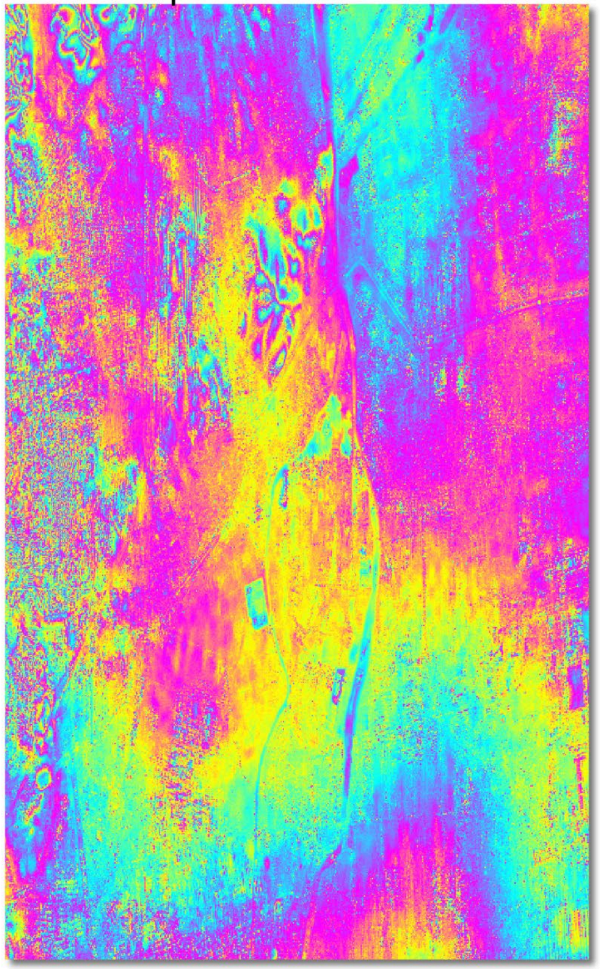
3. Results: Interferometry



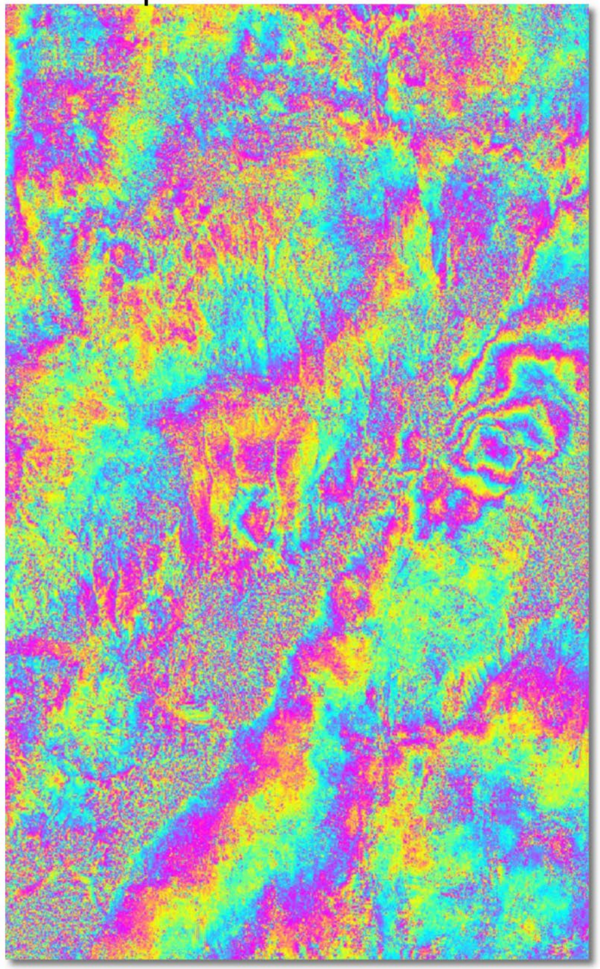


3. Results: Interferometry

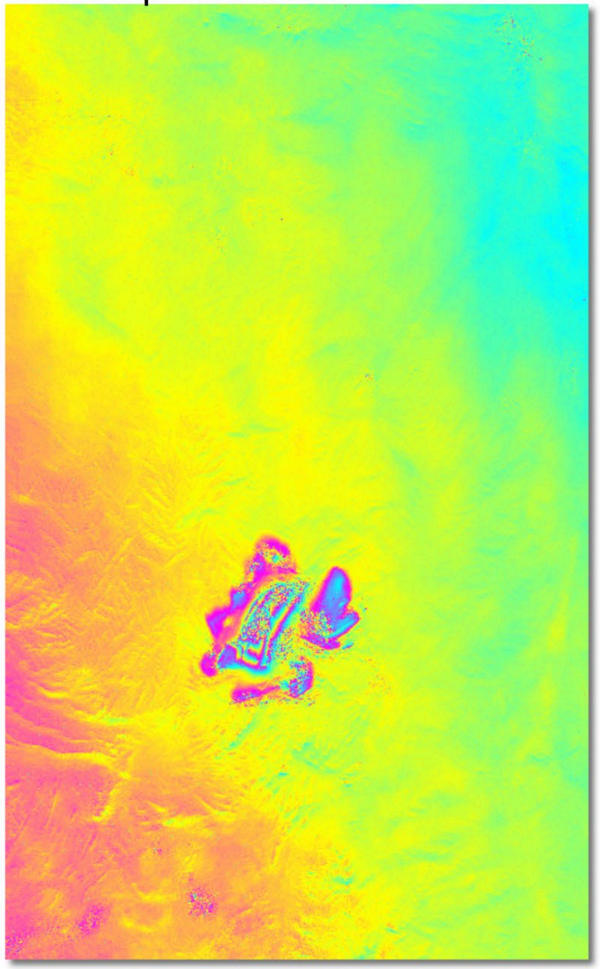
GF3, Spotlight Mode
Normal Baseline: 607m
Spatial Baseline: 29d



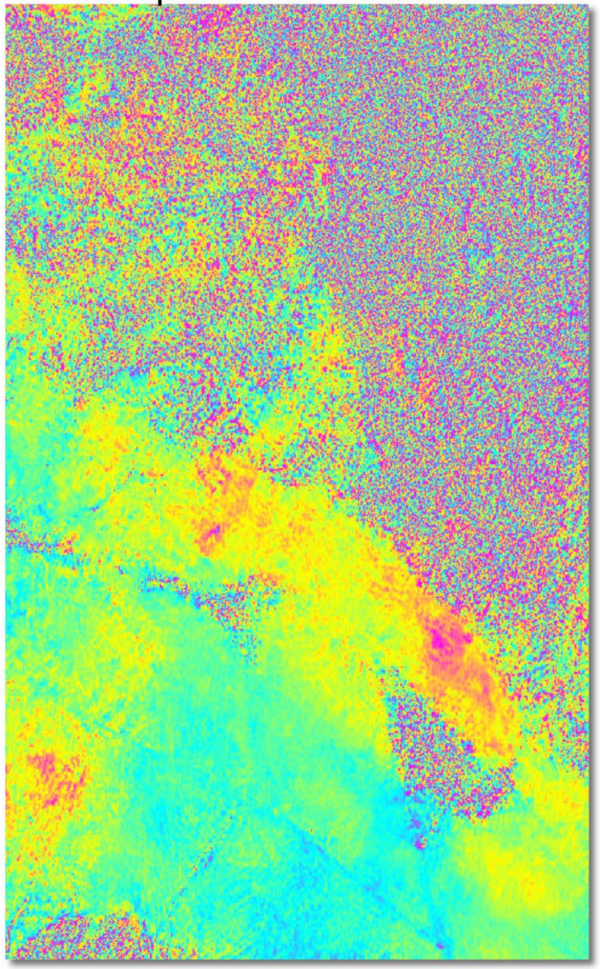
GF3B, FSI (Stripmap) Mode
Normal Baseline: 590m
Spatial Baseline: 58d

