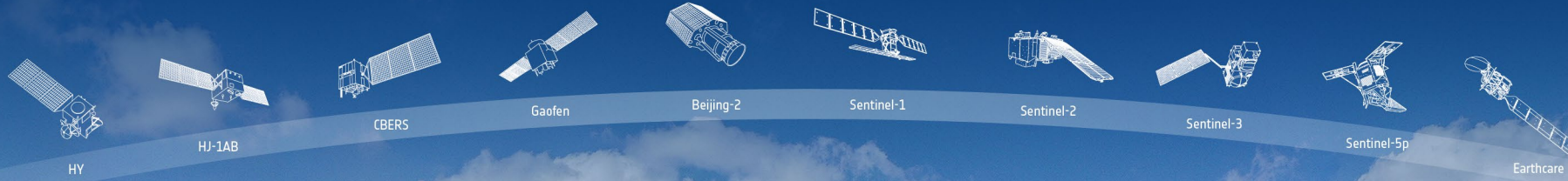




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2025 DRAGON 6 SYMPOSIUM

14-18 JULY 2025

PROJECT ID. 95387

MULTI-SENSOR REMOTE SENSING FOR CULTURAL HERITAGE CLIMATE CHANGE RESILIENCE



2025 Dragon 6 Symposium



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2025-7-17

ID. 95387

PROJECT TITLE: MULTI-SENSOR REMOTE SENSING FOR CULTURAL HERITAGE CLIMATE CHANGE RESILIENCE

PRINCIPAL INVESTIGATORS: TIMO BALZ & GINO CASPARI

CO-AUTHORS: ROSA LASAPONARA, FULONG CHEN, JINGHUI WANG, BAHAA MOHAMADI

PRESENTED BY: TIMO BALZ



UNESCO World Heritage Sites and many other important archaeological and cultural locales face increasing risk through climate change related factors

- These include flood damage, the melting of permafrost areas, desertification, storm intensity increase and many more.
- Remote sensing is an indispensable tool to assess these risks and safeguard our shared cultural heritage against destruction.
- The project “Multi-Sensor Remote Sensing for Cultural Heritage Climate Change Resilience” will address gaps in method development and assess the climate change risk for a number of important heritage sites around the world in a multitude of complex environmental settings, making the application of multi-sensor RS key to success.



Dr. Gino Caspari

Archaeologist focusing on human-environmental interaction

Extensive remote sensing and GIS experience

University of Bern

Excellent archaeology department covering Prehistory, Near Eastern Archaeology, and Mediterranean Archaeology.

Close ties to the Oeschger Climate Centre



^b
UNIVERSITÄT
BERN





The Institute of Methodologies for Environmental Analysis (IMAA-CNR) was officially created in 2002. The IMAA focuses on better harmonizing and integrating in-situ and remote observations and to develop innovative methods for environmental data analysis and modelling.



Prof. Rosa Lasaponara

Research Director and Chief of Argon Lab

Prof. Lasaponara is a world-renowned scientists in the fields of remote sensing and cultural heritage protection.

Long-term cooperation with AIRCAS



武汉大学
WUHAN UNIVERSITY



The State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS) of Wuhan University is the leading research facility in spatial information sciences in Wuhan University, which is the worldwide highest ranked university in remote sensing for eight consecutive years.

- Timo Balz, Professor for radar remote sensing, focusing on InSAR technologies and international education
- Dayuan Liu, PhD student, working on SAR coherence analysis
- Cem Sonmez Boyoglu, int. PhD student, working on using SAR for cultural heritage protection



HIST, an international academic institution under the auspices of UNESCO, offers an authoritative international communication platform for world heritage research using space technology.

- Fulong Chen, professor, focuses on remote sensing for cultural heritage and UN SDGs progress assessment;
- Meng Zhu, assistant professor, with research interests of radar interferometry for disasters and architectural heritage;
- Hongqiang Li, PhD student, pursuits in cultural heritage monitoring and risk mapping using developed InSAR and MTInSAR algorithms.



Guizhou University (GZU), one of China's "Project 211" as well as "Double First-Class" initiative university.

The Mining College of Guizhou University offers the first-level discipline master's program of Surveying and Mapping with directions of Photogrammetry and Remote Sensing, Geodesy and Survey Engineering, and Cartography and Geographic Information Engineering.

- **Jinghui Wang** , Associate Professor, Mining College of Guizhou University
 - focusing on Stereo SAR, SAR image dense matching and InSAR technologies.
 - young scientist of Dragon-4 "Topographic Mapping – Validation (32278_1)", 2016-2020.
 - got PhD degree as joint PhD student of LIESMARS of Wuhan University & ifp of University of Stuttgart.



Shaoxing University was founded in 1909. Shaoxing University boasts 15 schools, with four disciplines—computer science, engineering, chemistry, and environmental science—ranking in the top 1% of the ESI.

The Institute of Artificial Intelligence in Shaoxing University is chaired by an IEEE Fellow, a member of the Canadian Academy of Engineering. The institute houses research equipment such as handheld, unmanned aerial vehicles, and vehicle-mounted LiDAR.

- **Bahaa Mohamadi**, Associate Professor, Institute of Artificial Intelligence, Shaoxing University, Shaoxing City, Zhejiang Province, China.
 - GeoAI applications in optical and SAR imagery, and GIS modeling.
 - Worked on international projects in the industry and the academic fields in China, Egypt, Libya, Sudan, Kuwait, Peru, and Mexico.



- **Methods**
 - Multi-Sensor Fusion
 - Change Detection
 - Focus: Coherence Change Detection
 - Target Recognition
 - Distributed Scatterer Interferometry
- **Sites of Interest**
 - Wushaoling Great Wall
 - Jiayuguan Great Wall
 - Mongolian Glacial Site
 - Metaponto
 - Etc.

