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China Science and Technology Exchange Center



→ THE EUROPEAN SPACE AGENCY

2025 DRAGON 6 SYMPOSIUM

14-18 JULY 2025

[PROJECT ID. 95316]

PERCEIVING NATURAL AND ANTHROPOGENIC DISASTER CONDITIONS
AND ASSESSING RISKS IN COASTAL REGIONS THROUGH ARTIFICIAL
INTELLIGENCE, TRADITIONAL AND NOVEL SYNTHETIC APERTURE RADAR
TECHNOLOGIES (PREDICTOR)

DRAGON EUROPEAN PI: ANTONIO PEPE
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WEDNESDAY, 16/JULY/2025

ID. 95316

PROJECT TITLE: PERCEIVING NATURAL AND ANTHROPOGENIC DISASTER CONDITIONS AND ASSESSING RISKS IN COASTAL REGIONS THROUGH ARTIFICIAL INTELLIGENCE, TRADITIONAL AND NOVEL SYNTHETIC APERTURE RADAR TECHNOLOGIES (PREDICTOR**)**

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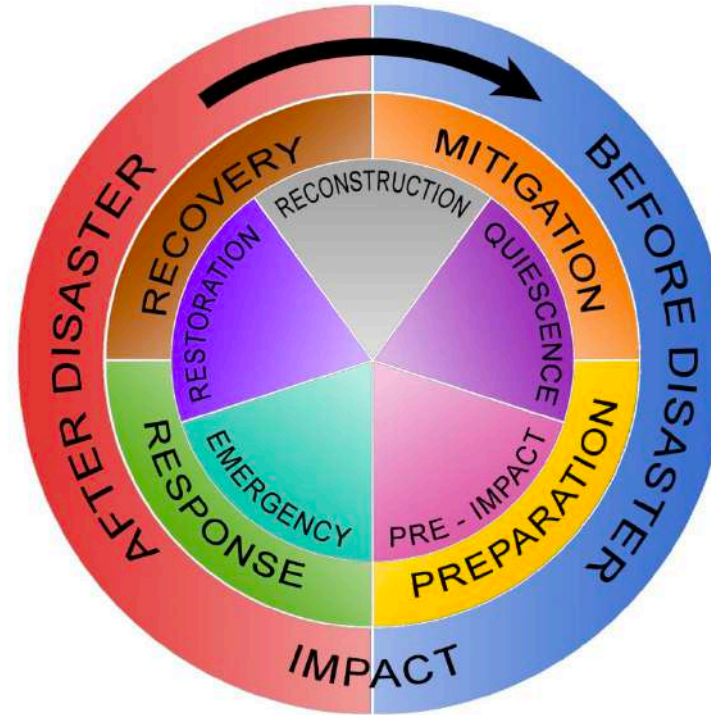
- ❖ PREDICTOR will provide analyses with **novel and traditional** synthetic aperture radar (SAR) technologies applied to zones (i.e., the Mediterranean basin and the Eastern Chinese Coast) subjected to natural (e.g., sea level rise, flooding) or anthropogenic (e.g., ground subsidence, coastal deterioration, etc.) disasters.
- ❖ PREDICTOR will quantify the combined risks due to the SLR, urban growth, coastal land deterioration/erosion, urban and coastal ground deformations, and other natural and anthropogenic phenomena.
- ❖ It will exploit multi-polarized/multi-satellite SAR data to develop some new SAR-based methods, also assisted by AI, to enhance our capability to detect and analyze changes occurring in coastal regions.
- ❖ The project will develop and apply new indicators based on SAR data that could characterize/quantify the different condition risks to which the population is exposed in highly urbanized coastal cities.



- ❖ Activity 1: Detecting Earth's Surface Changes for Disaster Risk Analyses
- ❖ Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR
- ❖ Activity 3: Monitoring Coastal and Lake Environments
- ❖ Activity 4: Assessing the combined risks of coastal megacity



Activity 1: Detecting Earth's Surface Changes for Disaster Risk Analyses



Copernicus Sentinel-1 (and/or CSK, CSG, PAZ data) related to disaster-prone

regions in Europe and China are going to be processed and analyzed.

The goal is to support all phases of the disaster management cycle—from risk mitigation and early warning to response and recovery—through systematic change detection and monitoring of surface dynamics.

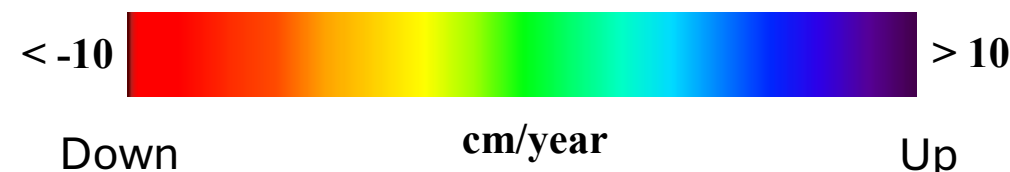
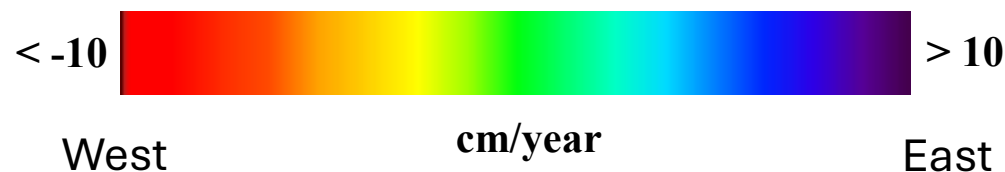
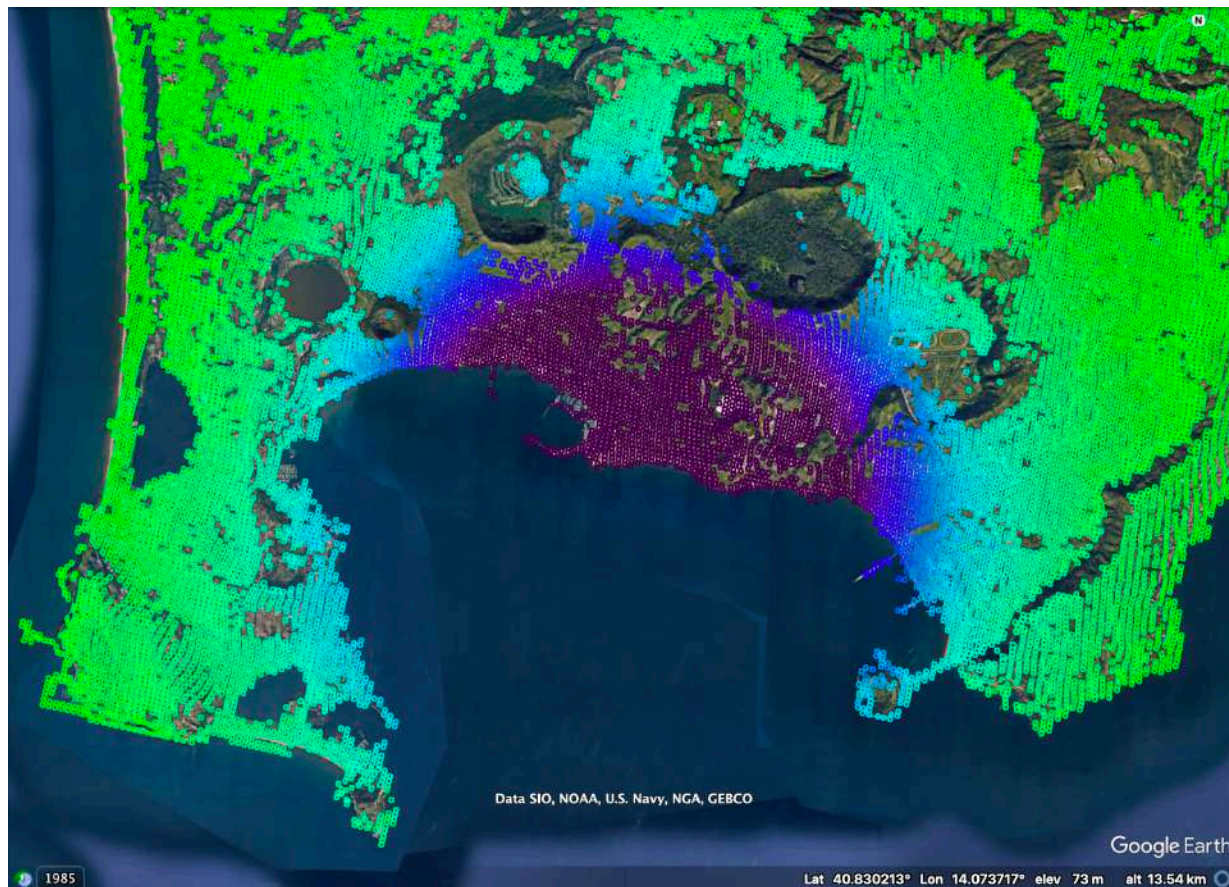
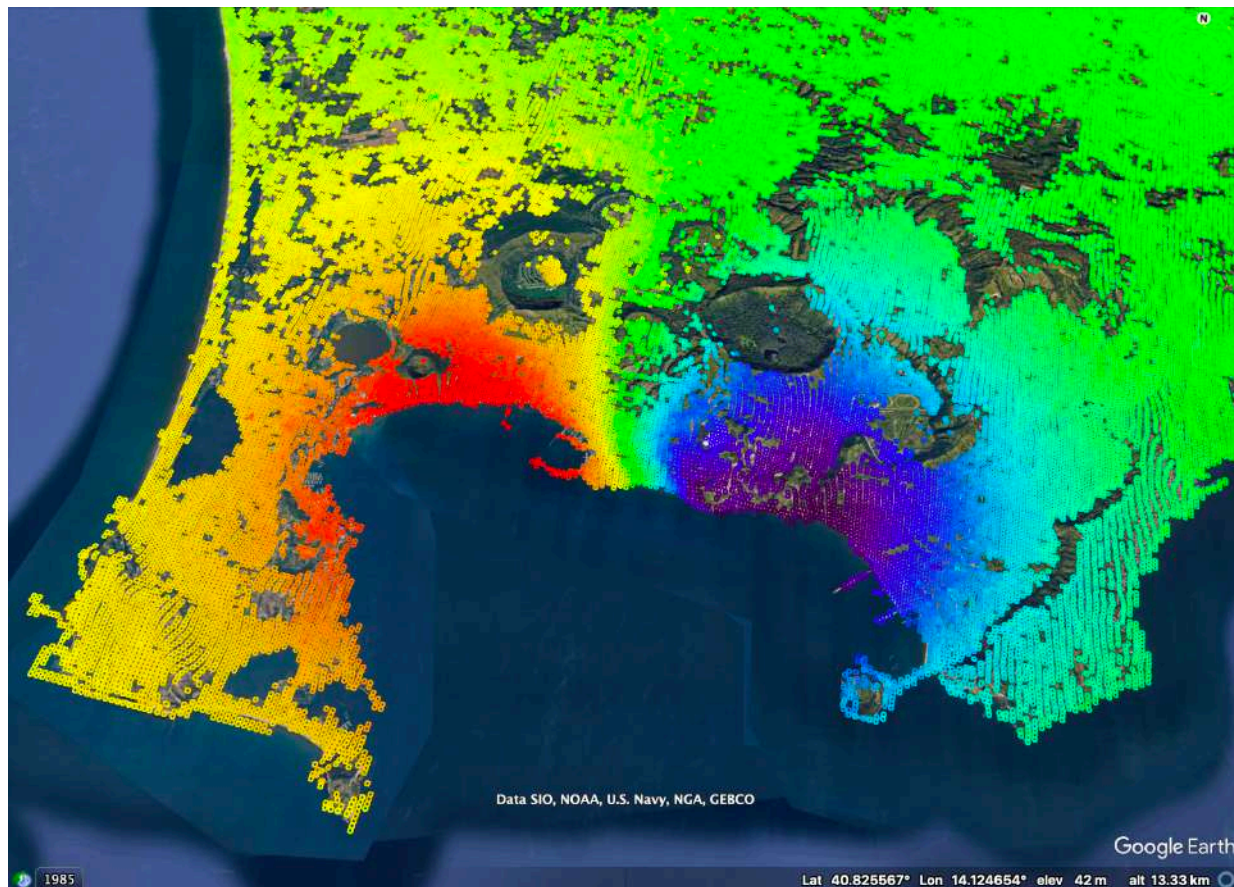
2018-2025 InSAR Ground Displacement Analyses: On-going Campi Flegrei Caldera Crisis



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we present mean ground deformation velocity maps derived from advanced InSAR processing (SBAS) of satellite data (Sentinel-1) spanning 2018 to 2025. The left panel illustrates horizontal (East-West) motion; the right panel depicts vertical (Up-Down) displacement, both expressed in centimeters per year.