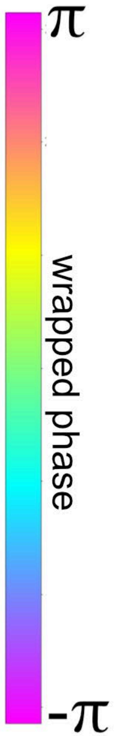


GF3C, FSII (Stripmap) Mode
Normal Baseline: 136m
Spatial Baseline: 29d

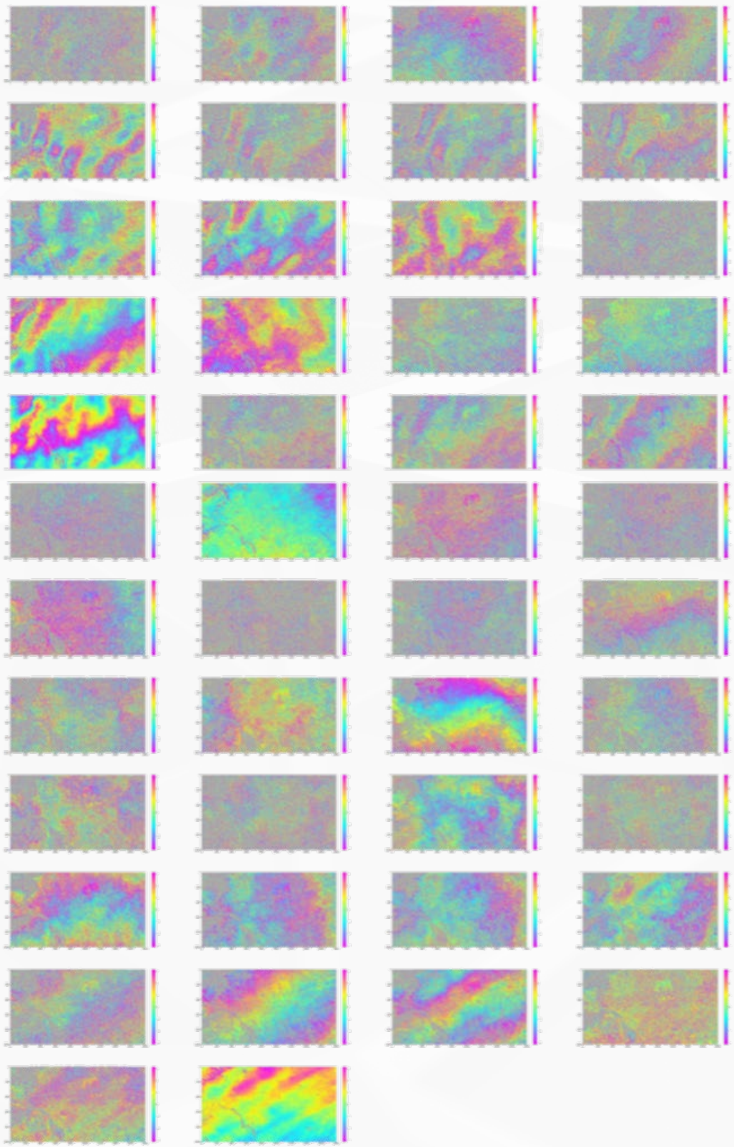


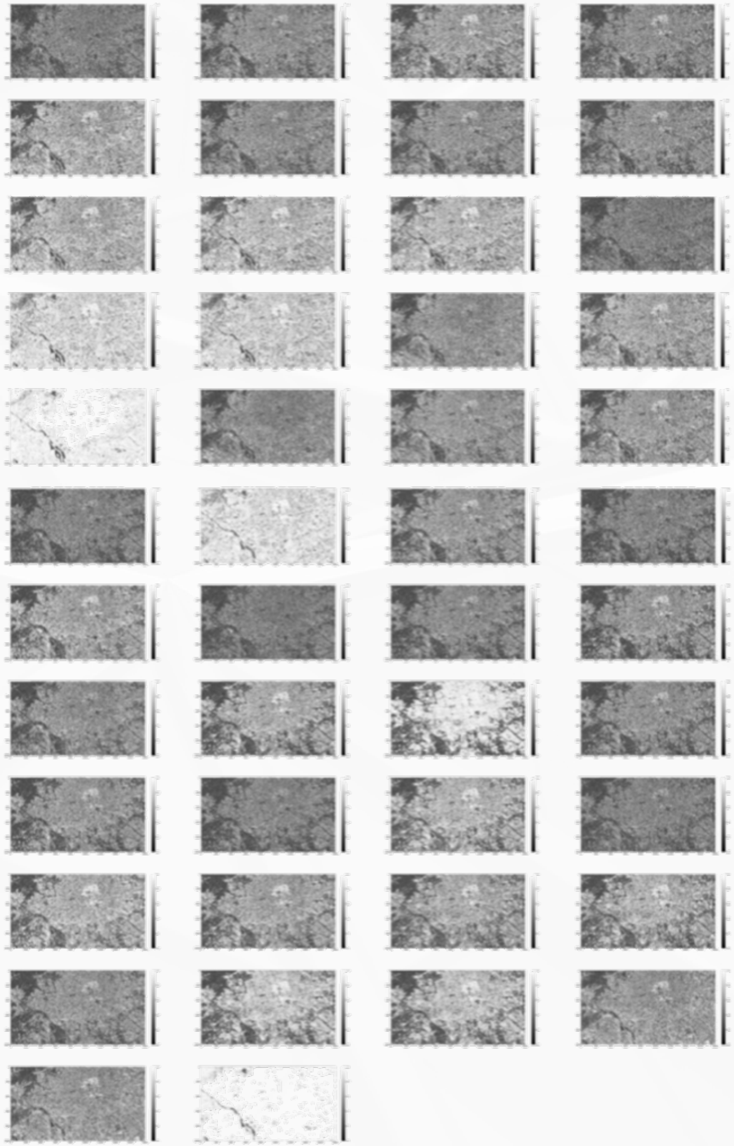
GF3 & GF3B, FSI (Stripmap) Mode
Normal Baseline: 1900m
Spatial Baseline: 6d