Coherence Estimation using Machine Learning - WHU



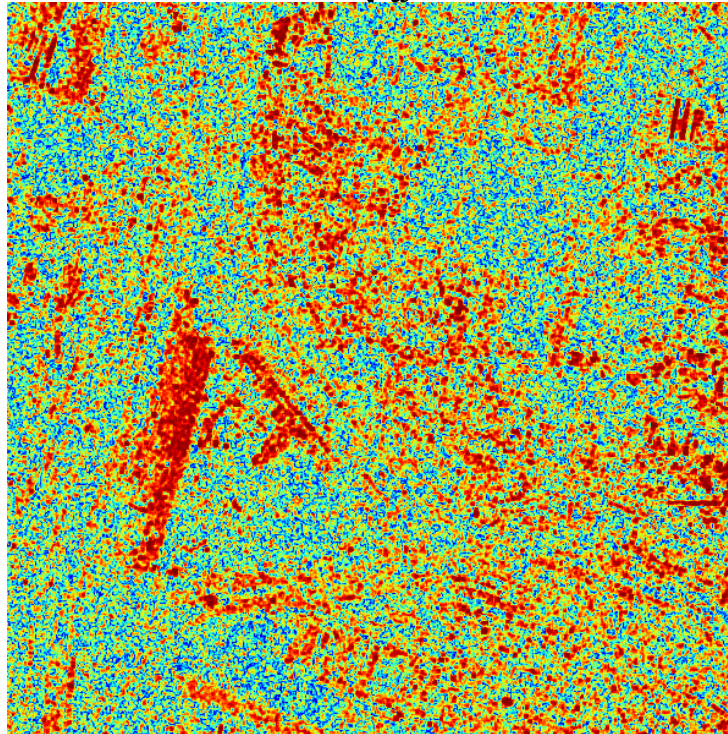
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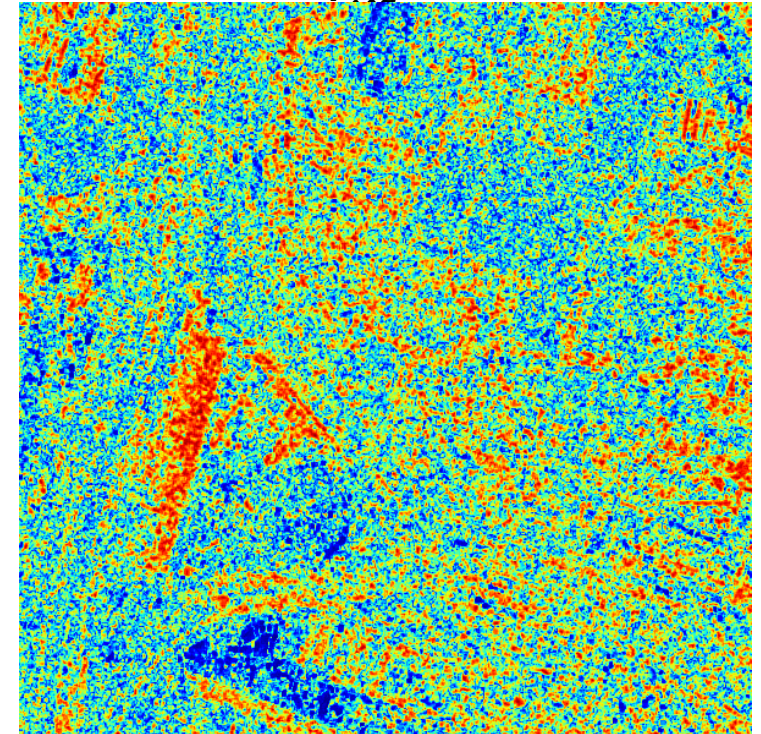
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γ_a