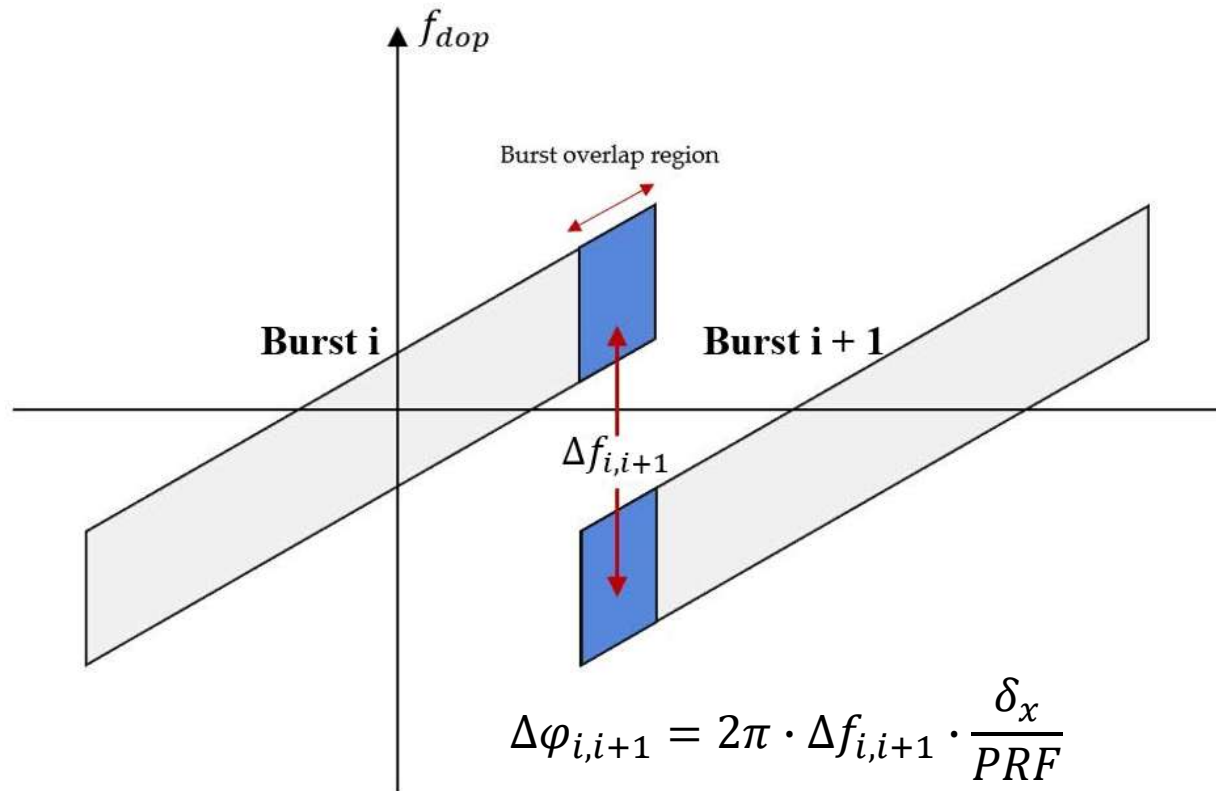
Experiments and New Developments of Burst Overlapped Interferometry



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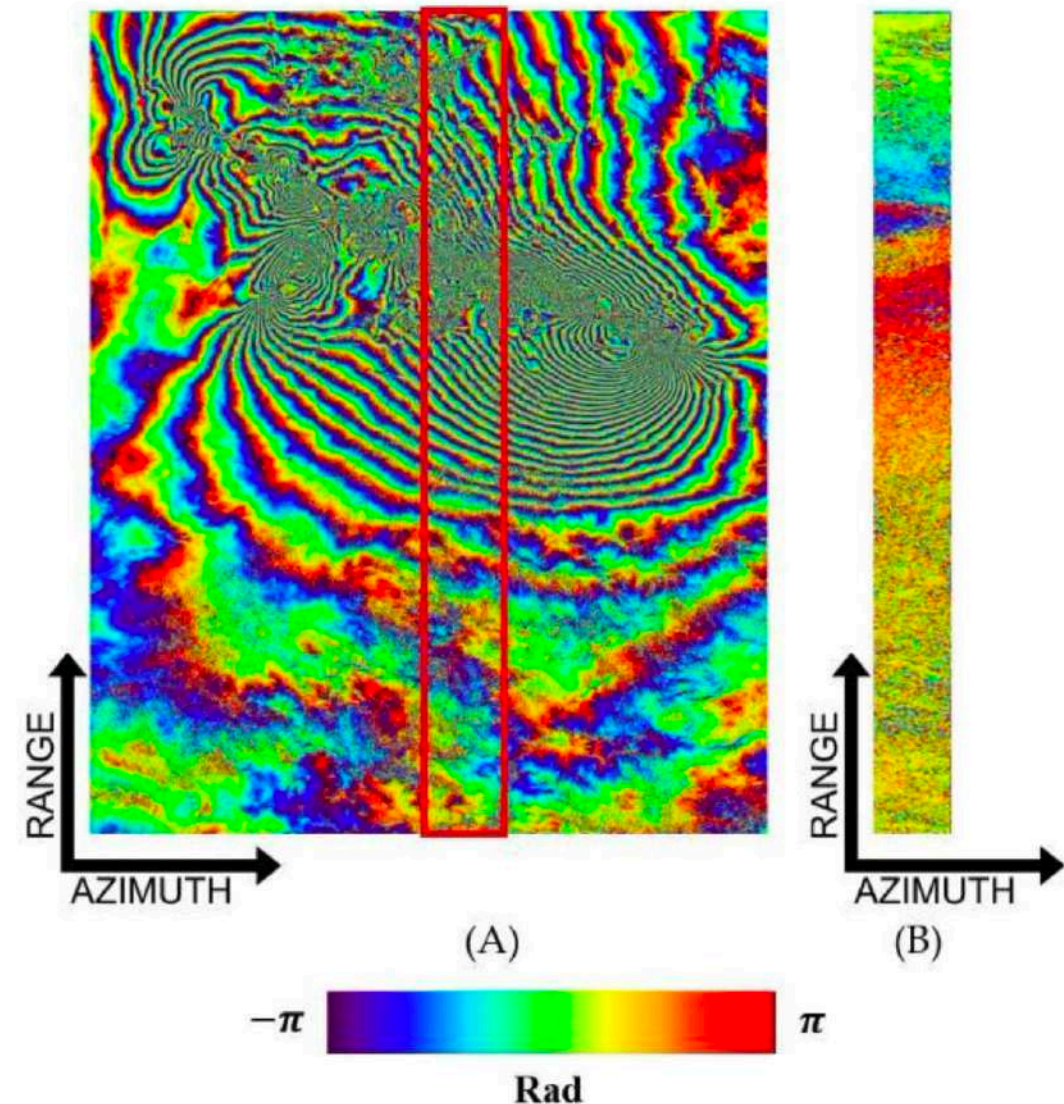


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- These techniques exploit the interferometric phase information in the overlap regions between adjacent bursts. This allows for the extraction of additional geophysical signals with high accuracy.
- One of the key advantages of BOI is its ability to retrieve deformation information along the SAR flight direction—approximately North–South—which is typically inaccessible with conventional InSAR techniques.

2017 RIDGECREST EARTHQUAKE



Experiments and new Developments of Burst Overlapped Interferometry (BOI)



we applied Burst Overlapped Interferometry to analyze ground deformation associated with the eruption that occurred between late June and August 2018.

65 SLC TOPSAR Images (ascending orbits)
From Feb 23, 2017 to Dec 27, 2018

Quasi-synchronous 65 SLC TOPSAR Images
(descending orbits)

➤ Eruption of 26 June-late August 2018

<https://youtu.be/ibZCguqUvQk>

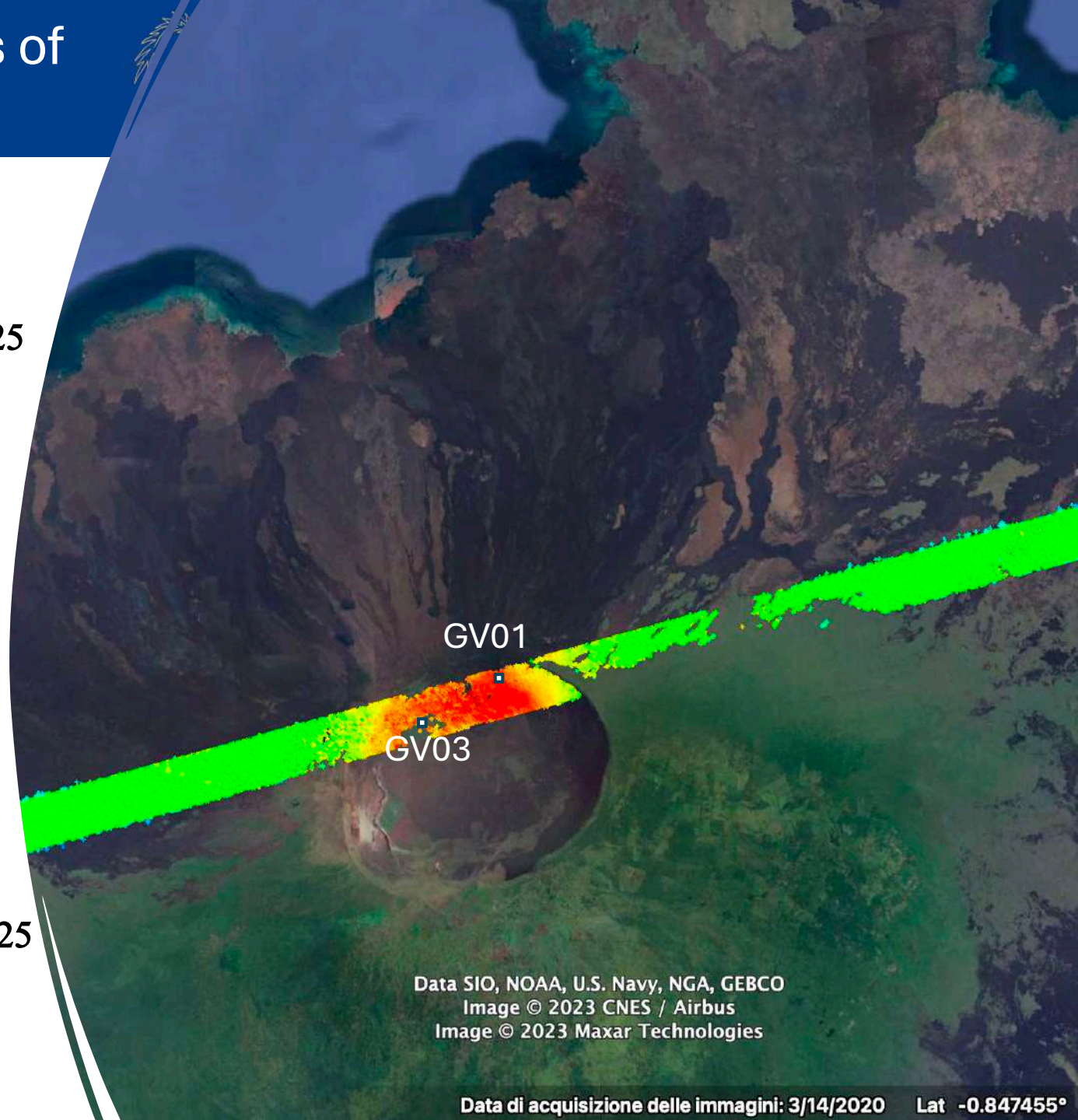
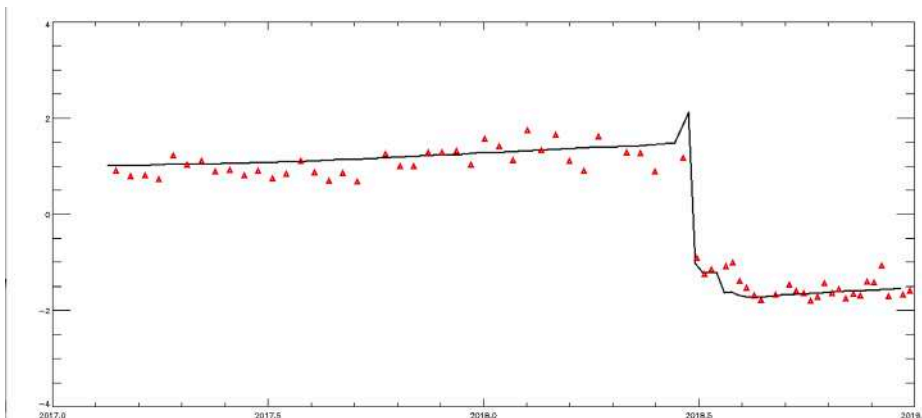
➤ Generation of pre-eruptive 3-D Displacement Time-Series with SBAS + BOI