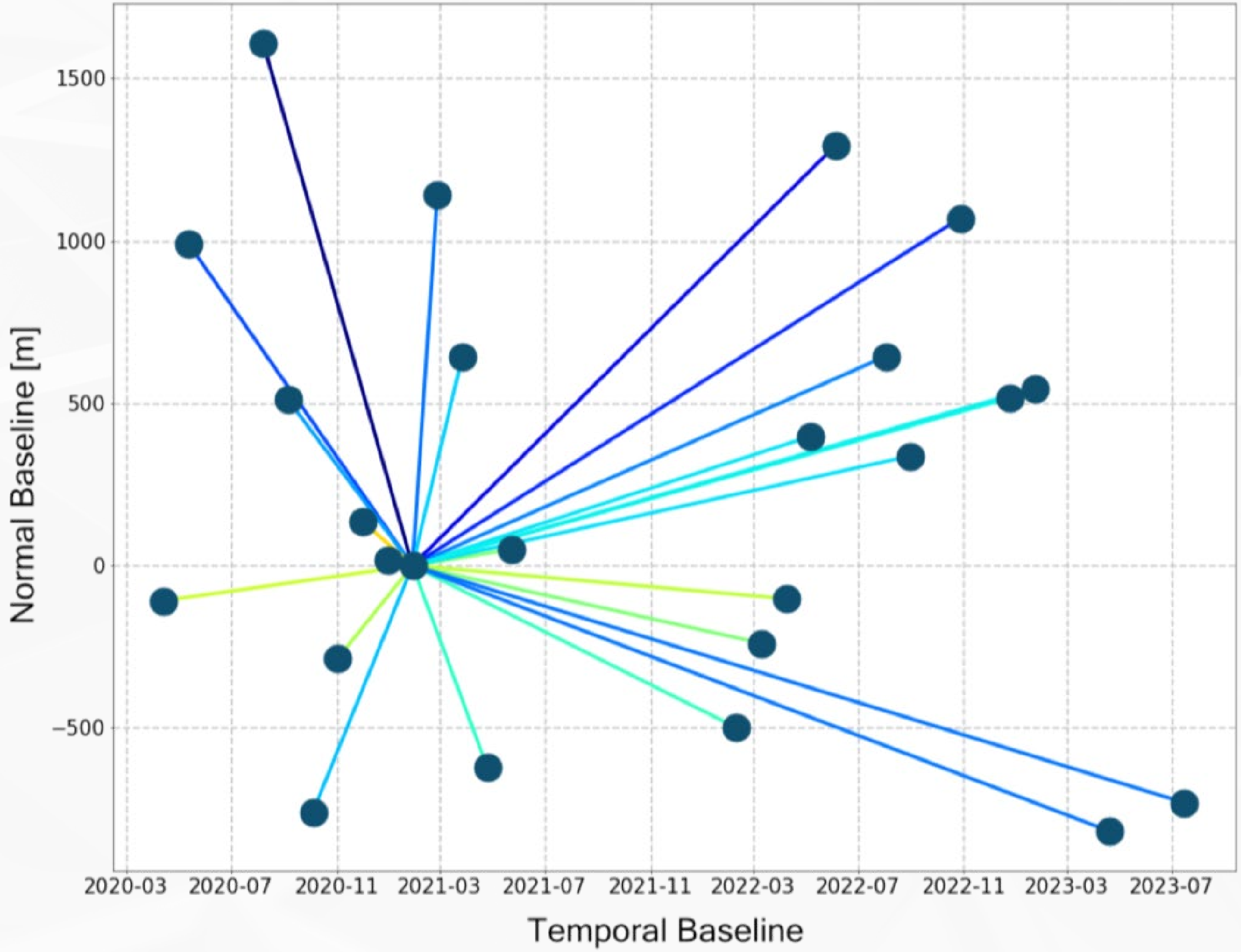
3. Results: Interferometry





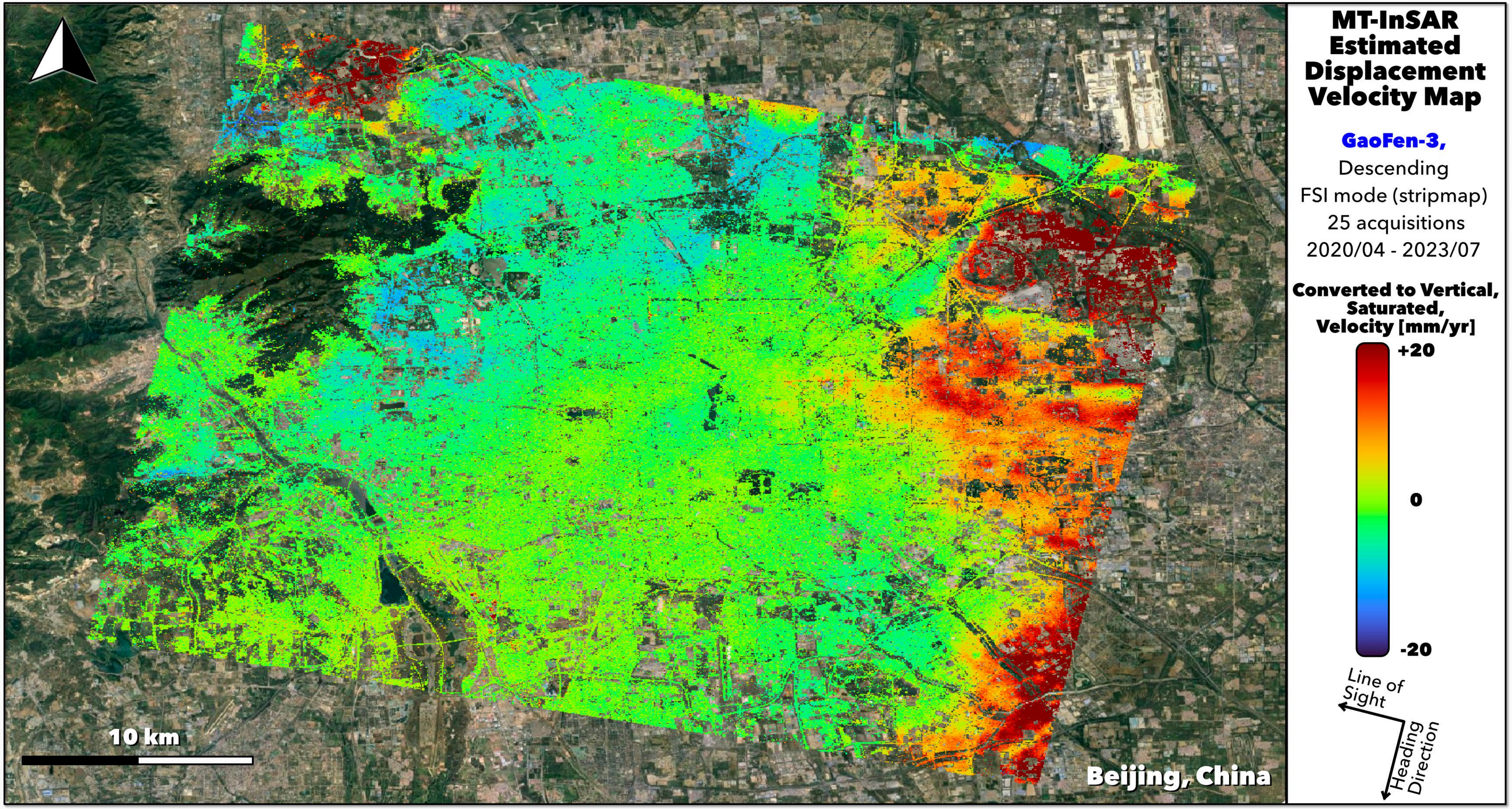
3. Results: MTInSAR

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY



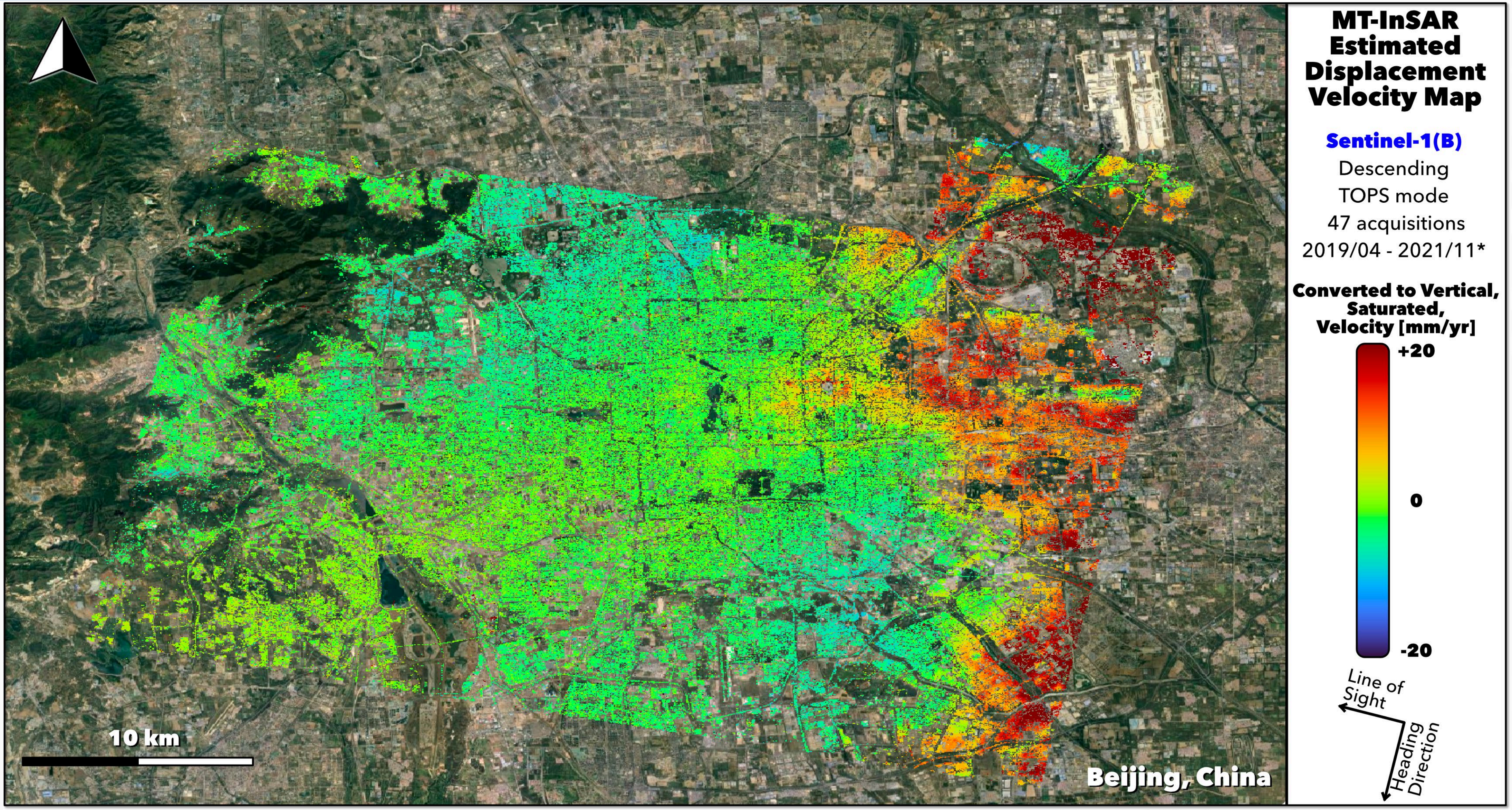
3. Results: MTInSAR

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY



3. Results: MTInSAR

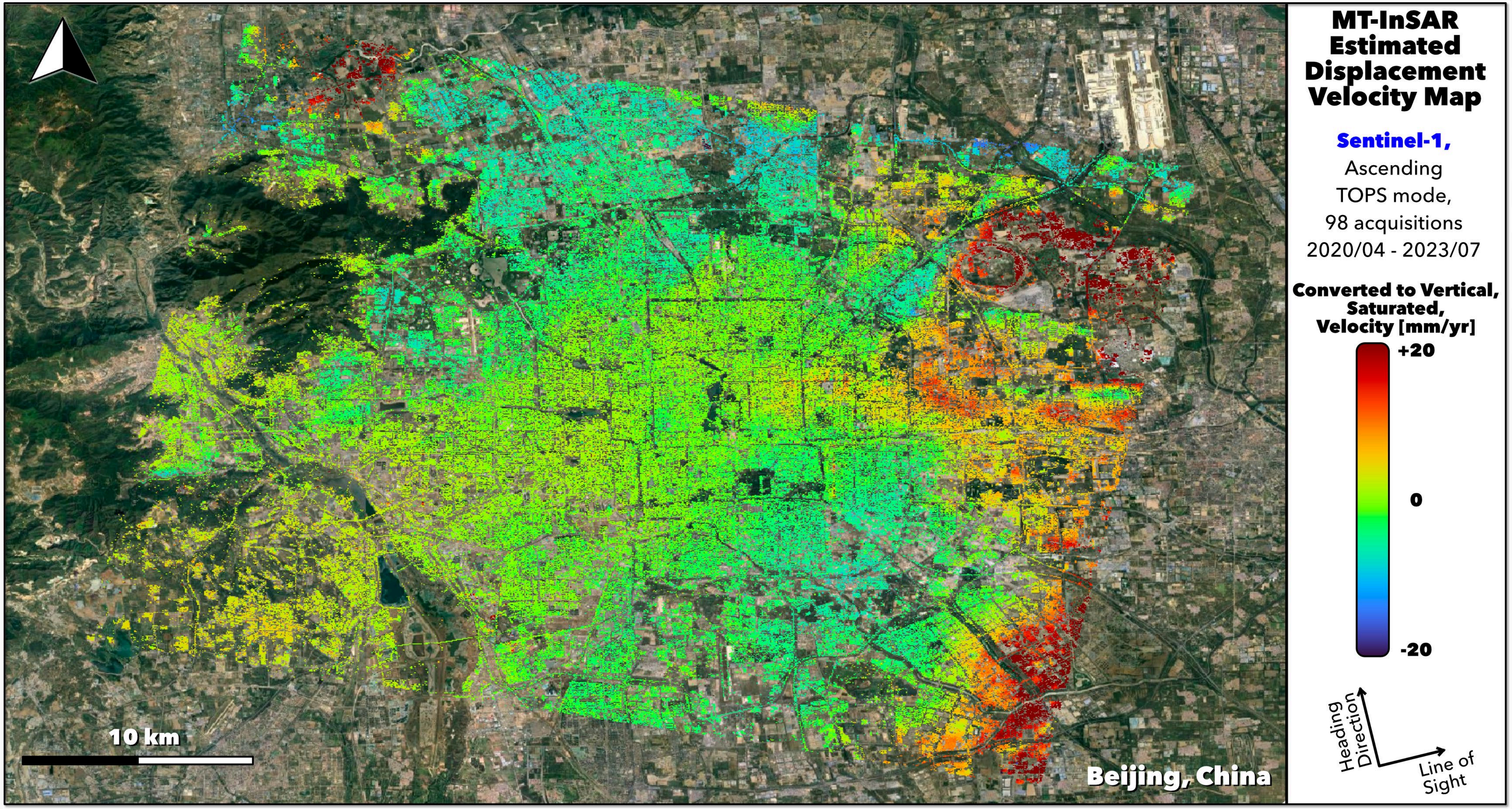
西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY



*: Sentinel-1B mission ended in December 2021.