γ_{ML}



Looting Hole Detection – Wuhan University



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2 x 2 m



3 x 1.2 m

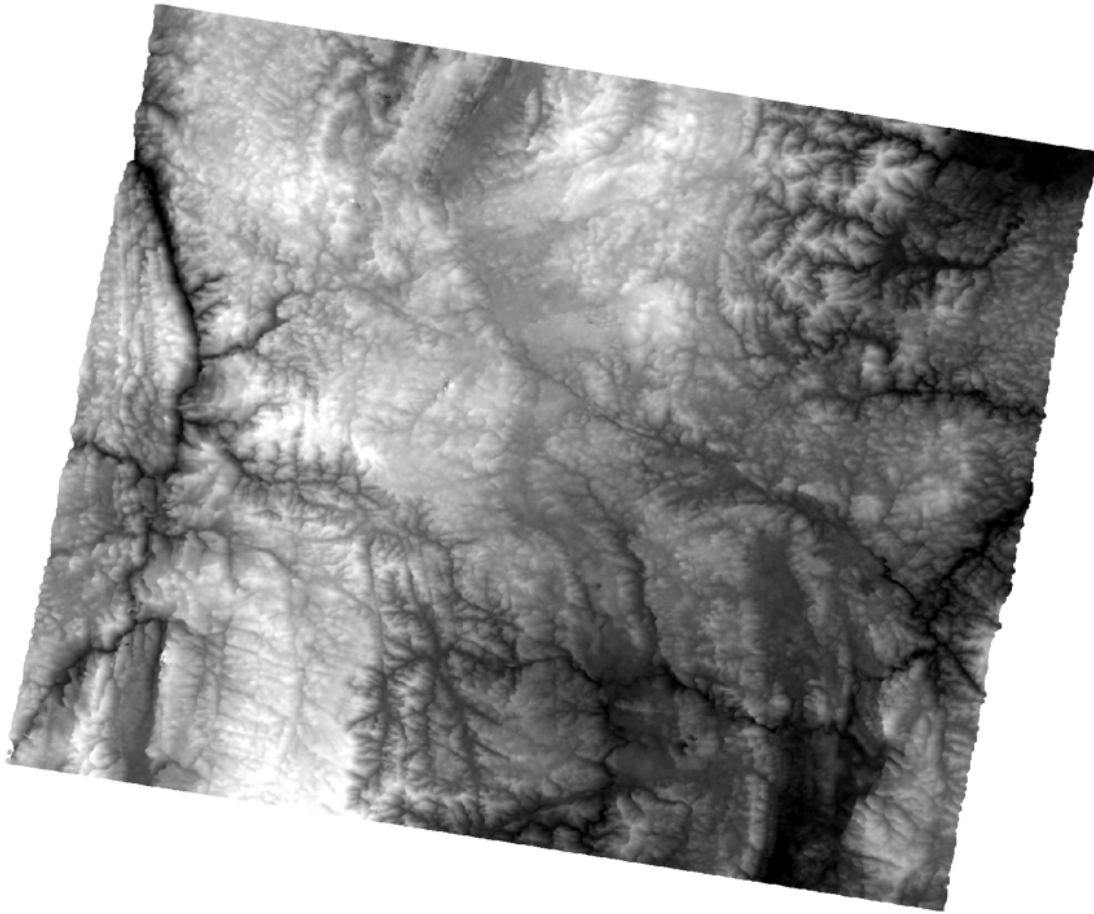
SAR-Optical Fusion – Wuhan University



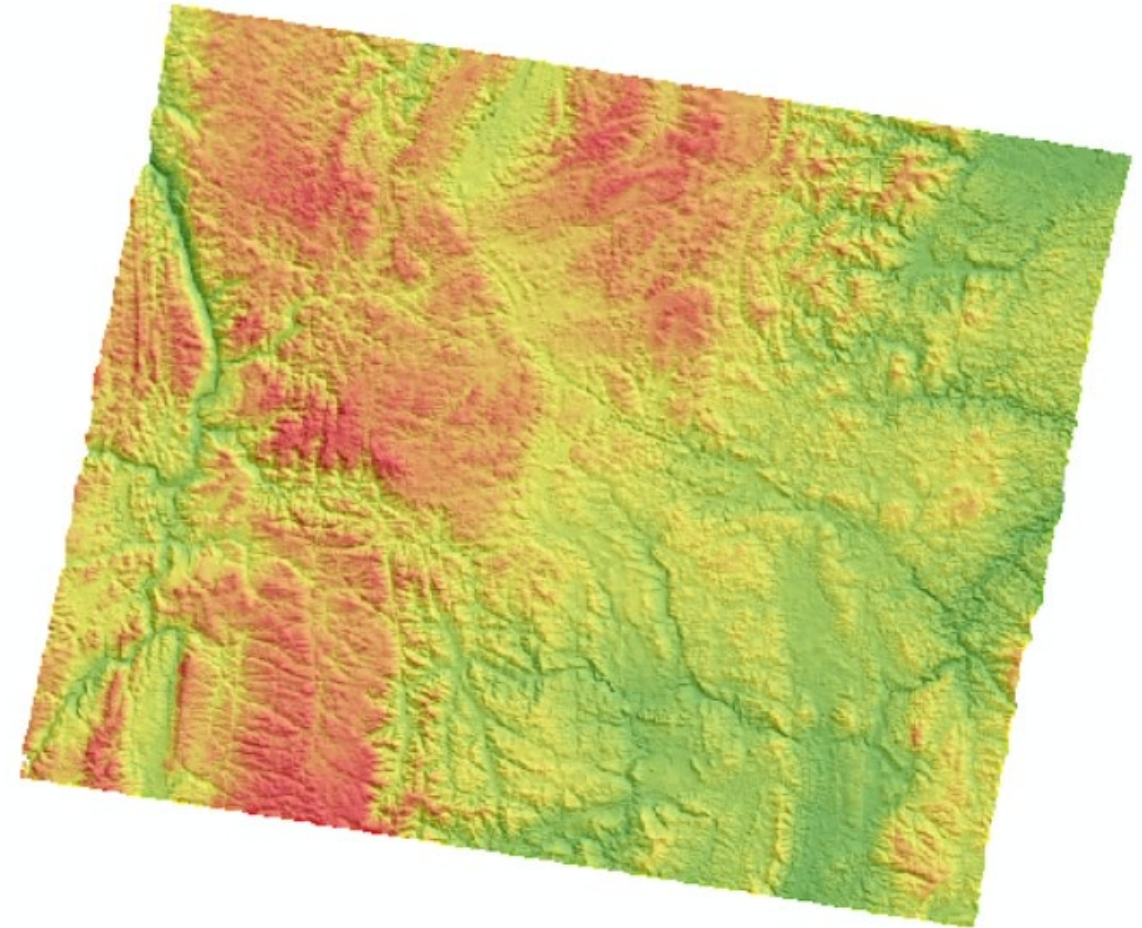
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DEM



DEM hillshade map

Distributed Scatterer Interferometry – WHU



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Metaponto Fire Damage Detection – CNR, Italy



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Metaponto Fire Damage Detection – CNR, Italy



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S2 for parasite identification in the Colosseum historical Pinus trees– CNR, Italy



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S2 for parasite identification from single pixel to site map - CNR, Italy