➤ Generation of co-eruptive azimuthal Ground displacement time-series with BOI



North-South Ground Displacement Velocity Map

- A set of 588 BOI Interferogram (2017 – 2018) have been inverted to generate ground displacement time-series.



Activity 1: Detecting Earth's Surface Changes for Disaster Risk Analyses

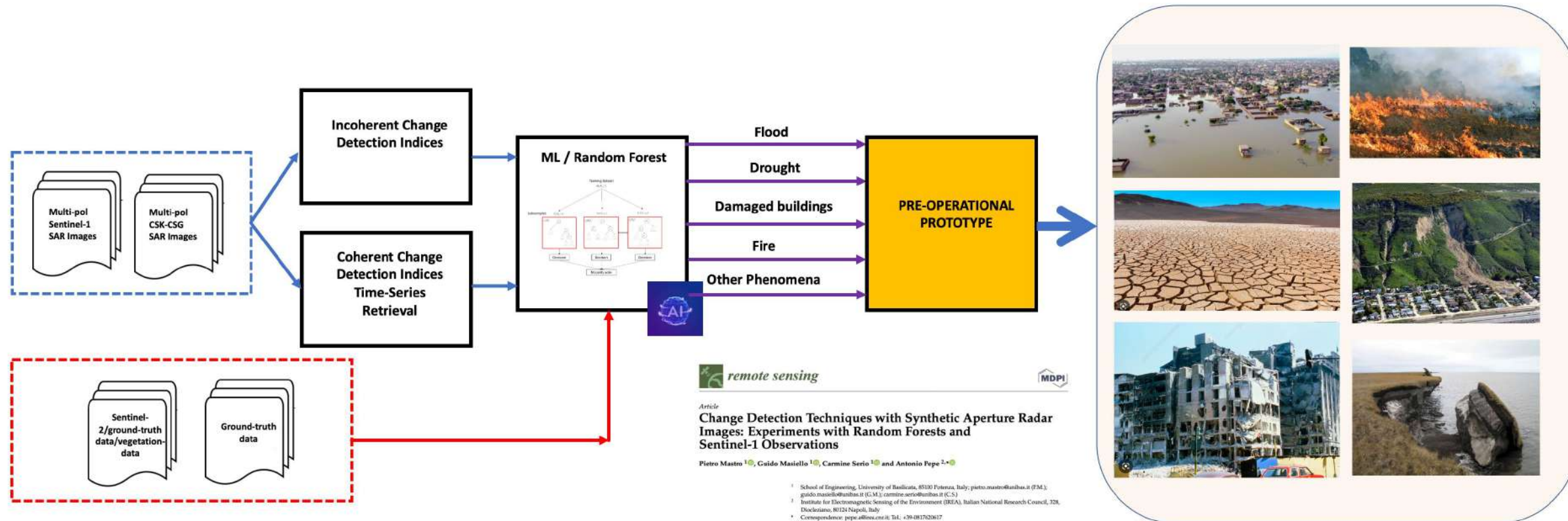


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We are working to implement a workflow based on Coherent and Incoherent SAR indices for the Identification of damaged areas and evaluation of the impacts.



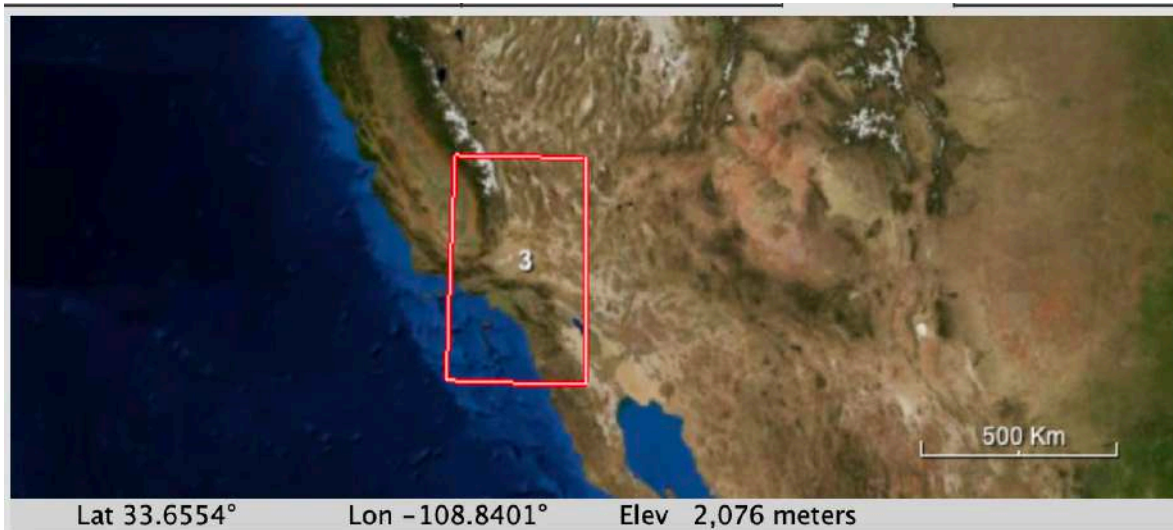
January 2025 California Wildfire Experiments



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Four Dual-pol (VV+HV) SAR Images Acquired on

December 16, 2024

December 28, 2024

January 9, 2024

January 22, 2024

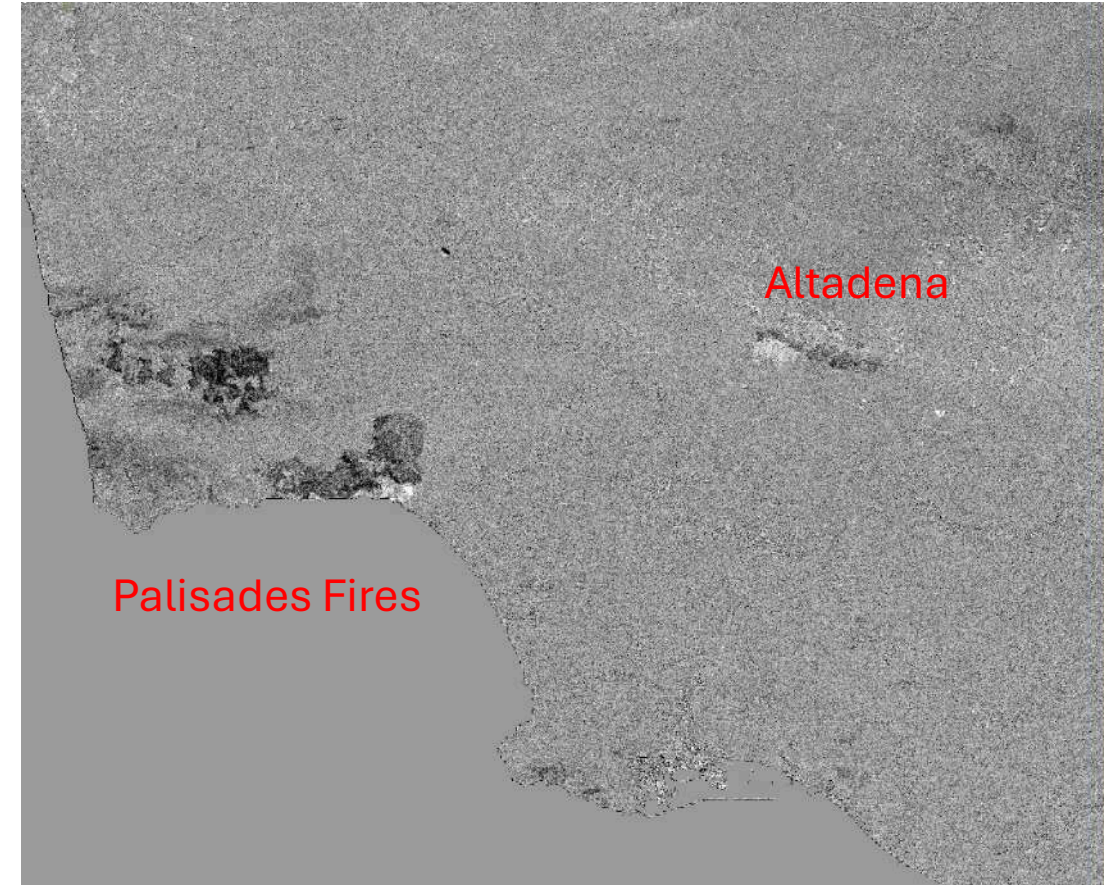
To monitor changes in the backscattering signal associated with fire-related surface changes.



2025 California Wildfire Experiments: Incoherent SAR Indices



Highlight zones affected by fire events.
These preliminary results demonstrate the potential of SAR-based indicators to support rapid damage mapping in wildfire scenarios.



$$LR = \ln\left(\frac{\langle X_2 \rangle_N}{\langle X_1 \rangle_N}\right) = \ln(\langle X_2 \rangle_N) - \ln(\langle X_1 \rangle_N)$$

X1: Dec. 28, 2024.