3. Results: MTInSAR

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY



3. Results: MTInSAR

西北工业大学 NORTHWESTERN POLYTECHNICAL UNIVERSITY

	GF-3	Sentinel-1	Sentinel-1
satellite parameters			
mode	FSI (stripmap)	TOPS	TOPS
pixel spacing (az x rg)	2.25 x 2.60m	2.3x14.1m	2.3x14.1m
revisit days	29d	12d	12d
incidence angle			
pass	descending	ascending	descending
MT-InSAR processing statistics			
no. of acquisitions	25	98	47
start time	2020/04	2020/04	2019/04
end time	2023/07	2023/07	2021/11
processed areas	1564km^2	1564km^2	1370km^2
delivered no. of points	11899250	489259	441722
point density	7608	313	322
coherence threshold	0.75	0.65	0.70

3. Results: MTInSAR

3.1. Product Quality Control

Each of the EGMS products has undergone an extensive quality control protocol in order to generate the best possible results. For this purpose, a variety of criteria were examined, including in addition to format demands [RD4], e.g. sufficient point density in selected CORINE Land Cover 18 (CLC) classes as well as other requirements listed in Table 2 below followed by a brief description of each quality parameter.

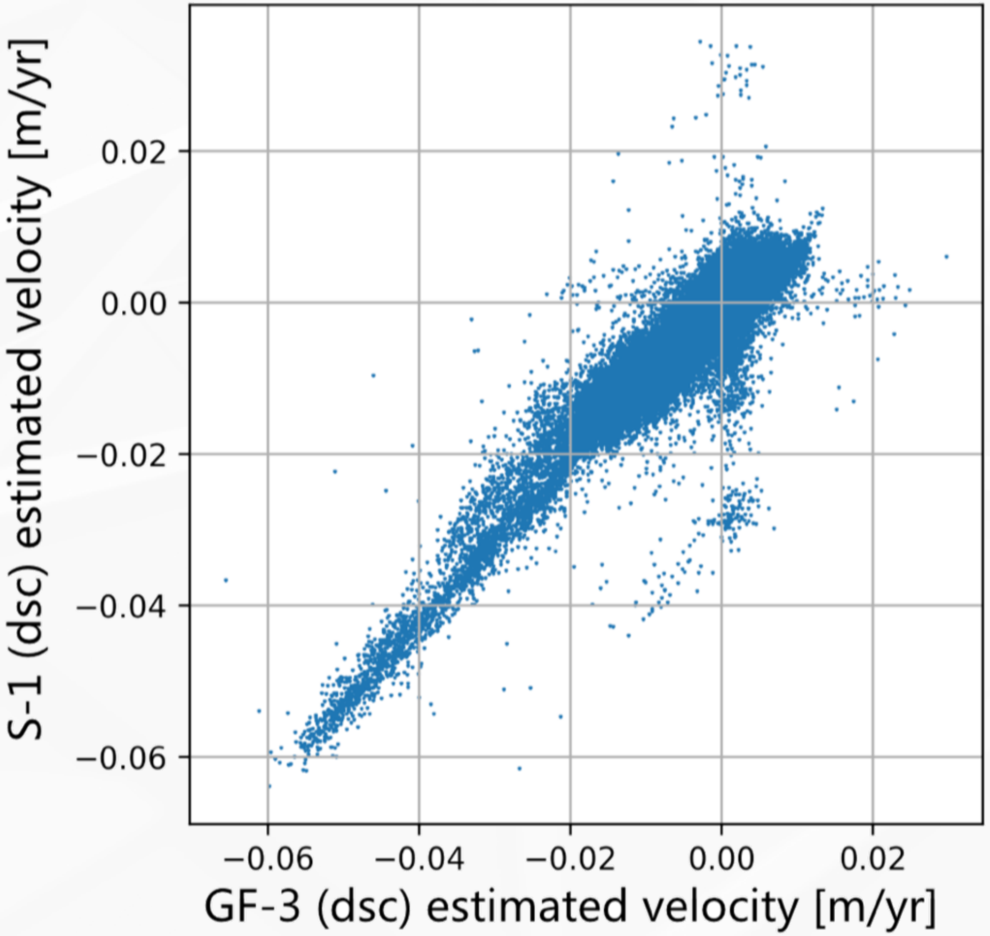
Table 2 EGMS product specifications and requirements

Specifications	*Basic*	*Calibrated*	*Ortho*
3D Geolocation accuracy	<10m	<10m	<10m
Mean velocity STD	0.7 mm/yr	0.7 mm/yr	0.7 mm/yr
Displacement STD	4 mm	8mm	8mm
Measurement Density	CORINE Land Cover 18: Class 1.1.1 > 5000 MP/km² Class 1.1.2 > 1000 MP/km² Class 1.2 > 1000 MP/km² Class 3.3 > 100 MP/km²	The same as *Basic*	Reduced due to resampling

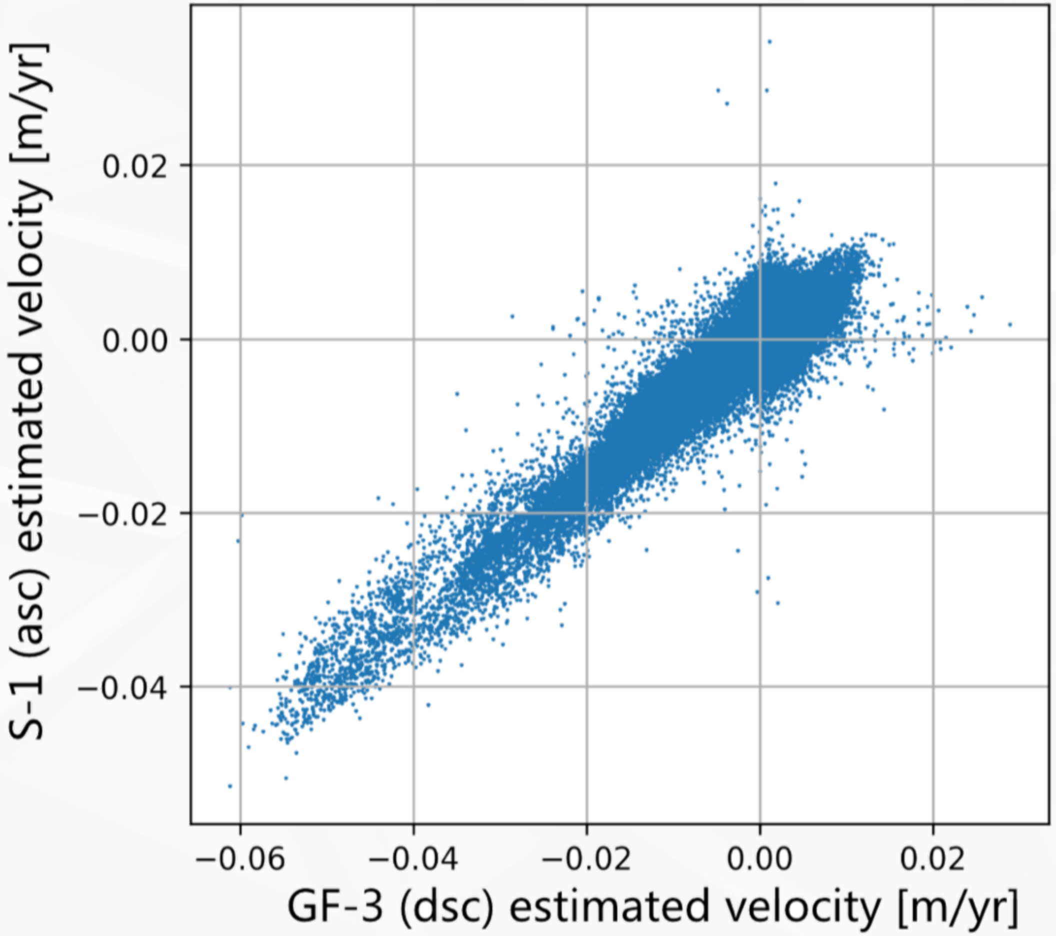
delivered no. of points	11899250	489259	441722
point density	7608	313	322
coherence threshold	0.75	0.65	0.70

3. Results: MTInSAR

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

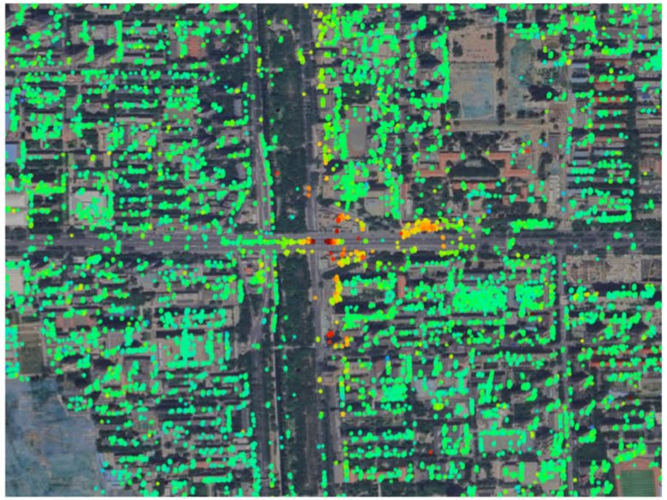


R^2 = 0.87
slope = 0.95
RMSE = 2.22 [mm/yr]