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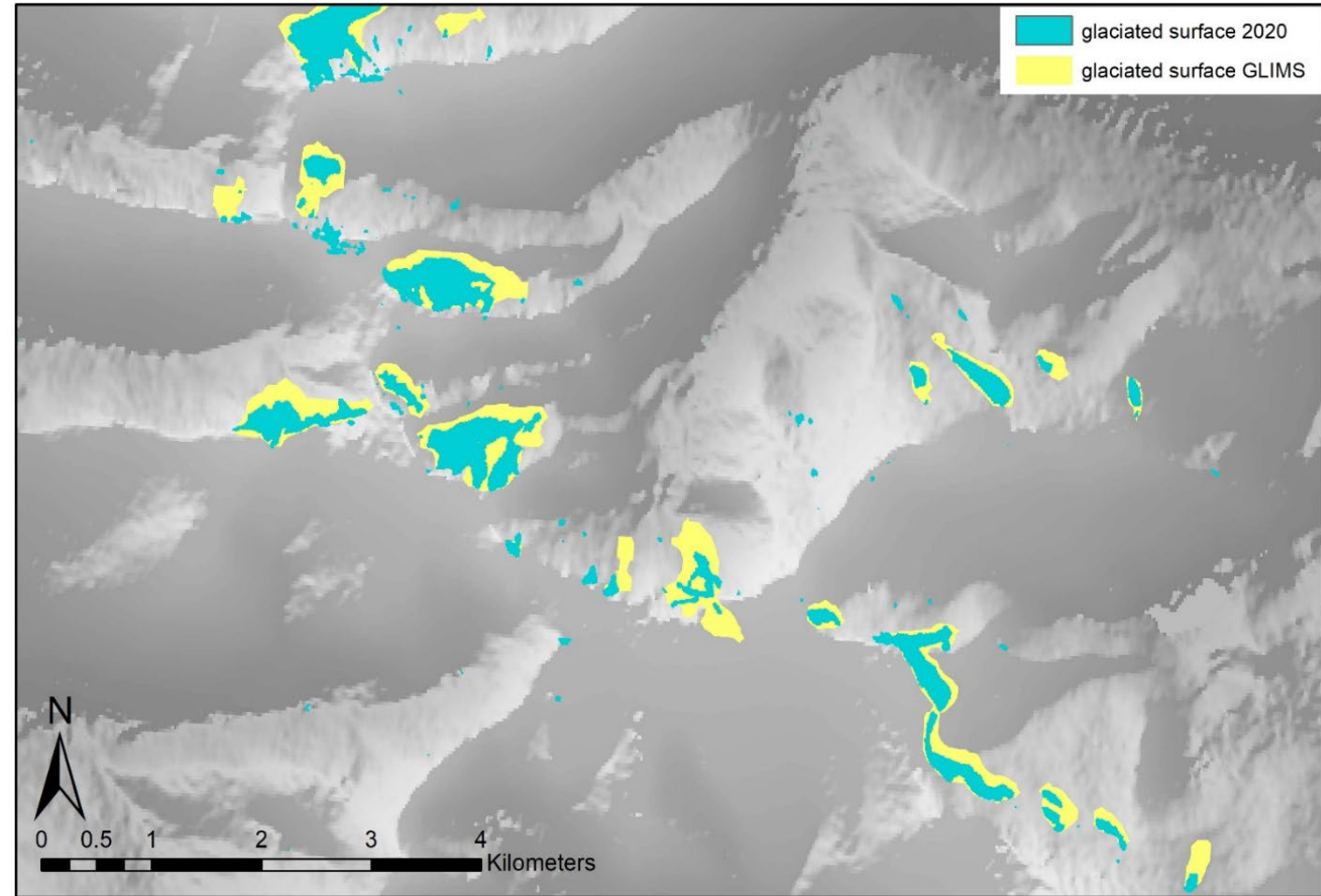
Glacial Sites in Mongolia – University of Bern



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Sentinel 2A ice patch extent estimation and shrinkage.

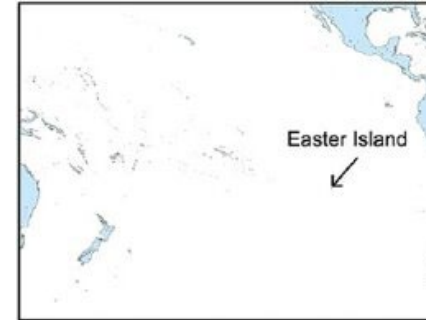
Decaying Moai Roads Rapa Nui – University of Bern



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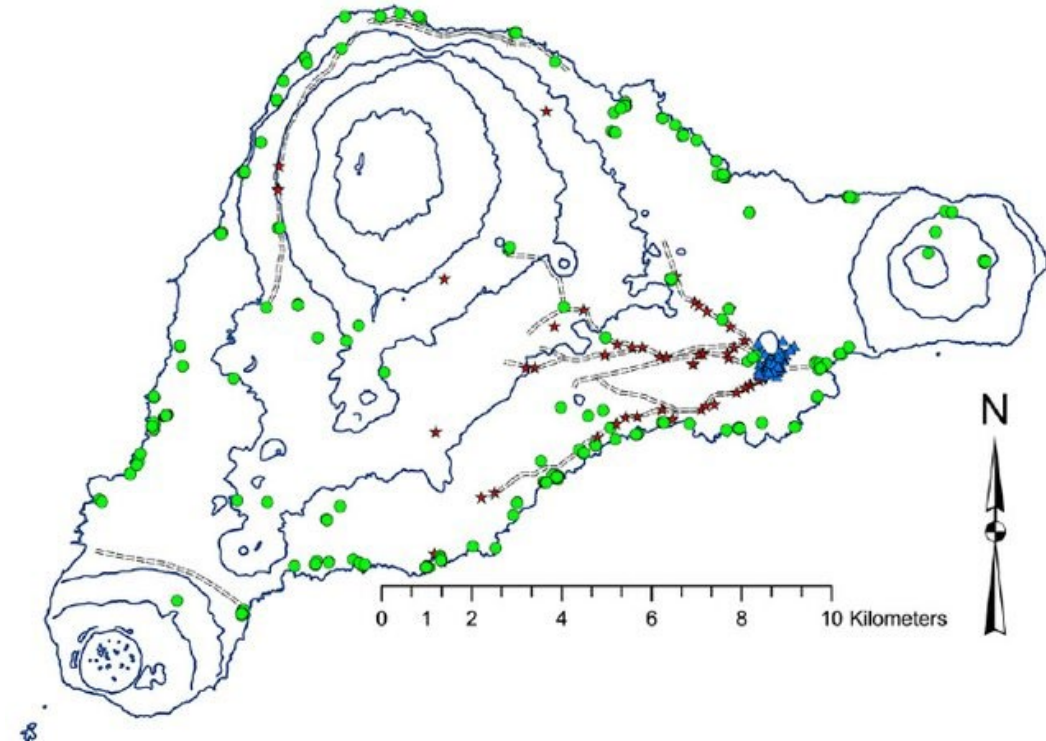