X2: Jan. 09, 2025

2025 California Wildfire Experiments: Coherent SAR Indices, VV Polarization



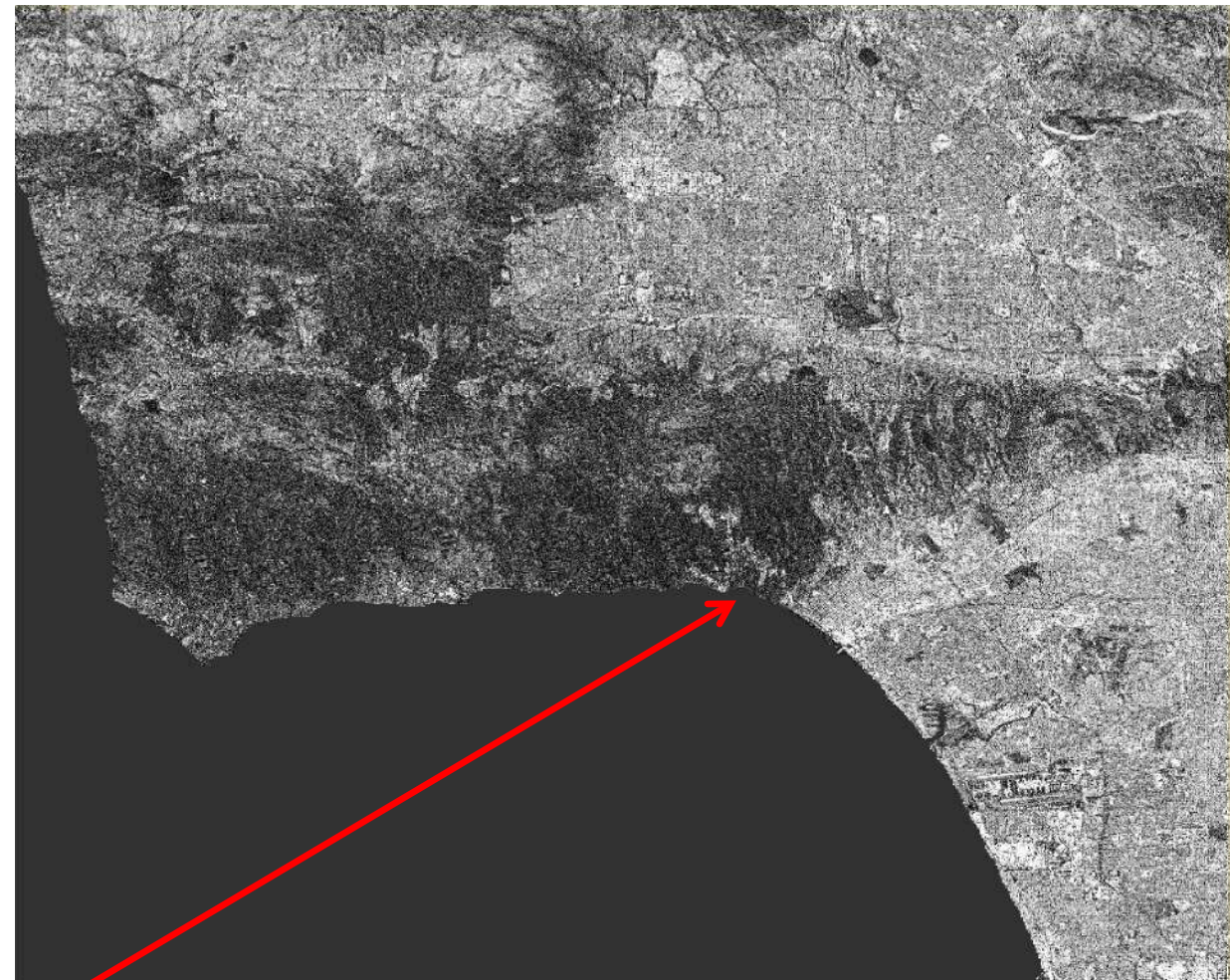
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Pre-Event
Dec.16, 2025 – Dec 28, 2025



COHERENCE DROP

Cross-Event
Dec.28, 2025 – Jan. 9, 2025

2025 California Wildfire Experiments: Coherent SAR Indices, VH Polarization



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Pre-Event
Dec.16, 2025 – Dec 28, 2025



COHERENCE DROP

Cross-Event
Dec.28, 2025 – Jan. 9, 2025

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Retrieval of 2-D Ground Deformation in the Red River Delta and Hanoi

Red River Delta

Red River Delta located in northern part of Vietnam.

It is the core area of agriculture and economy in Vietnam.

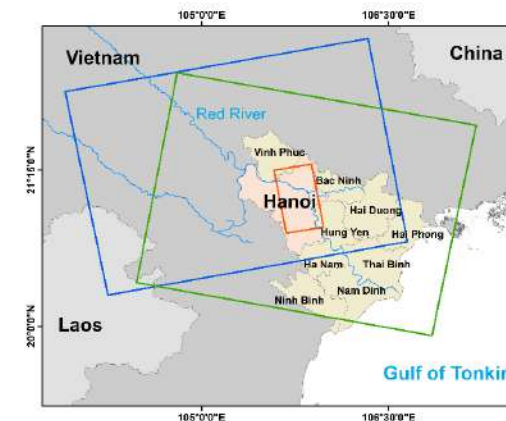
Hanoi

Northern Vietnam, on the Red River Delta.

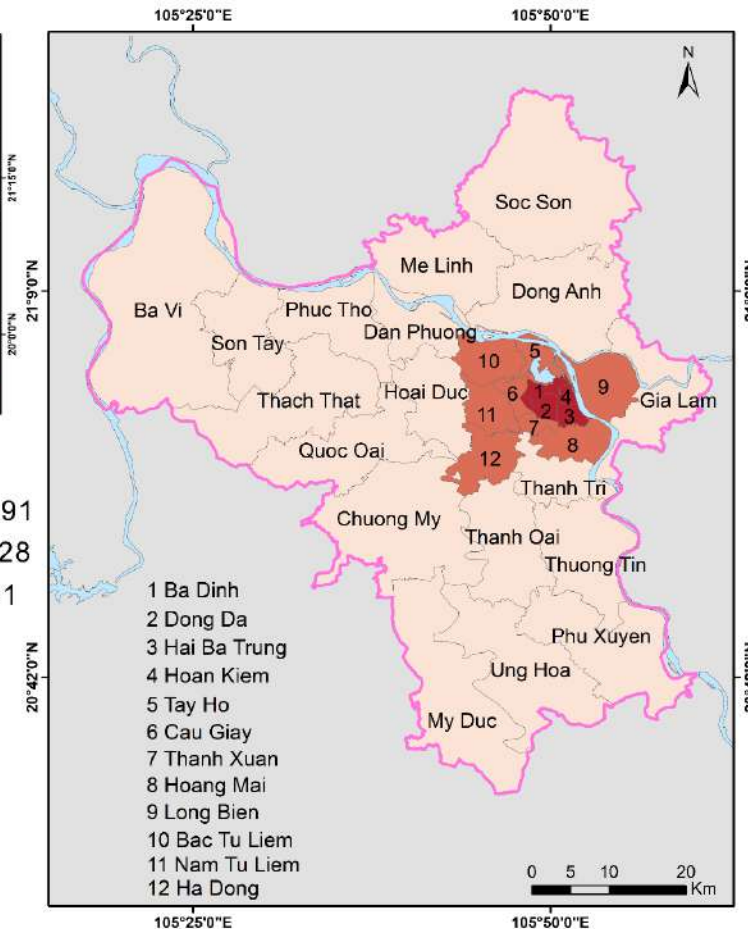
The capital of Vietnam, the second-largest city.

12 urban districts, **18** suburban districts

2,556 people/km²



- Sentinel-1A Descending Track 91
- Sentinel-1A Ascending Track 128
- TerraSAR-X Ascending Track 21
- River
- Red River Delta
- Old urban districts
- New urban districts
- Suburban districts
- Boundary of Hanoi



Activity 2: Delta deformation retrieval and predication with AI-driven InSAR

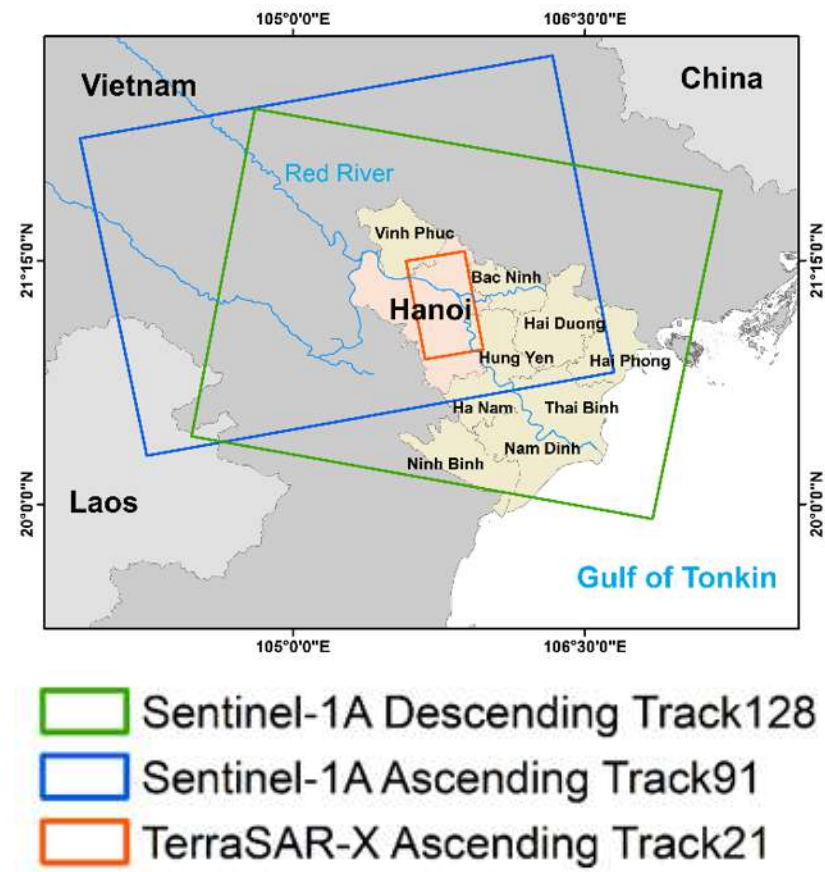


Dataset

S

Satellites	SAR Images	Incidence Angle	Time Range
Sentinel-1A ASC	105	41.98°	201704~202405
Sentinel-1A DESC	107	38.61°	201703~202405
TerraSAR-X ASC	18	37.28°	201903~202007

Factors	Data	Time	Spatial Resolution
DEM	COP-DEM	2015	30 m
Slope	COP-DEM	2015	30 m
Soil Type	HWSD 2.0	2023	1 km
Land-cover	GLC_FCS30D	2022	30 m
GDP	Global gridded GDP	2017-2020	1 km
Population Density	LandScan	2017-2022	1 km
Building height	3D-GloBFP	2020	1 km