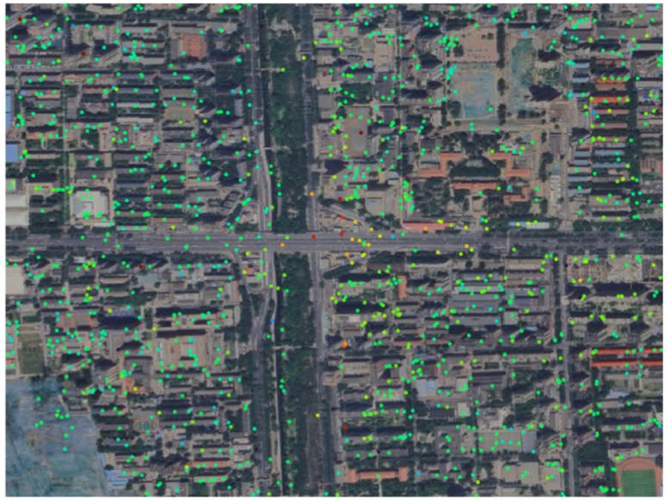


R^2 = 0.81
slope = 0.72
RMSE = 2.20 [mm/yr]

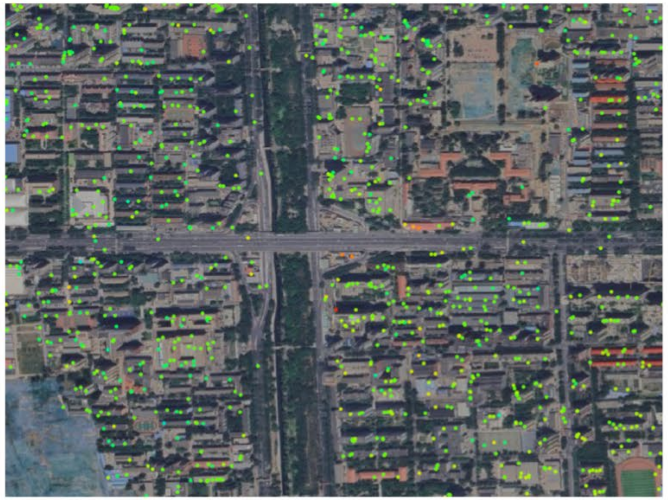
3. Results: MTInSAR



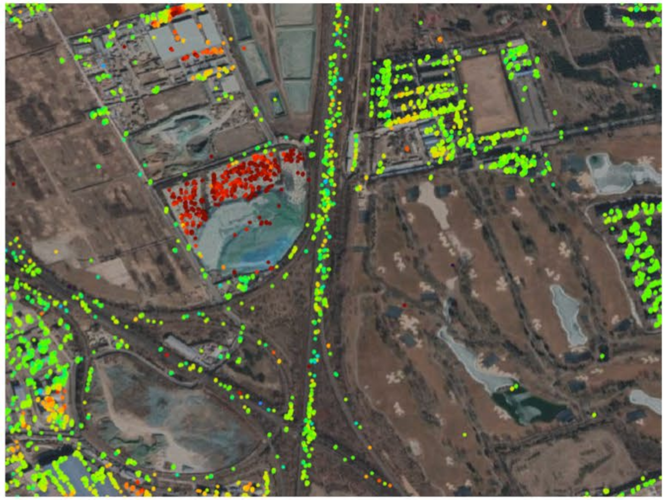
(d) GF-3 descending



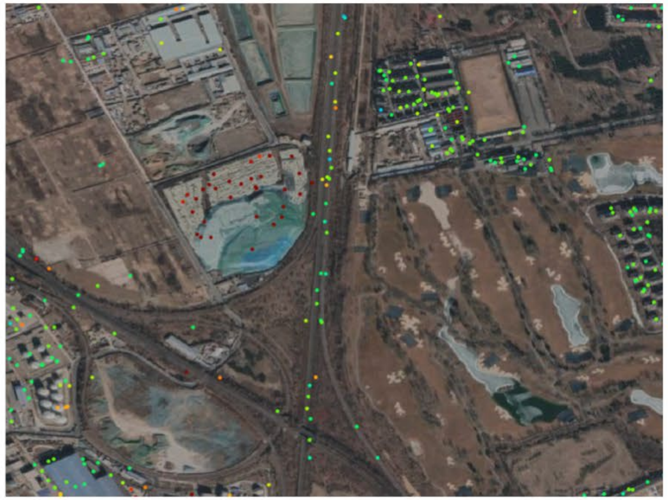
(e) S1 descending



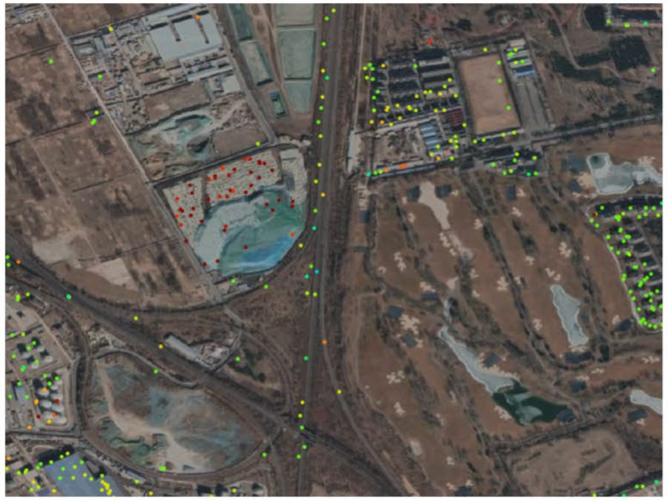
(f) S1 ascending



(g) GF-3 descending

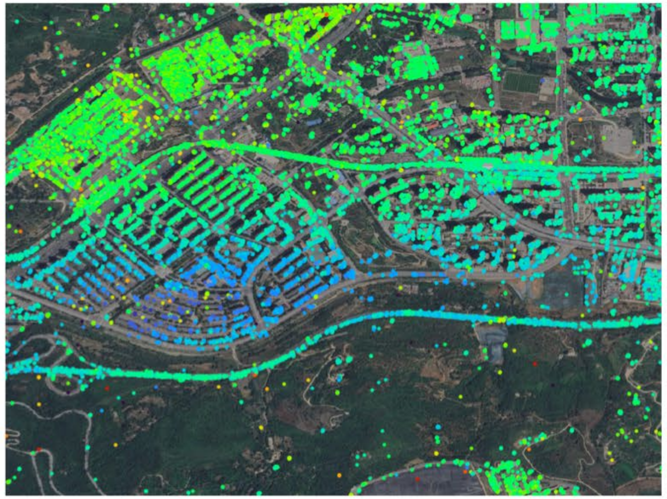


(h) S1 descending