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Easter Island
↙

- Completed Moai at Final Destination
- ▲ Unfinished Moai at Rano Raraku Quarry
- ★ Unfinished Moai in Transit (i.e., road moai)
- Identified Moai Road
- 100 Meter Elevation Contours





Dayuan	Liu	Wuhan University
Meng	Zhu	Aerospace Information Research Institute
Hongqiang	Li	Aerospace Information Research Institute
Wenyuan	Zhang	Aerospace Information Research Institute
Nicodemo	Abate	Consiglio Nazionale delle Ricerche
Dario	Gioia	Consiglio Nazionale delle Ricerche
Antonio	Minervino	Consiglio Nazionale delle Ricerche
Daoji	Long	Guizhou University
Lujun	Li	Guizhou University
Zukuan	Yu	Guizhou University

Dragon 6 EO Data Delivery



Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since June 2024) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA /Copernicus Missions	No. Scenes	ESA Third Party Missions	No. Scenes	Chinese EO data	No. Scenes
1. Sentinel-1	120	1. TerraSAR-X	40	1. WH-1	2
2.Sentinel-2	40	2.		2. LT-1	8
3.		3.		3.	
4.		4.		4.	
5.		5.		5.	
6.		6.		6.	
Total:		Total:		Total:	
Issues:		Issues:		Issues:	

Chinese Young Scientists contributions in Dragon 6



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Name	Institution	Poster title	Contribution including period of research
Liu, Dayuan	Wuhan University	Robust SAR Coherence Estimation for Low-Coherence Regions Using Machine Learning	Poster presentation, 2024-now
Cem Boyoglu	Wuhan University	EXPERIMENT, SIMULATION AND VERIFICATION OF LOOTING HOLES WITH SAR	Poster presentation, 2024-now
Aigerim Sultanbekova	Wuhan University	SAR-Optical Image Matching Enhancement Using Conditional Generative Adversarial Networks	Poster presentation, 2024-now
Gao, Ruonan	Wuhan University	A Sample Spatiotemporal Generation Method Using Optical-SAR Fusion For Crop Classification In Cloudy And Rainy Regions	Poster presentation, 2024-now

Chinese Young Scientists contributions in Dragon 6



Name	Institution	Poster title	Contribution including period of research
Mostafa Ewais	Wuhan University	Multi-Temporal InSAR Analysis of Karst-Induced Subsidence and Its Effects on Structural Stability at Gharbanyiat Area, Alexandria, Egypt	Poster presentation, 2024-now
Long,Daoji	Guizhou University	Research and prediction of subway subsidence in Guiyang City are conducted based on time-series InSAR technology.	2024-now



- Coherence Estimation with ML (Liu, Dayuan)
- Looting Detection (Cem Boyoglu)
- SAR-Optical Fusion with cGAN (Aigerim Sultanbekova)
- Research and prediction of subway subsidence in Guiyang City are conducted based on time-series InSAR technology (Long, Daoji)

Coherence Estimation with ML

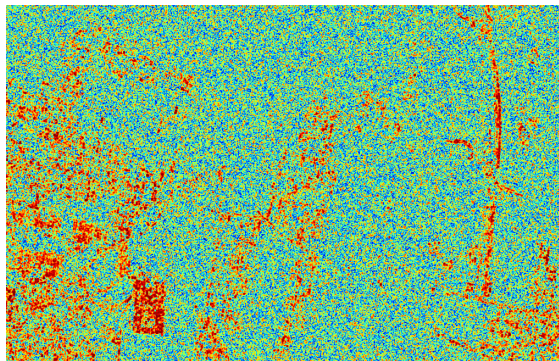
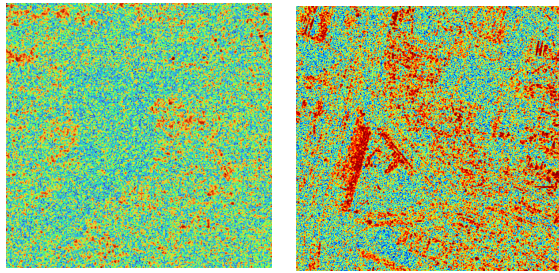


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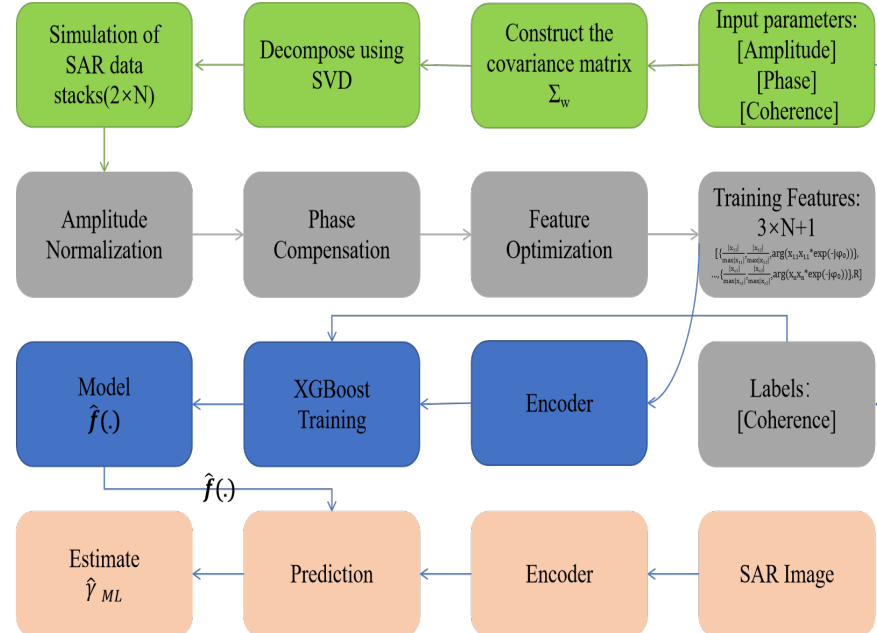