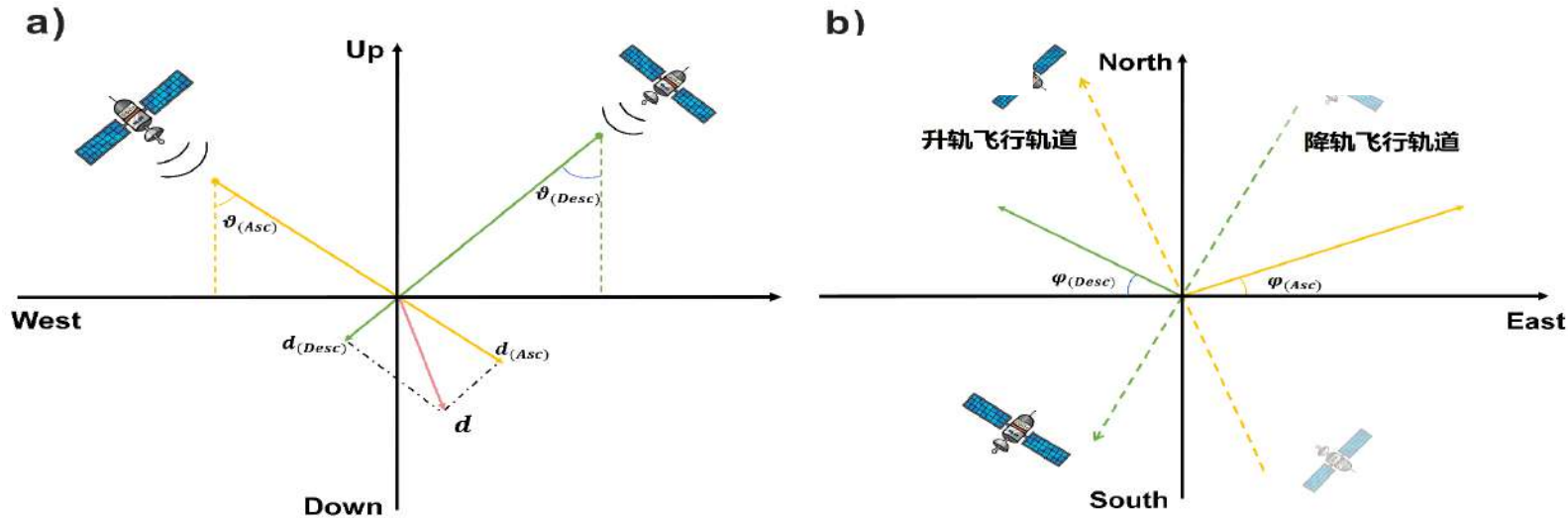
Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Methodolog

y

MinA



Geometric Diagram of SAR Satellites for MinA Decomposition Algorithm

$$\begin{cases} d_{LOS,asc} = \sin \theta_{asc} \cdot d_{E-W} + \cos \theta_{asc} \cdot d_{U-D} \\ d_{LOS,desc} = -\sin \theta_{desc} \cdot d_{E-W} + \cos \theta_{desc} \cdot d_{U-D} \end{cases} \quad (1)$$

$$B \cdot \begin{bmatrix} V_{EW} \\ V_{UD} \end{bmatrix} = \begin{bmatrix} d_{LOS}^1 \\ d_{LOS}^2 \\ \vdots \\ d_{LOS}^N \end{bmatrix} \quad (2) \quad B = \begin{bmatrix} B^1 \sin \vartheta^1 & -B^1 \cos \vartheta^1 \\ B^2 \sin \vartheta^2 & -B^2 \cos \vartheta^2 \\ \vdots & \vdots \\ B^N \sin \vartheta^N & -B^N \cos \vartheta^N \end{bmatrix}$$

$$C = \begin{cases} \alpha(V_{EW_{i+1}} - V_{EW_i}) = 0 & i = 1, \dots, Q-2 \\ \alpha(V_{UD_{i+1}} - V_{UD_i}) = 0 & i = 1, \dots, Q-2 \end{cases} \quad (3)$$

$$\begin{bmatrix} B \\ C \end{bmatrix} \cdot \begin{bmatrix} V_{EW} \\ V_{UD} \end{bmatrix} = \begin{bmatrix} d_{LOS}^1 \\ d_{LOS}^2 \\ \vdots \\ d_{LOS}^N \\ 0 \end{bmatrix} \quad (4)$$

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Theoretical Error Estimation of MinA Algorithm

$$\left\{ \begin{array}{l} A \cdot \varphi = \Delta\psi \\ \mathbf{C}_\varphi = I_g \mathbf{C}_{\Delta\psi} I_g^T \\ \mathbf{C}_{d_{LOS}} = \left(\frac{\lambda}{4\pi}\right)^2 \mathbf{C}_\varphi \end{array} \right. \quad (1) \quad \begin{bmatrix} \mathbf{B} \\ \mathbf{C} \end{bmatrix} \cdot \begin{bmatrix} \mathbf{V}_{EW} \\ \mathbf{V}_{UD} \end{bmatrix} = \begin{bmatrix} d_{LOS}^1 \\ d_{LOS}^2 \\ \vdots \\ d_{LOS}^N \\ 0 \end{bmatrix} \longrightarrow \begin{bmatrix} \mathbf{V}_{EW} \\ \mathbf{V}_{UD} \end{bmatrix} = \Lambda \begin{bmatrix} d_{LOS}^1 \\ d_{LOS}^2 \\ \vdots \\ d_{LOS}^N \end{bmatrix} \quad (2)$$

Matrix of the time interval:

$$\mathbf{C}_V = \begin{bmatrix} \boxed{\mathbf{C}_{V_{EW}}} & \mathbf{C}_{V_{EW}, V_{UD}} \\ \mathbf{C}_{V_{UD}, V_{EW}} & \boxed{\mathbf{C}_{V_{UD}}} \end{bmatrix} = \Lambda \begin{bmatrix} \mathbf{C}_{d_{LOS}^1} & 0 & \dots & 0 \\ 0 & \mathbf{C}_{d_{LOS}^2} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & \mathbf{C}_{d_{LOS}^N} \end{bmatrix} \Lambda^T \quad (3) \quad \Upsilon = \begin{bmatrix} T_2 - T_1 & 0 & \dots & 0 \\ T_2 - T_1 & T_3 - T_2 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ T_2 - T_1 & T_3 - T_2 & \dots & T_Q - T_{Q-1} \end{bmatrix}$$

$$\left\{ \begin{array}{l} \mathbf{C}_{d_{UD}} = \Upsilon \mathbf{C}_{V_{UD}} \Upsilon^T \\ \mathbf{C}_{d_{EW}} = \Upsilon \mathbf{C}_{V_{EW}} \Upsilon^T \end{array} \right. \quad (4)$$

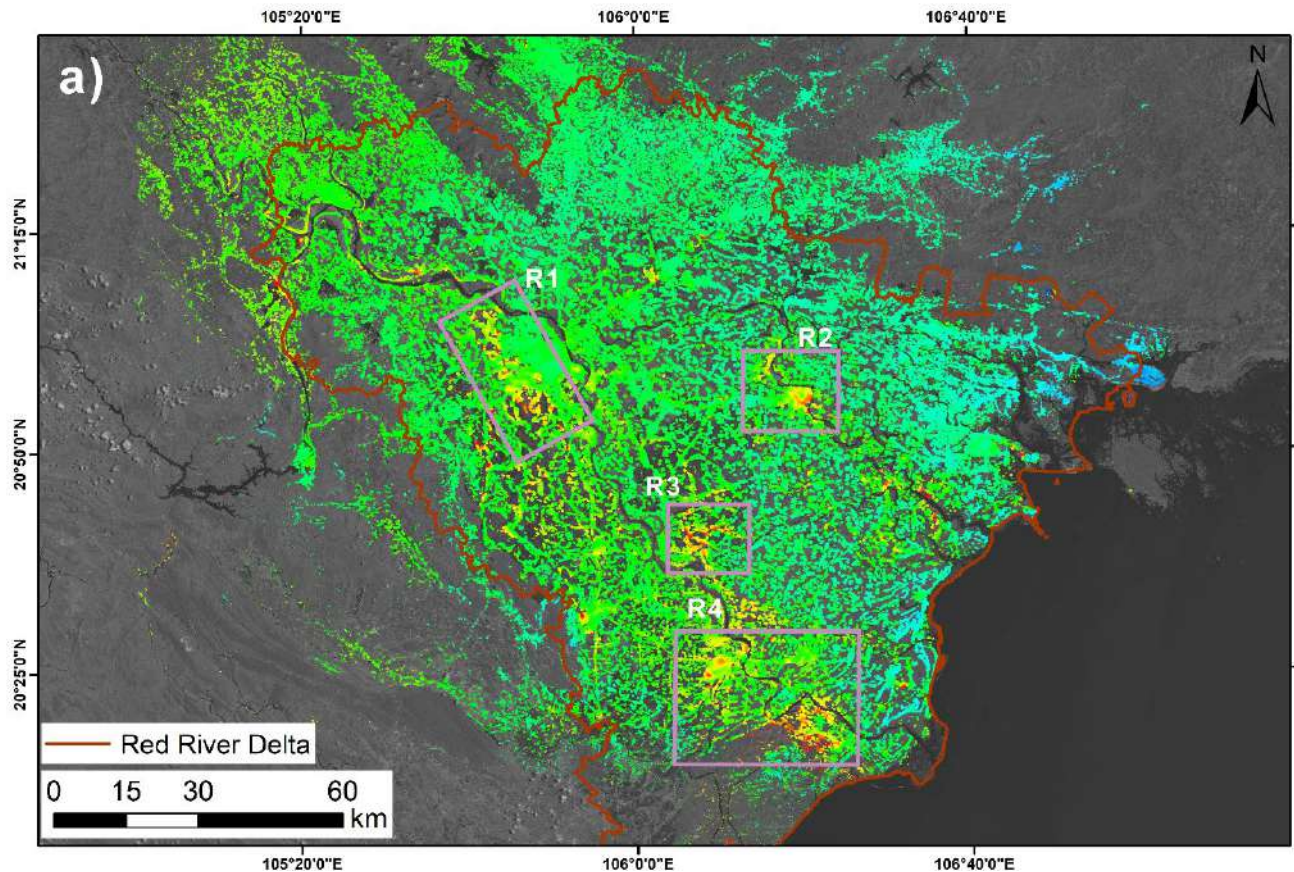
Full Coherence Matrix

$$\mathbf{FCM} = \begin{bmatrix} \sigma_1^2 & \sigma_1 \sigma_2 & \dots & \sigma_1 \sigma_M \\ \sigma_2 \sigma_1 & \sigma_2^2 & & \sigma_2 \sigma_M \\ \vdots & & \ddots & \vdots \\ \sigma_M \sigma_1 & \sigma_M \sigma_2 & \dots & \sigma_M^2 \end{bmatrix}$$

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Retrieval of LOS Ground Deformation Field in the Red River Delta and Hanoi



LOS Deformation Field of the Red River Delta

The main subsidence areas (R1-R4) in the Red River Delta correspond to the four cities of **Hanoi (R1)**, **Hai Duong (R2)**, **Vinh An (R3)** and **Nam Dinh (R4)**.