(i) S1 ascending

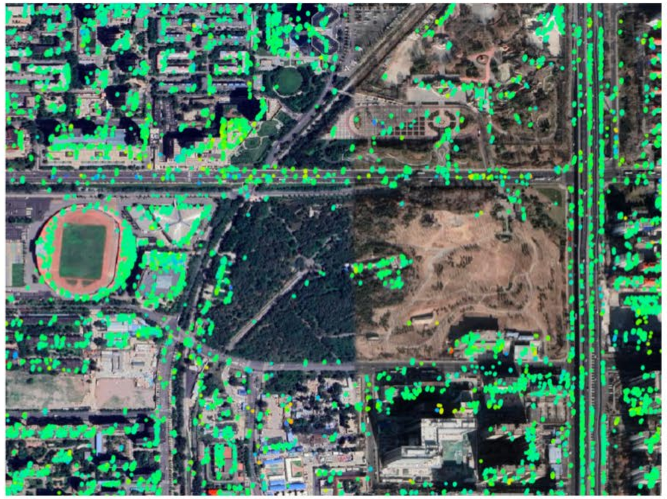
3. Results: MTInSAR



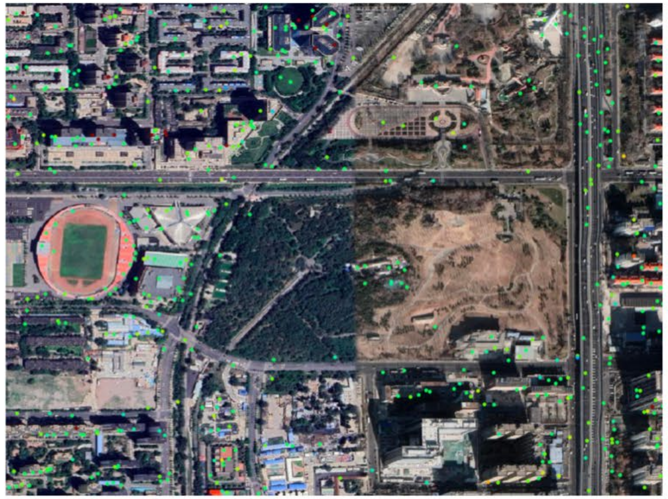
(j) GF-3 descending

(k) S1 descending

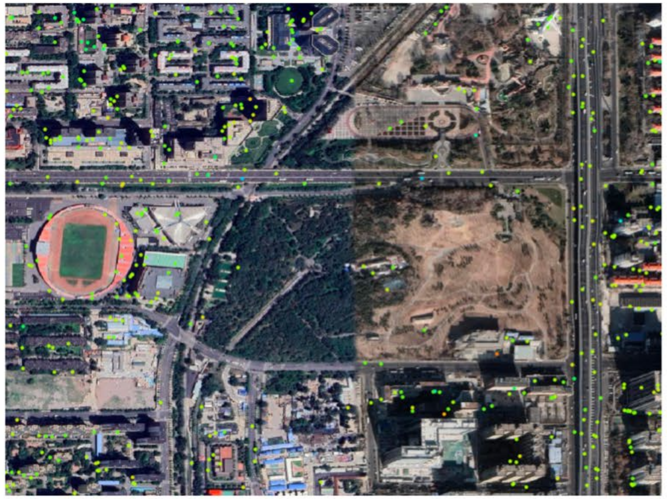
(l) S1 ascending



(m) GF-3 descending



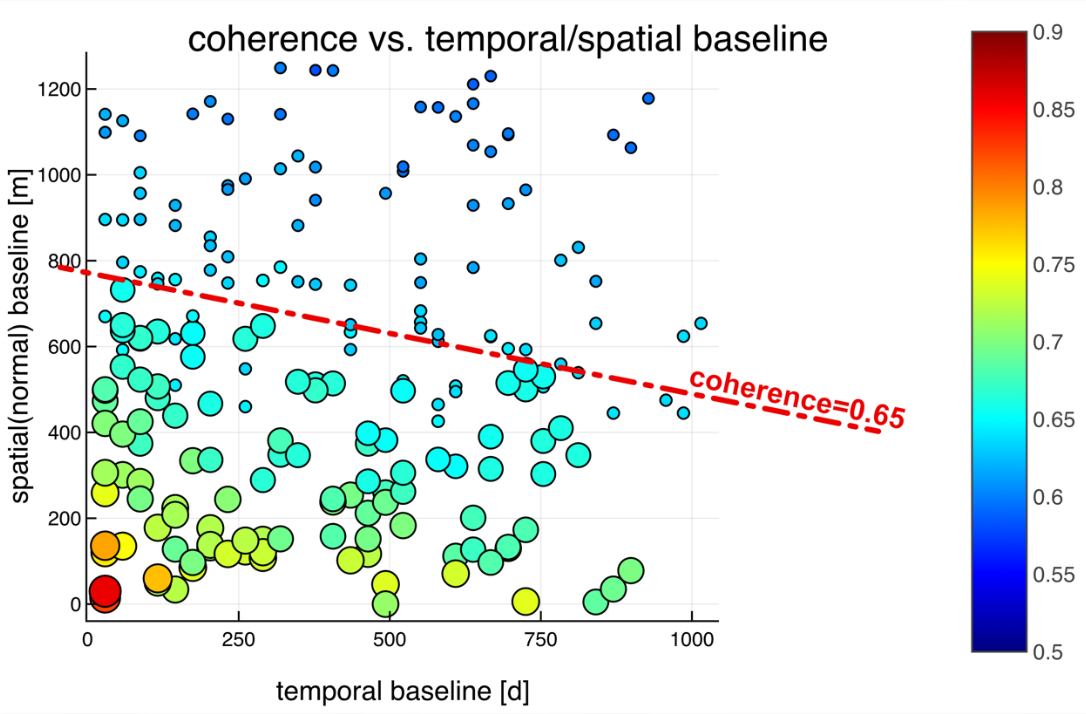
(n) S1 descending



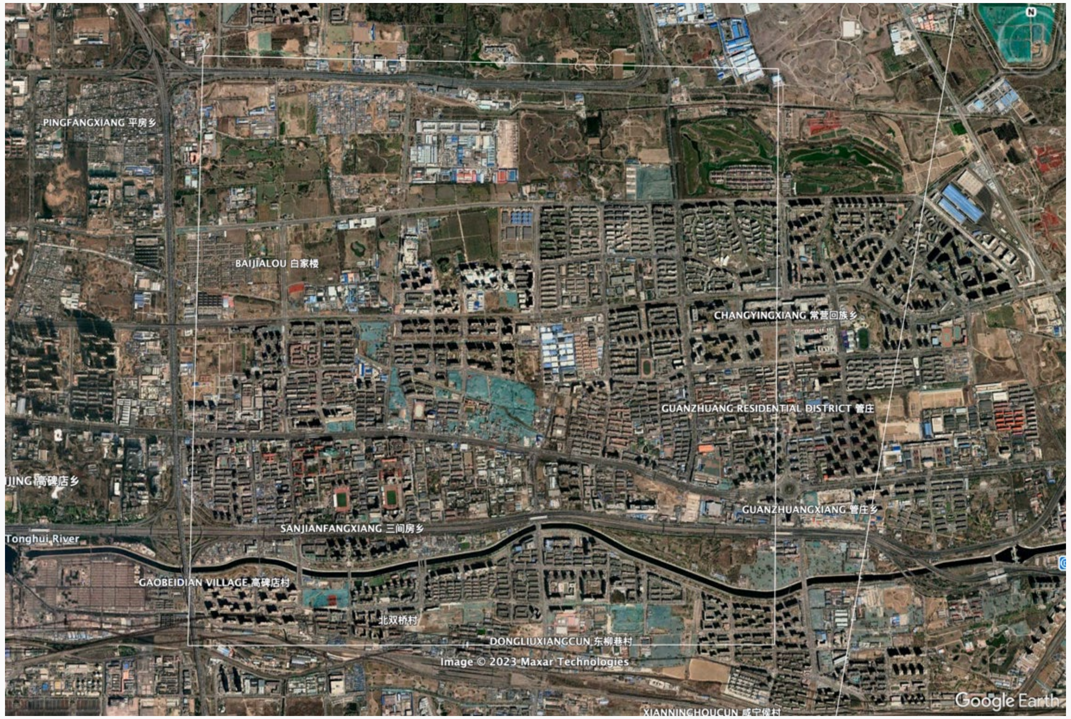
(o) S1 ascending

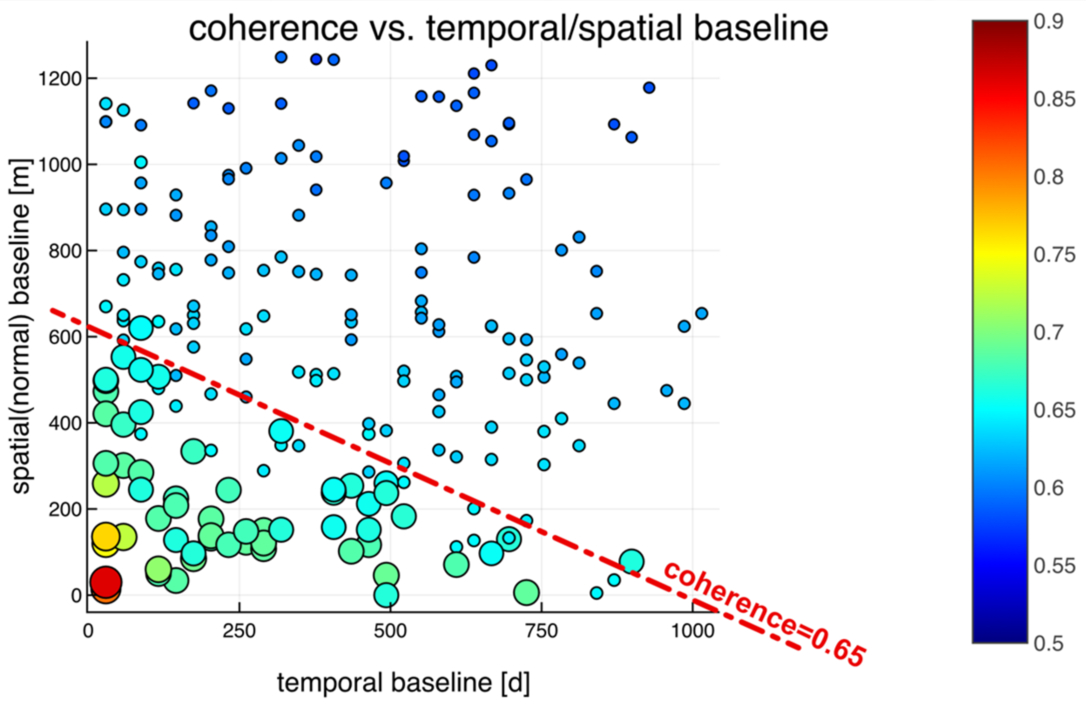
Baselines?