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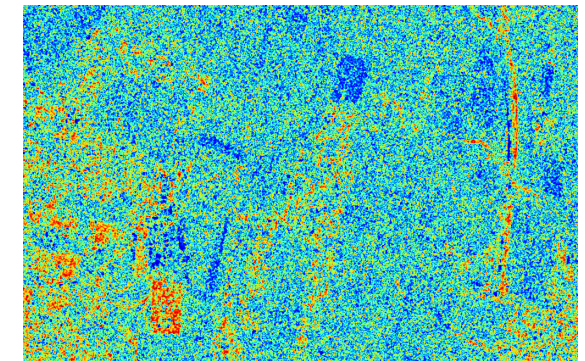
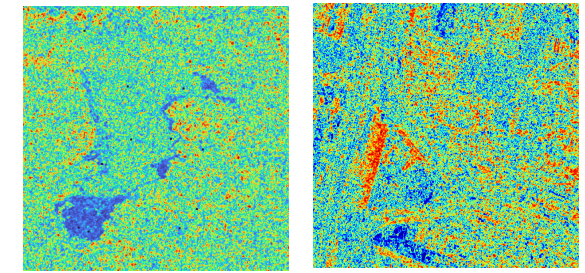
- ◆ SAR images are sensitive to noise in low coherence areas. Traditional coherence estimators have large deviations under low coherence and small sample conditions and cannot reliably characterize the characteristics of changing areas.
- ◆ A novel method that integrates machine learning with weighted coherence statistics is proposed, overcoming the limitations of the equal variance assumption in SAR imagery.



Unclear change regions



A machine learning framework for improved SAR coherence estimation



Coherence estimation results based on ML

Improves the robustness of coherence estimation and enhances contrast specifically in low-coherence regions.

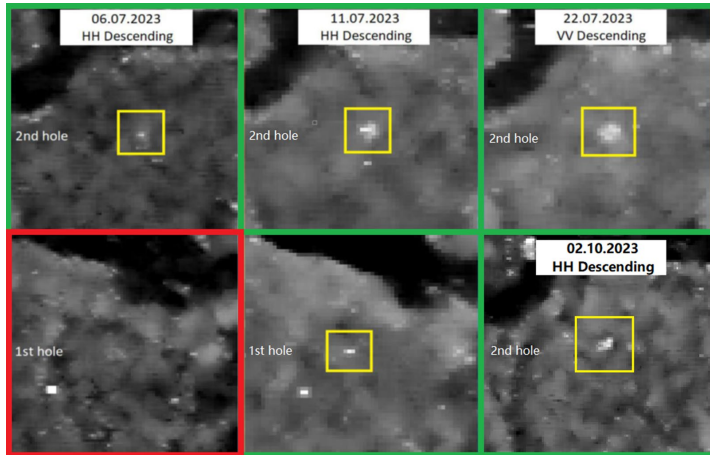
Looting Hole Detection



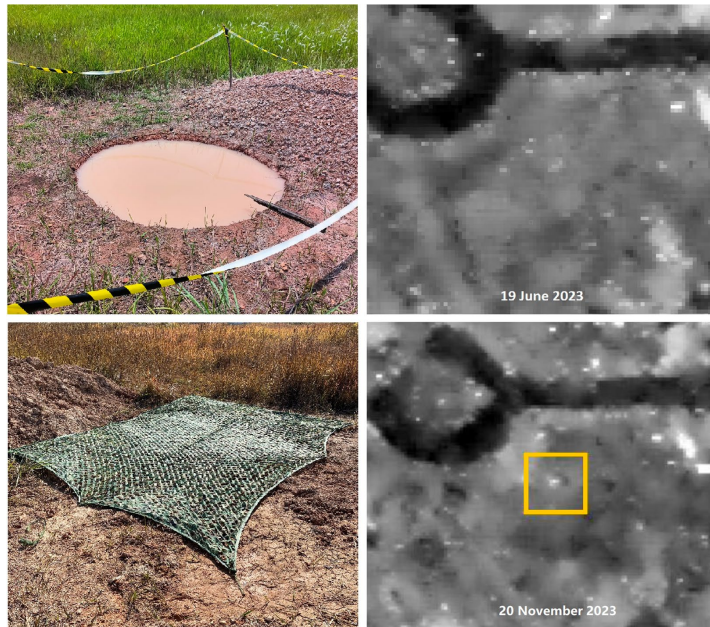
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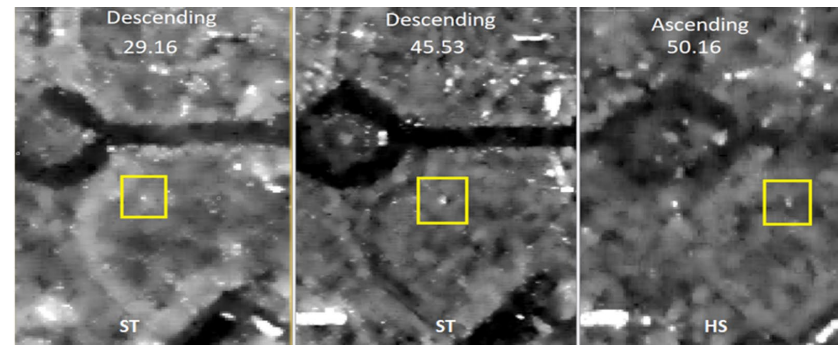


Best results from different dates where we can clearly detect the holes.

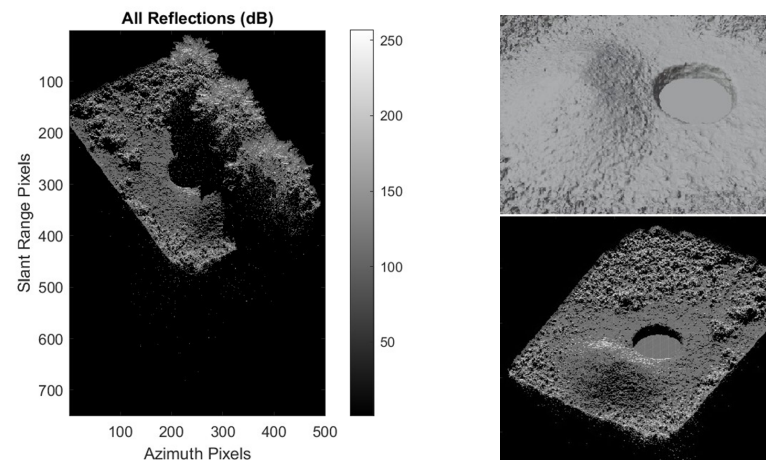


Top: Image taken after the rainfall. Water filled hole become invisible in SAR Picture.
Bottom: Camouflage covered hole still visible in SAR image.