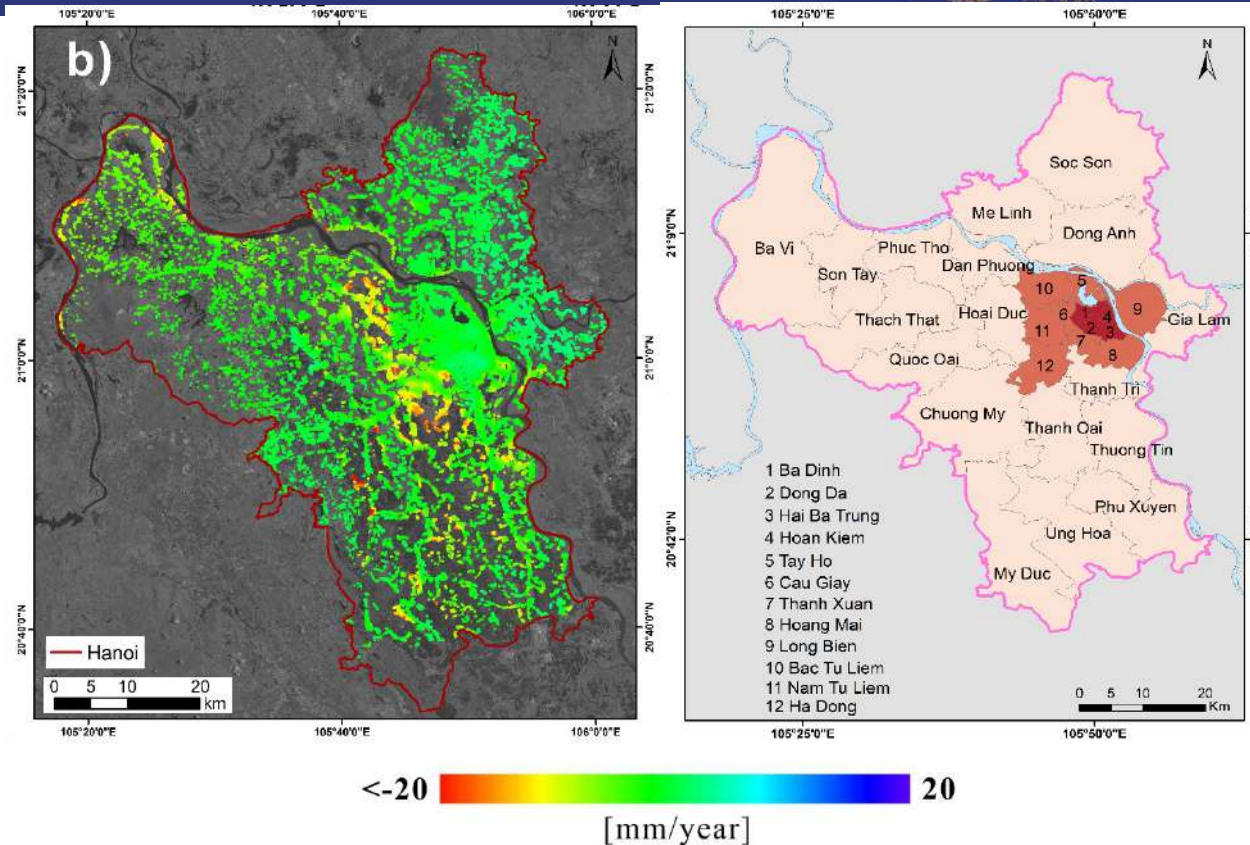
- R1 in Hanoi is located in the urban-rural transitional zone
- R2 & R3 are distributed along the rivers
- R4 in Nam Dinh is coastal area

2017-2024 LOS Deformation Velocity Map of the Red River Delta
Derived by descending S-1A

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Retrieval of LOS
Ground
Deformation Field
in the Red River
Delta and Hanoi



Hanoi

The LOS deformation velocity map of Hanoi derived by [ascending S-1A](#) datasets acquired from 2017-2024.

There are two primary subsidence bowls located in:

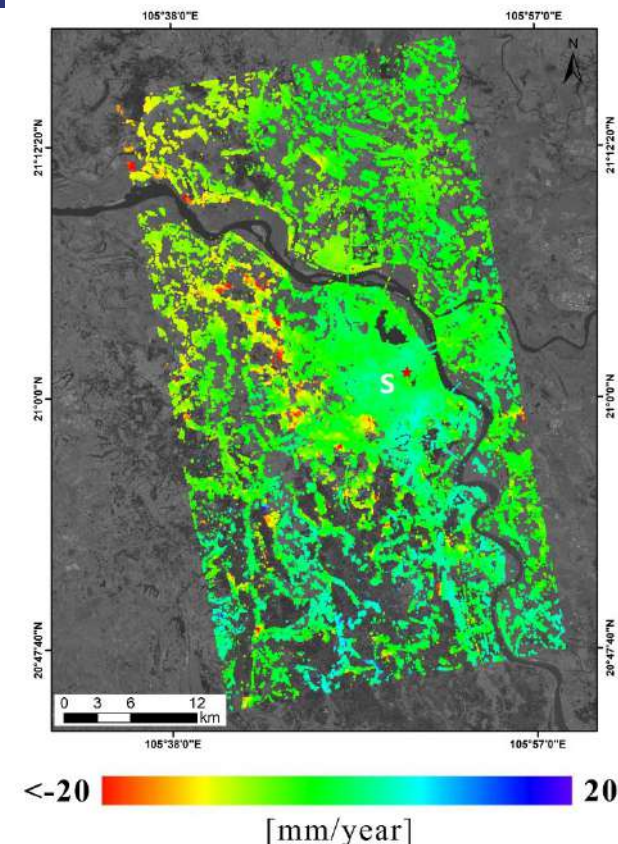
1. [Ha Dong-Thanh Tri District](#):

- South of Red River
- Urban-rural transitional zone

There are two primary subsidence bowls located in:

2. [Hoai Duc District](#):

- Northwestern suburban area

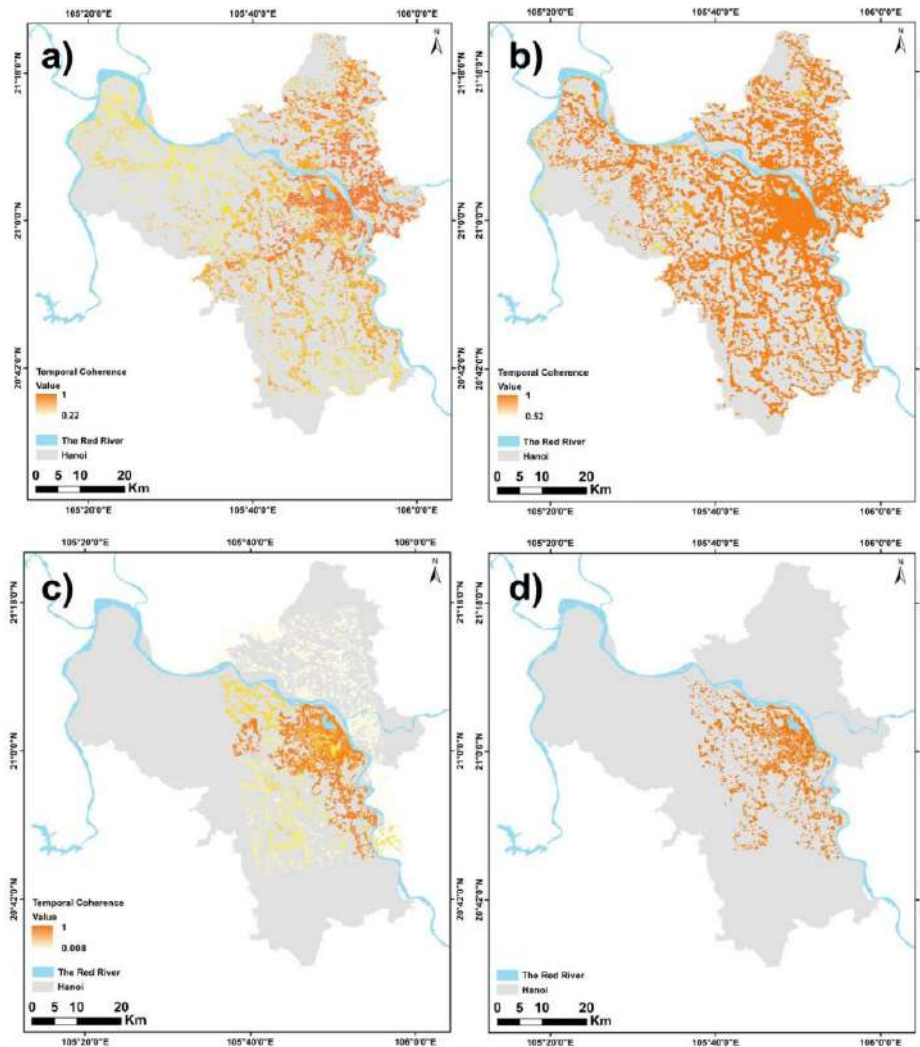


The LOS deformation velocity map of Hanoi derived by [ascending TSX](#) datasets from 2019-2020.

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



2-D
Deformation
Decompositio
n and
Theoretical
Error Analysis
in Hanoi with
Full
Coherence
Matrix



High-Temporal-Coherence Extraction

Pixel

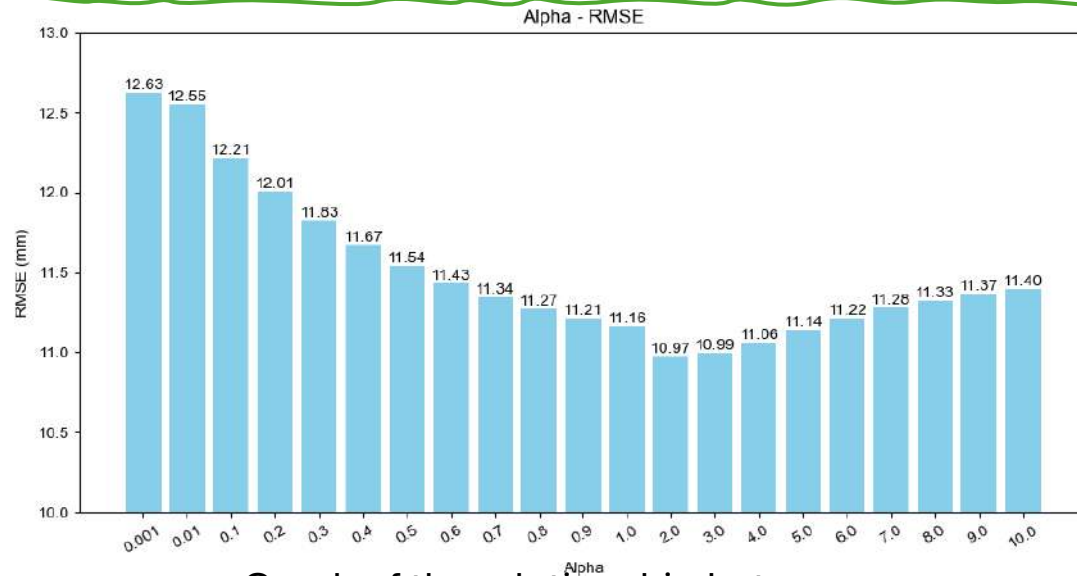
- Calculate the temporal coherence of each of the three datasets.
- Set a threshold of 0.8 to extract common high-temporal-coherent pixels.

The temporal coherence maps of three datasets and the common high-temporal-coherence pixels.

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



2-D Deformation Decomposition and Theoretical Error Analysis in Hanoi with Full Coherence Matrix

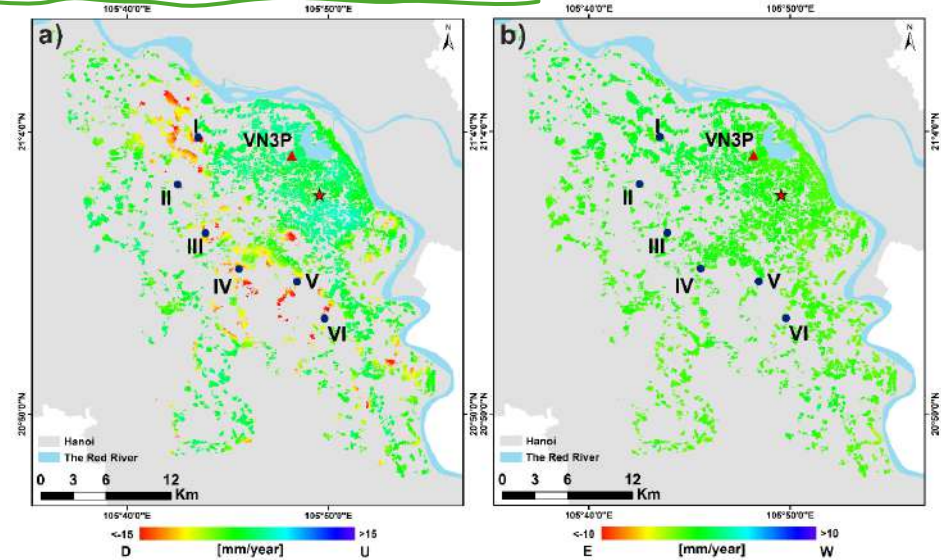


Graph of the relationship between different decomposition weights α and RMSE

Determine the optimal weight of MinA

1. Cross-Validation of 2D Decomposition Results

- The vertical (U) and east-west (EW) displacement components derived from decomposition with varying α weights were reprojected to the TSX-LOS geometry.
- The RMSE between these reprojected results and the original TSX-LOS time series obtained via SBAS-InSAR was calculated for validation. The optimal weight was determined to be $\alpha=2$.