JINGSHAN NEIGHBORHOOD 景山
Qiongdao Island
Tongzi River
DONGHUAMEN SUBDISTRICT 东华门
JIANGUOMEN RESIDENTIAL
XIZONGBU COMMUNITY 西总布社区
DONGDAN 东单
XICHENG DISTRICT 西城区
WEST CHANG'AN AVENUE RESIDENTIAL DISTRICT 西长安街
CHONGWENMEN 崇文门
Image © 2023 Airbus
Google Earth


coherence vs. temporal/spatial baseline
spatial(normal) baseline [m]
temporal baseline [d]
0
250
500
750
1000
200
400
600
800
1000
1200
coherence=0.65
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5

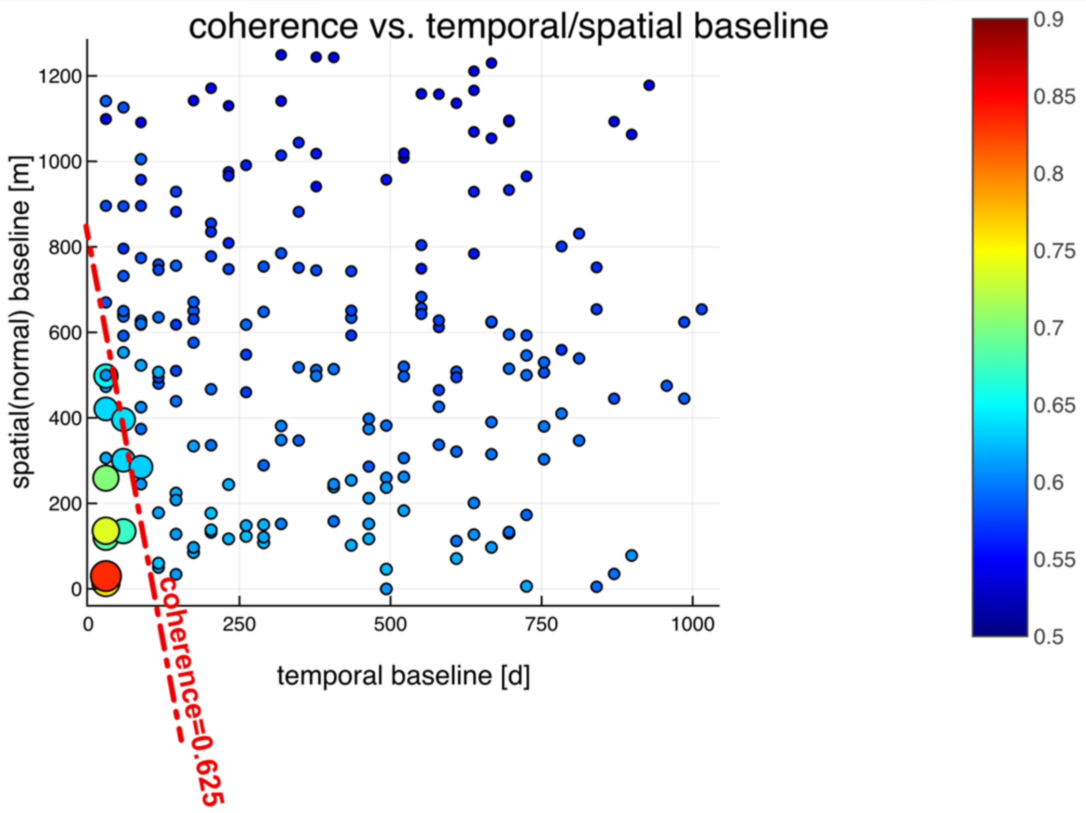
Baselines?


PINGFANGXIANG 平房乡
BAIJIALOU 白家楼
CHANGYINGXIANG 常营回族乡
GUANZHUANG RESIDENTIAL DISTRICT 管庄
GUANZHUANGXIANG 管庄乡
SANJIANFANGXIANG 三间房乡
Tonghui River
GAOBEIDIAN VILLAGE 高碑店村
北双桥村
DONGLIUXIANGCUN 东柳巷村
Image © 2023 Maxar Technologies
Google Earth

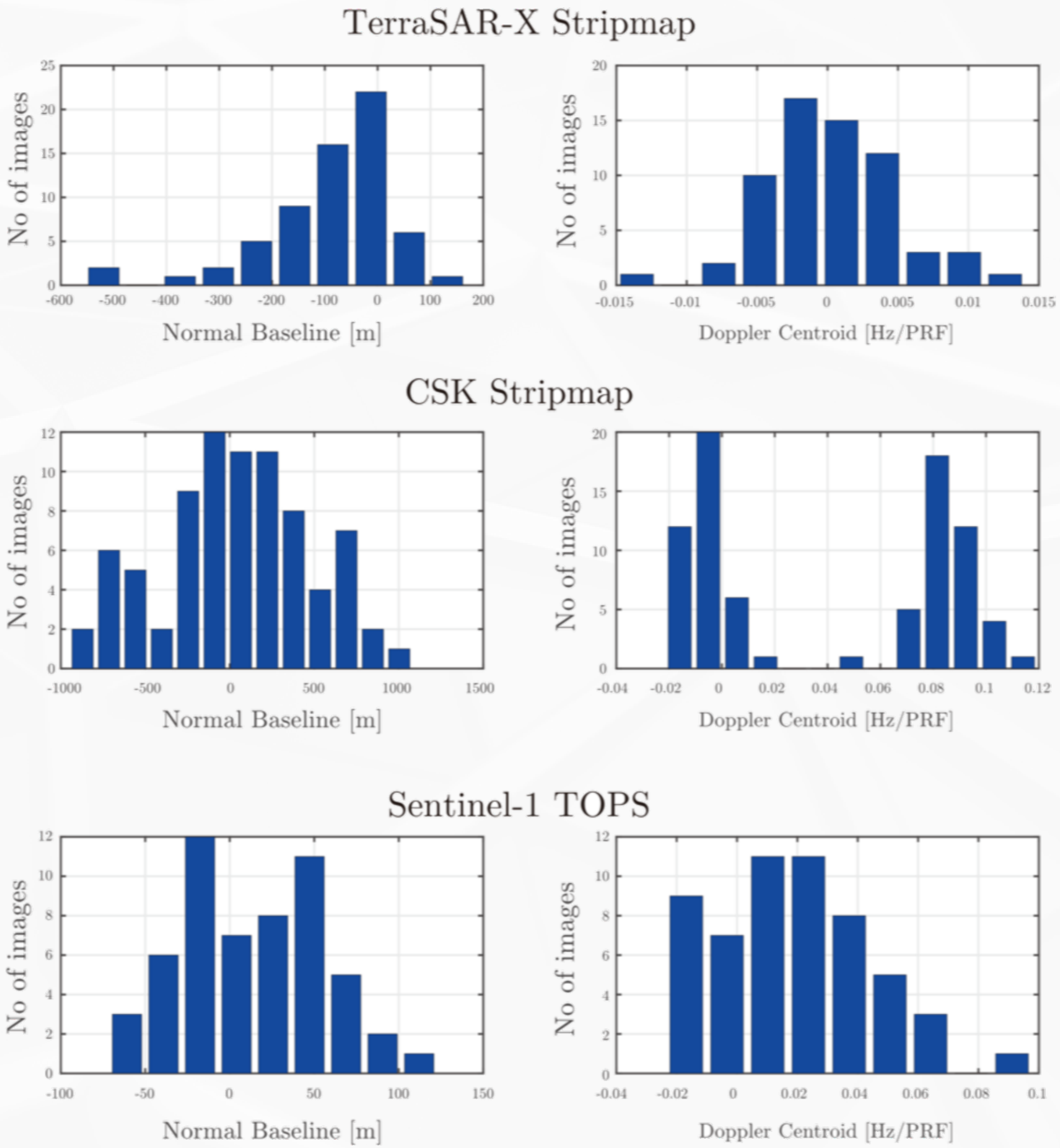

coherence vs. temporal/spatial baseline
spatial(normal) baseline [m]
1200
1000
800
600
400
200
0
temporal baseline [d]
0
250
500
750
1000
coherence=0.65
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5

Baselines?

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY



Baselines?



TerraSAR-X Stripmap
No of images
Normal Baseline [m]
Doppler Centroid [Hz/PRF]
CSK Stripmap
No of images
Normal Baseline [m]
Doppler Centroid [Hz/PRF]
Sentinel-1 TOPS
No of images
Normal Baseline [m]
Doppler Centroid [Hz/PRF]

/04 Next Steps

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

Openness

New in SNAP 9.0.0

SNAP 9 provides several new tools, features and bug fixes to the users. The noteworthy news is highlighted in the following sections. For the full list of changes check our issue tracker: snap9_changelog

Sentinel-1 Toolbox

The Sentinel-1 Toolbox continues to support most SAR missions with updates to the Sentinel-1 format and support for Cosmo-Skymed SG, Gaofen-3 and Spacety. ARD functionality has been enhanced with the addition of a Noise Power Image and Gamma-to-Sigma ratio image in Terrain Flattening and the estimation of noise equivalent beta0, sigma0 and gamma0 in Thermal Noise Removal. InSAR functionality now includes ionospheric estimation and correction using a splitbandwidth approach and retrieval of Vertical and E W motion components from a pair of interferograms. Polarimetric processing now includes Kennaugh Matrix, and Huynen, Krogager, Cameron, Yang decompositions as well as Radar Vegetation Indices.

Openness

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

New in SNAP 9.0.0

SNA
sect

Se

The
Cos
and
The
app
incl

3. Methods

3.1. Pre-Processing

The S1 IW acquisitions are downloaded in their SLC product format from the ESA hub. The data processing is performed using the Radar Interferometric Parallel Processing Lab (RIPPL), a TU Delft's in-house Sentinel-1 InSAR processing tool. **Figure 2** provides an overview of the processing steps performed to obtain the interferometric co... Only the interferograms between the consecutive (12-days interval) image pairs are formed and su... geo-referenced. The backscatter intensity computation includes the radiometric calibration and terrain

RIPPL

- Source
- Commits
- Branches
- Pull requests
- Pipelines

grsradar-tudelft / InSAR Processing

RIPPL

Clone

The [R]adar [I]nterferometric [P]arallel [P]rocessing [L]ab.

main | Files | Filter files

/

Name	Size	Last commit	Message

Openness

New in SNAP 9.0.0

3. Methods

Open Access | Article

GECORIS: An Open-Source Toolbox for Analyzing Time Series of Corner Reflectors in InSAR Geodesy

by Richard Czikhardt [1,*], Hans van der Marel [2] and Juraj Papco [1]

1 Department of Theoretical Geodesy and Geoinformatics, Faculty of Civil Engineering, Slovak University of Technology, Radlinskeho 11, 810 05 Bratislava, Slovakia

2 Department of Geoscience and Remote Sensing, Delft University of Technology, 2628 CN Delft, The Netherlands

* Author to whom correspondence should be addressed.