After collecting SAR images, we realized that it was mostly in descending images where we can see the hole. That helped us to realize that location of the soil waste was blocking the signals since it was on the west of the hole. To verify that, we moved the soil waste to the east of the hole and then collected TerraSAR-X image. In the first image we received – even that it was HS- we were able to see the hole.

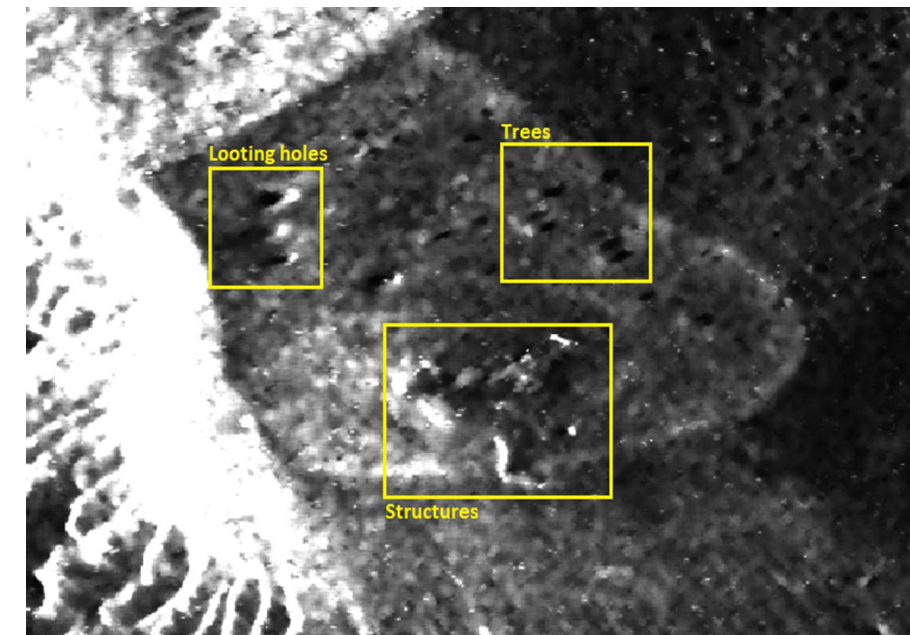


Results from descending and ascending images. Ascending image shows how hole is visible after moving the soil waste



Left : 2nd looting hole with 2x2m size, under the shadow of tree, added in Blender software.
Top right: Modified blender model, Top left: RaySAR simulation result of the modified model.

SAR images from Zeugma ancient city showed us that in real scenario of looting hole detection, there is a specific backscatter difference between below ground level and above ground level. As you can see below, difference between holes and trees are totally opposite. While trees have strong backscatter first and then shadow behind it, holes have totally opposite of it, first shadow, then strong backscatter.



Ascending SAR image of Zeugma ancient city, Belkis Hill.

SAR simulation results was promising enough to use for future studies when we need a training data for small scale looting holes. Besides that, realizing the importance of location of the soil waste and how SAR can penetrate camouflage was one of the best knowledge we achieved from this study. Real pits from Zeugma ancient city helped us to understand backscatter geometry of holes in SAR images clearly. For the future studies, using optical images together with SAR images can increase the quality of the result.

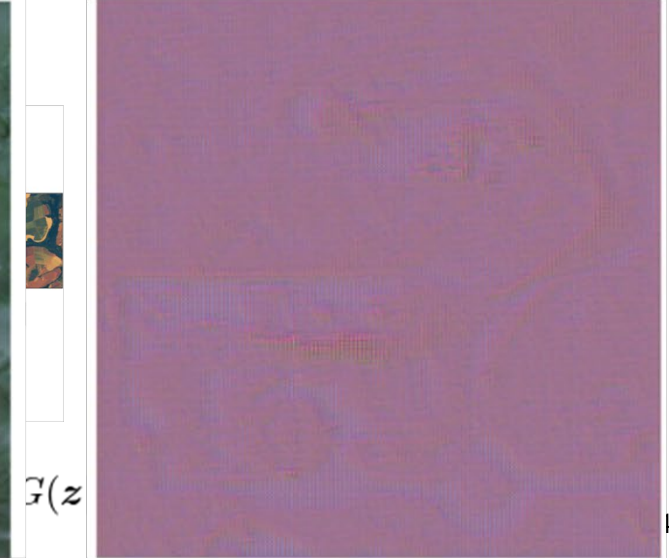
SAR-Optical Image Matching Enhancement Using