2-D deformation velocity map of Hanoi from 2017-2024

2. Final 2D Time-Series Deformation Field

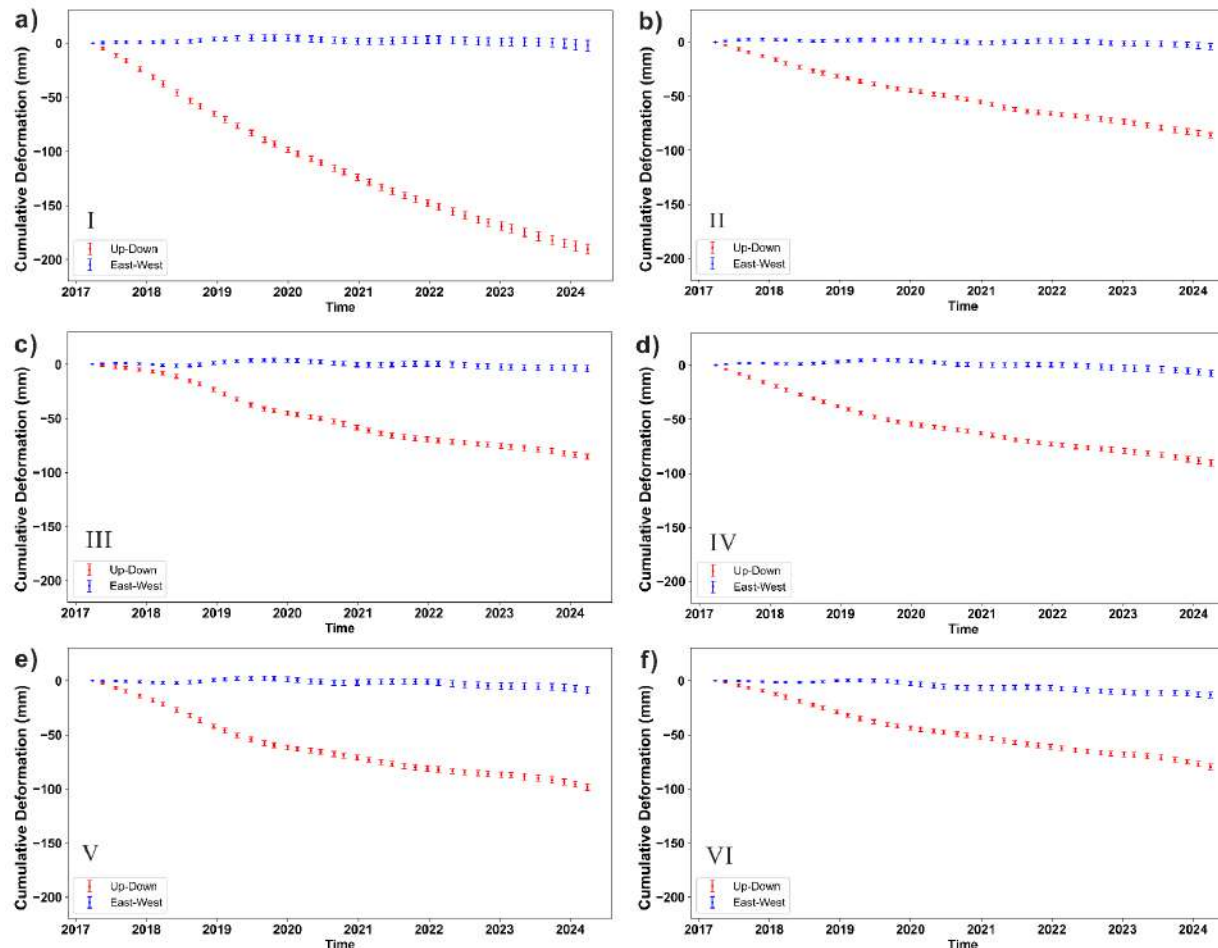
Using both:

- High-temporal-coherence pixels ($\gamma \geq 0.8$)
- The optimized MinA algorithm with $\alpha=2$

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



2-D Deformation Decomposition and Theoretical Error Analysis in Hanoi with Full Coherence Matrix



2-D Time-Series Deformation and Theoretical Errors

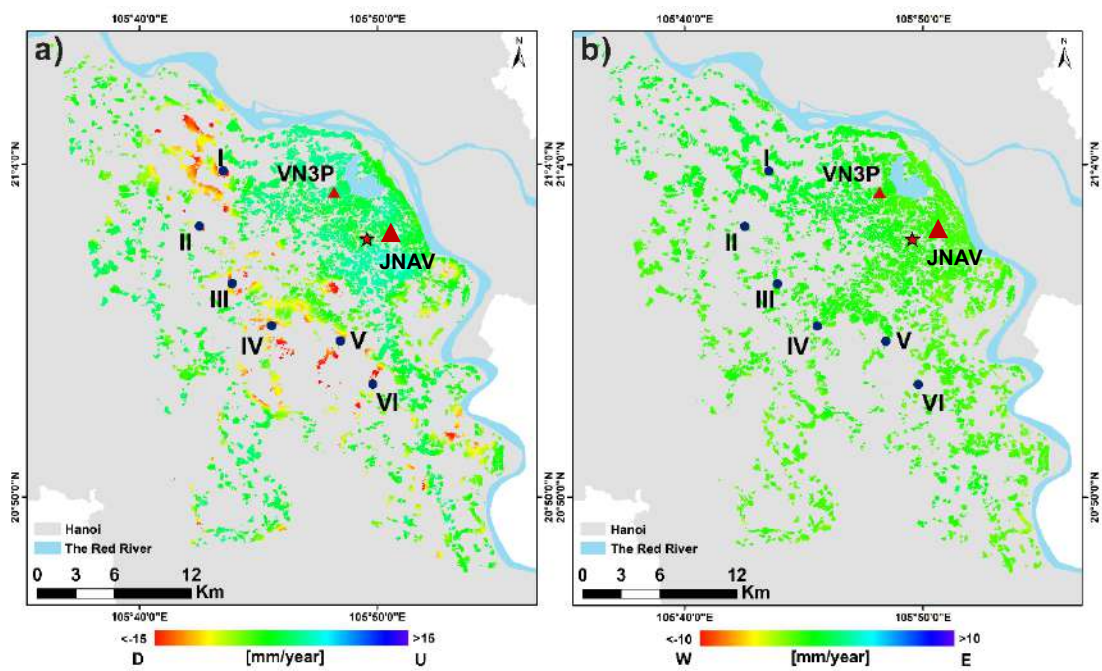
- **Preprocessing:** Utilizes high-temporal-coherence pixels and optimized weighting
- **Error Propagation:** Incorporates full coherence matrix theory
- **Precision Validation:** Accurately reflects true error levels of the MinA decomposition algorithm, with **2D deformation errors in Hanoi quantified at ± 2 mm**

The 2-D deformation time series of six points and the corresponding error estimation.

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



2-D Deformation Decomposition and Theoretical Error Analysis in Hanoi with Full Coherence Matrix



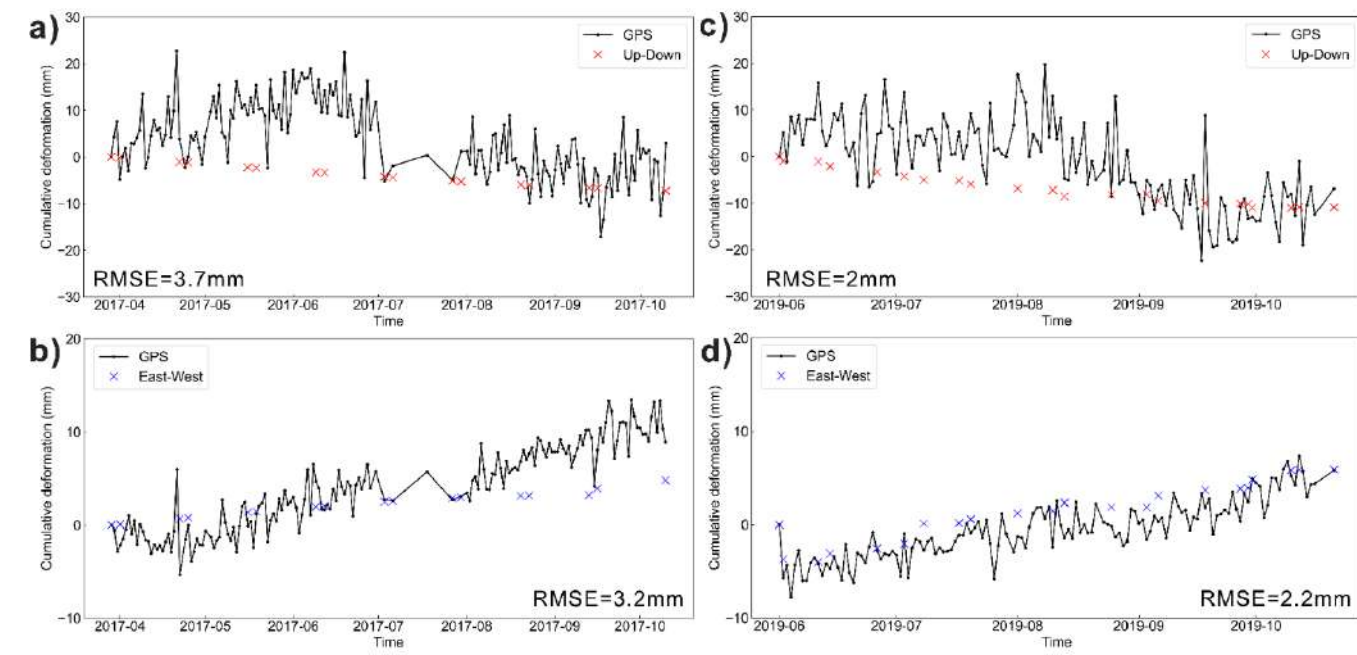
2-D deformation velocity map in Hanoi from 2017-2024

GPS Validation

The 2D decomposition results were validated with measurements from two GPS stations, demonstrating high reliability:

- **Vertical (U) RMSE: 3.7 mm (Site 1) | 3.2 mm (Site 2)**
- **East-West (EW) RMSE: 2.0 mm (Site 1) | 2.2 mm (Site 2)**

The millimeter-level consistency confirms the robustness of our method.