Remote Sens. **2021**, *13*(5), 926; https://doi.org/10.3390/rs13050926

Received: 28 January 2021 / Revised: 23 February 2021 / Accepted: 24 February 2021 / Published: 2 March 2021

(This article belongs to the Section Remote Sensing Image Processing)

Download | Browse Figures | Versions Notes

We aim at openness of the data, of the tools, and reproducible results.

China launches Gaofen-3-03 payload on CZ-4C from Jiuquan

written by Adrian Beil | April 7, 2022

China launched another Gaofen satellite Thursday morning to a Sun-Synchronous Orbit (SSO). The launch was carried out on a Chang Zheng 4C from the Jiuquan Satellite Launch Center in China. The liftoff time was confirmed to be 7:47 AM local time on April 7 (23:47 UTC on April 6).

The destination of today's mission is a 738 x 745 km orbit with an inclination of 98.4°.

The Gaofen 3 satellites were developed and constructed by the China Academy of Space Technology (CAST). CASt is part of the China Aerospace Science and Technology Corporation (CASC), which is the primary state-owned contractor for activities regarding the Chinese space program.

Missions

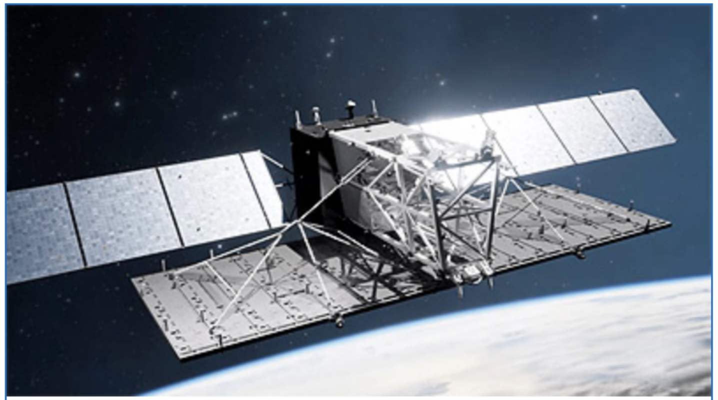
GF-3 Constellation

- AIS supports on GF-3B/C
- Switching to TOPS mode for wide swath
- On-board Data Processing
- InSAR as a major application

西北工業大學 NORTHWESTERN POLYTECHNICAL UNIVERSITY

Ludi Tance 1-01A, 1-01B (L-SAR 01A, 01B)

Ludi Tance 1-01 (**LuTan**) is a series of Chinese civilian remote sensing satellites.



Ludi Tance 1-01A

The weight of the 01-group A satellite of Land Exploration-1 is about 3.2 tons, and the total area of the SAR antenna exceeds 33 square meters. It is currently the largest SAR satellite in orbit in China. The satellite operates in a quasi-sun-synchronous orbit at an altitude of 607 kilometers, and is equipped with an advanced L-band multi-polarization and multi-channel SAR payload. It has all-day, all-weather, and multi-mode Earth observation capabilities. The satellite is mainly used for effective monitoring of geological environment, landslides and earthquake disasters.

The first satellite, **Ludi Tance 1-01A** was launched on 26 January 2022 on a CZ-4C rocket from China's Jiuquan space center.

The second satellite, **Ludi Tance 1-01B** is followed a month later.

Nation:	China
Type / Application:	Earth observation
Operator:	
Contractors:	CAST
Equipment:	L-band SAR
Configuration:	
Propulsion:	
Power:	2 deployable solar arrays, batteries
Lifetime:	8 years
Mass:	~3200 kg
Orbit:	595 km × 602 km, 97.80°

Missions

LuTan-1 Constellation

- High resolution (3m) L band
- Bistatic
- Full-polarimetric
- Specifically designed for InSAR
- Currently completed commissioning phase
- … …

西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

X-band bistatic mission

?

China launches first geosynchronous orbit radar satellite

Andrew Jones August 14, 2023

A Long March 3B lifts off from Xichang on Aug. 12, 2023, carrying the Ludi Tance-4 (01) satellite into GTO. Credit: Ourspace

HELSINKI — China launched what is thought to be the world's first geosynchronous orbit synthetic aperture radar satellite on Saturday.

A Long March 3B rocket lifted off from Xichang Satellite Launch Center in southwest China at 1:36 p.m. Eastern (1736 UTC) Aug. 12. The Land Exploration-4 01 (Ludi Tance-4 (01)) satellite successfully entered geosynchronous transfer orbit, the China Aerospace Science and Technology Corp., (CASC) announced within an hour of liftoff.

Missions

LuTan-4 01

- First geosynchronous SAR satellite
- Launched successfully in August 2023
- L-band
- 20m resolution
- Aim for InSAR?

西北工業大學 NORTHWESTERN POLYTECHNICAL UNIVERSITY

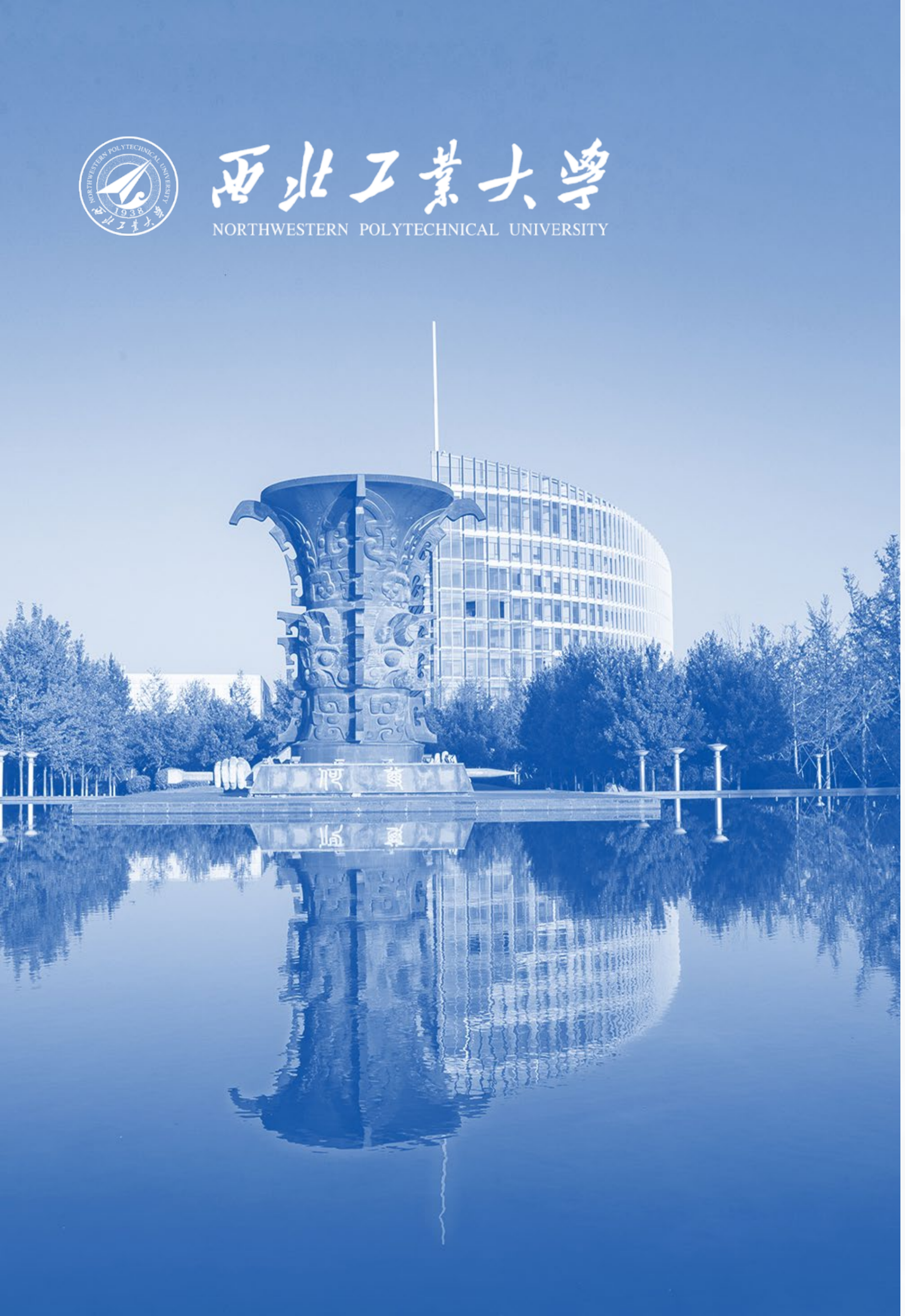
Takeaway Message

Process & Results

- GF-3 is showing great potential in InSAR and MTInSAR applications, first results already promising;
- Processing flow still needs to be improved for InSAR purpose;

Next Steps

- We are now doing more experiments to understand the optimized configurations for the constellation for InSAR purpose;
- We aim at promoting more InSAR and MTInSAR for ongoing/future China SAR missions;
- We aim at developing/sharing data/tools for processing such data.



Thank

Yuxiao QIN

- hi@yuxiaoq.in
- yuxiao.qin@nwpu.edu.cn