Cond

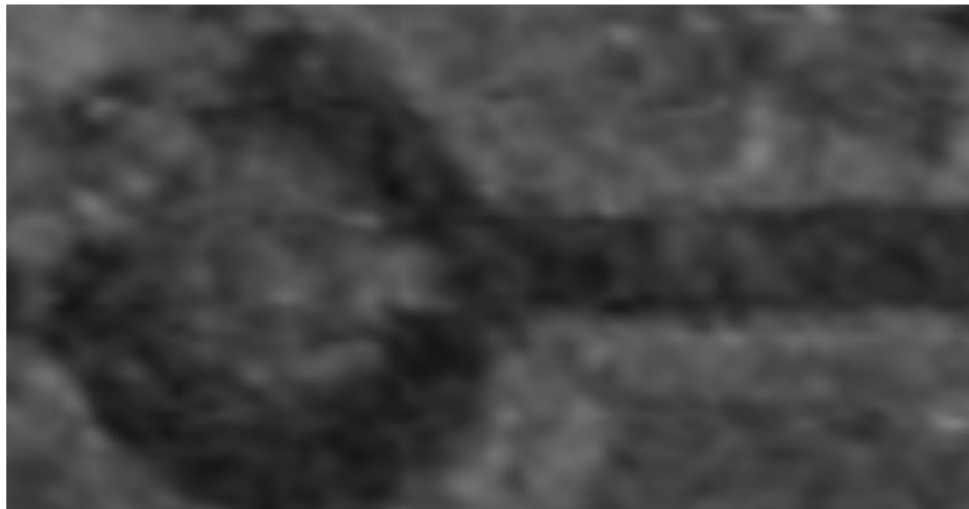
RESULT

Top: Outputs of cGANs with two different Encoder-Decoder Architecture. Left to Right: SAR image, Standard Unet Generated Image, UNet with Skip Connections Generated Image

Bottom: Zoomed images to see the gradient. Left to Right: SAR image, UNet with Skip Connections Generated Image



; Lee et al., 2021)



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SAR-Optical Image Matching Enhancement Using Conditional Generative Adversarial Networks (cGANs)

RESULTS

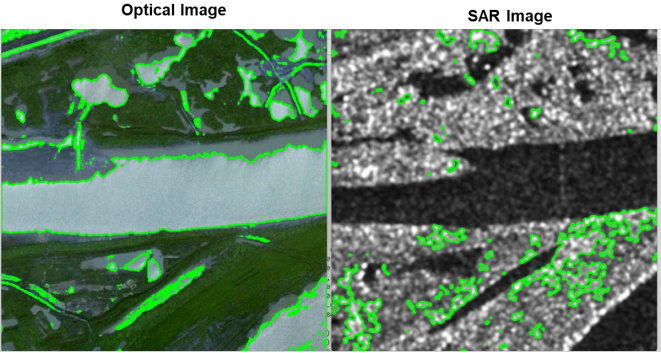


Figure 1 . Shape and contour-based matching

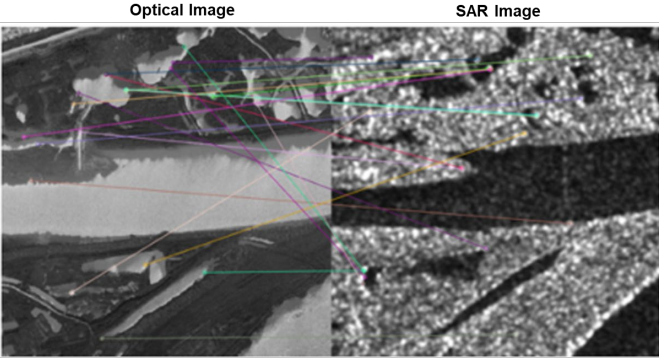


Figure 2. Feature based: SIFT and RANSAC

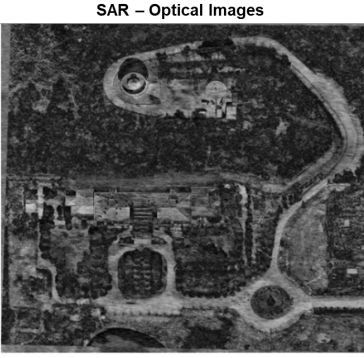


Figure 3. Pixel-wise Absolute Difference

Method	Evaluation
Shape and contour-based matching	Matching score 0.94
Feature based: SIFT and RANSAC	Structural similarity indices (SSIM) 0.10
Pixel-wise Absolute Difference	Score 0.67

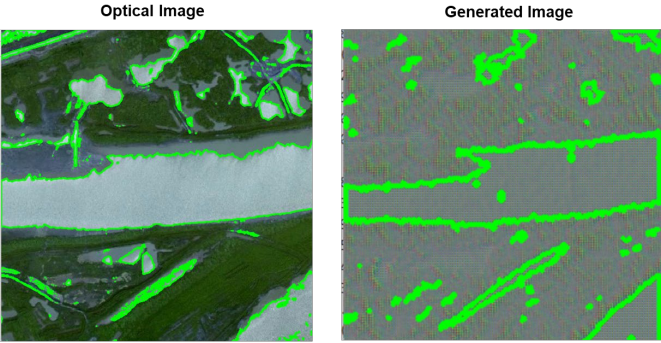


Figure 4. Shape and contour-based matching

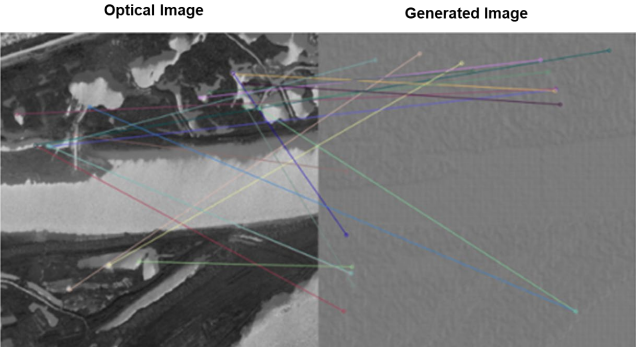


Figure 5. Feature based: SIFT and RANSAC

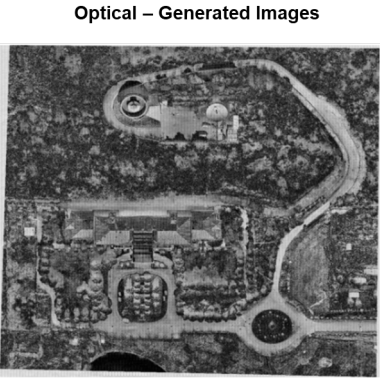


Figure 6. Pixel-wise Absolute Difference

Method	Evaluation
Shape and contour-based matching	Matching score 0.94
Feature based: SIFT and RANSAC	Structural similarity indices (SSIM) 0.20
Pixel-wise Absolute Difference	Score 0.81



balz@whu.edu.cn