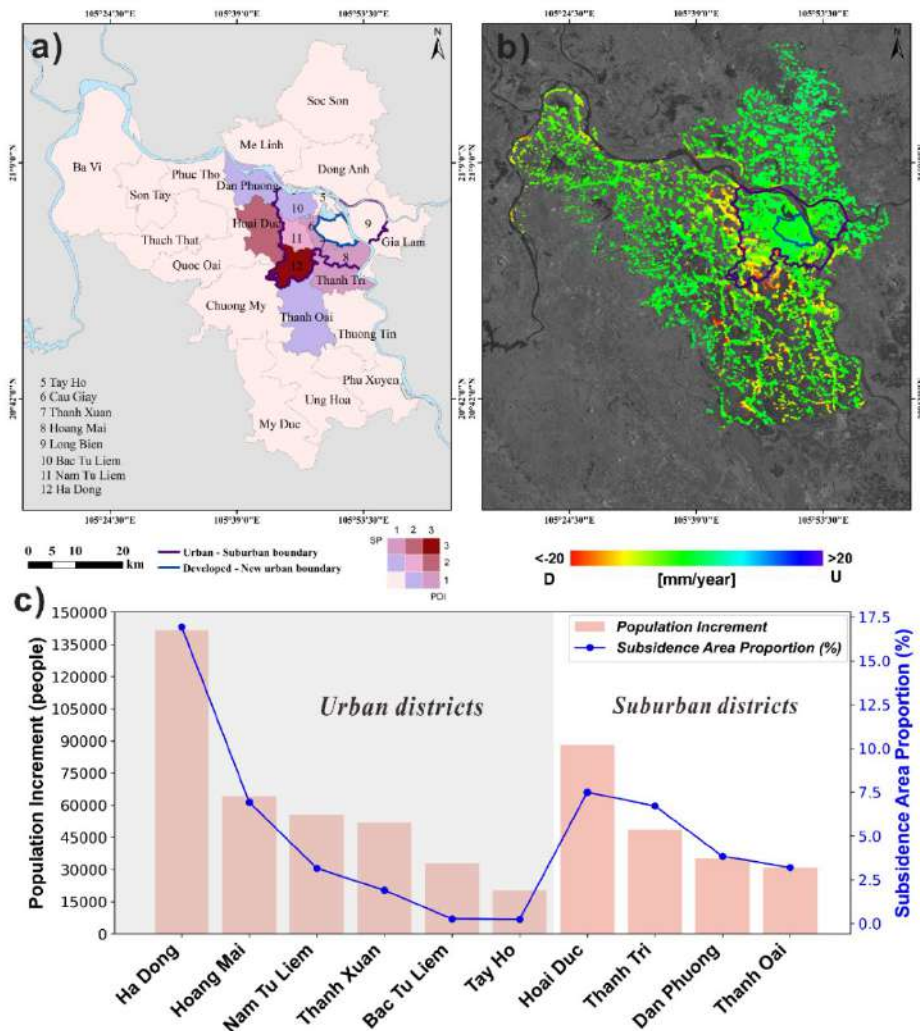


2-D Deformation series and GPS measurement data

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Correlation Analysis Between ground Subsidence and Population Changes in Hanoi



Population changes

Relationship between ground subsidence and population dynamics

Classification Method: Natural breaks (Jenks) applied

- *Population Density Increment (PDI)*
 - *Subsidence Area Percentage (SP)*
- Significant positive correlation between subsidence and population changes observed in **urban-rural transitional zones**.
- The classification map indicates a high correlation between population and ground subsidence in these districts.

Correlation between increased population and ground subsidence.

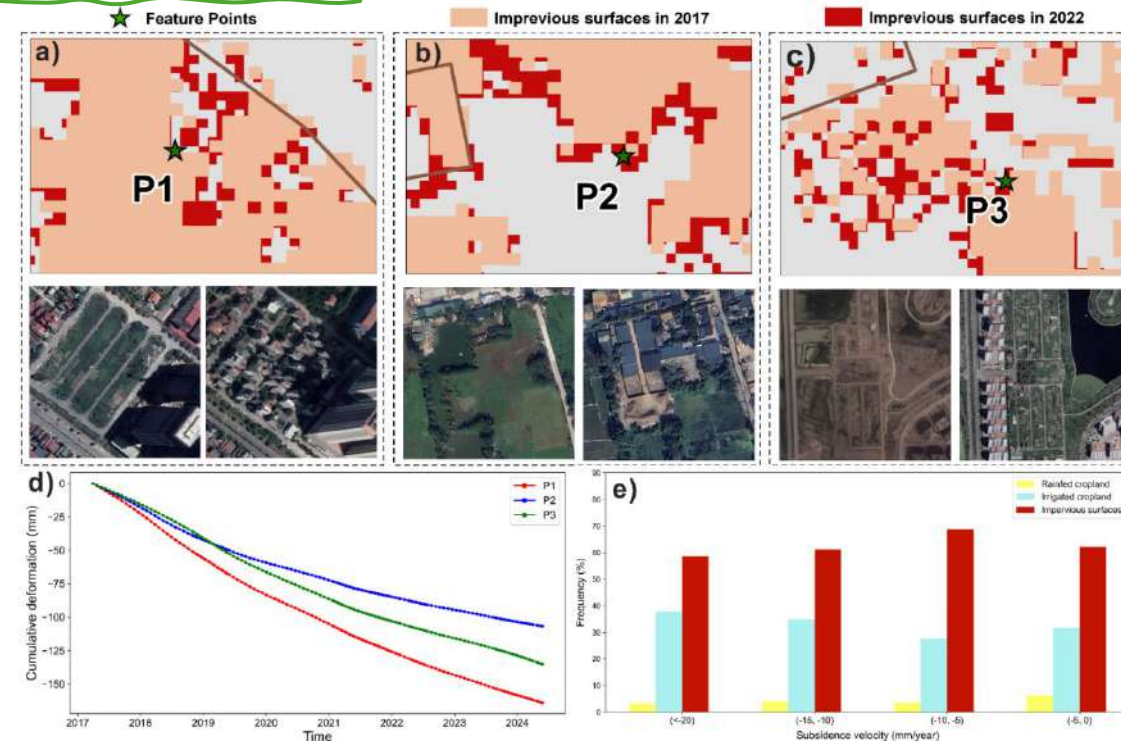
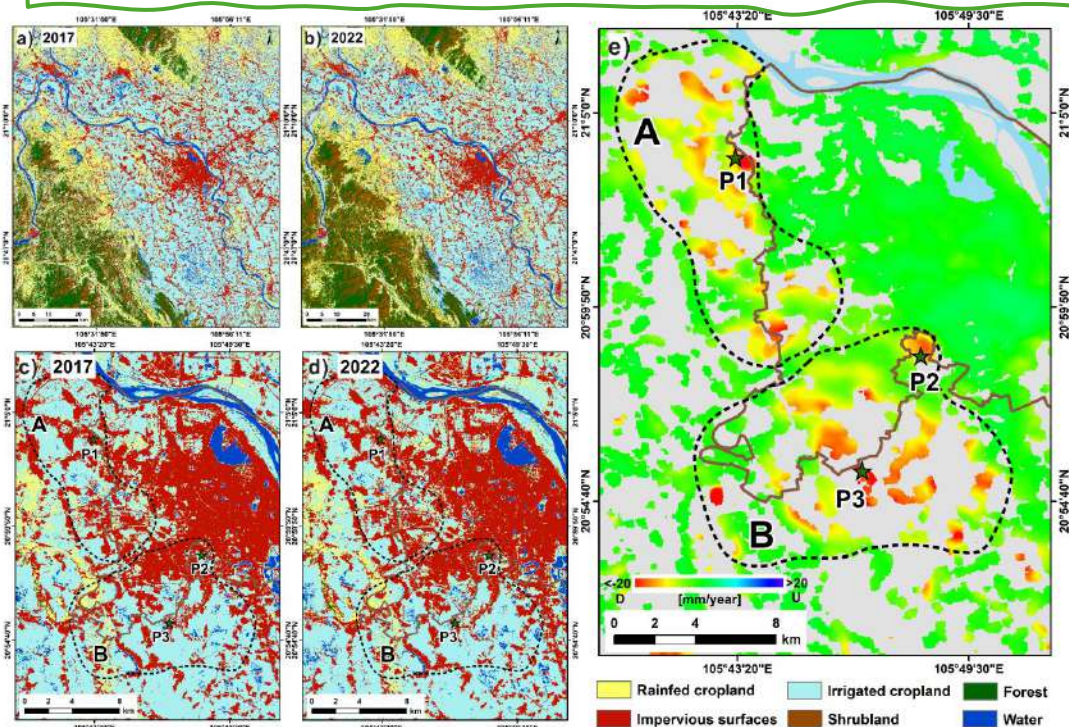
The red bar represents the increase in the population of the ten districts of Hanoi from 2017 to 2022.

The blue line represents the proportion of district subsidence areas with a cumulative subsidence value greater than 50 mm between 2017 and 2024, as a percentage of the district area.

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Correlation Analysis Between ground Subsidence and land-cover changes in Hanoi



Land-cover changes

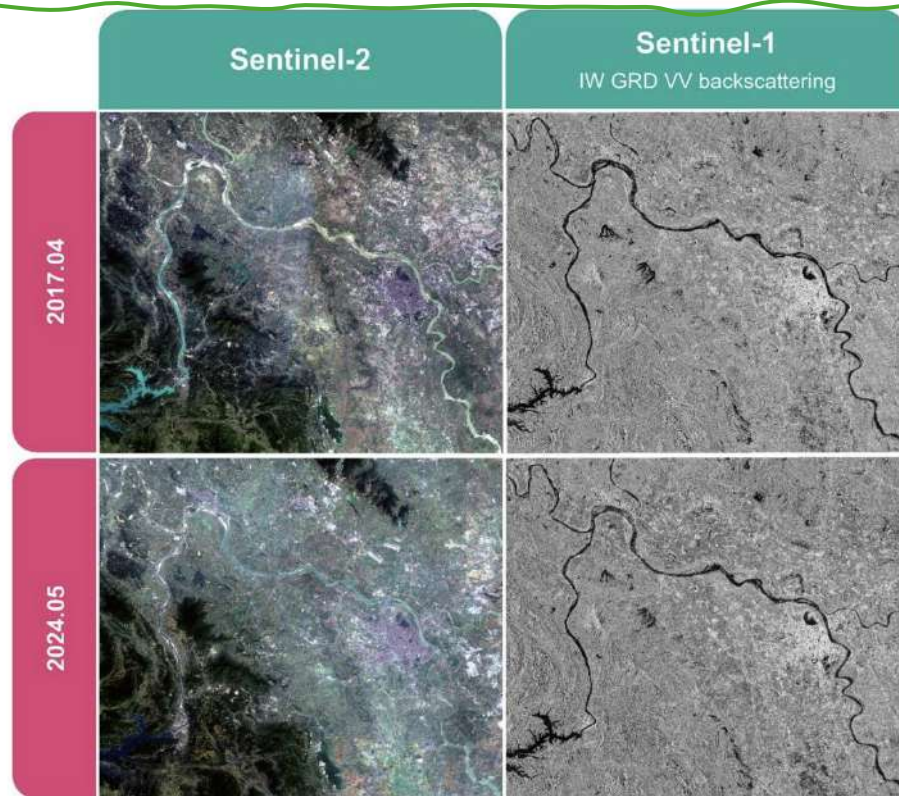
- Subsidence in Hanoi is mainly concentrated in Area A and Area B along the urban-rural boundary.
- Maximum subsidence (180 mm) occurs in areas converted from irrigated farmland to impervious surfaces.
- Impervious surfaces (e.g., roads, buildings) consistently show higher subsidence rates across all velocity categories.

The selected P1, P2, and P3 points at which the land cover type has transformed from other types to impervious surfaces. The subsidence velocity distribution histogram of high-coherent points in areas A and B at different land-cover types.

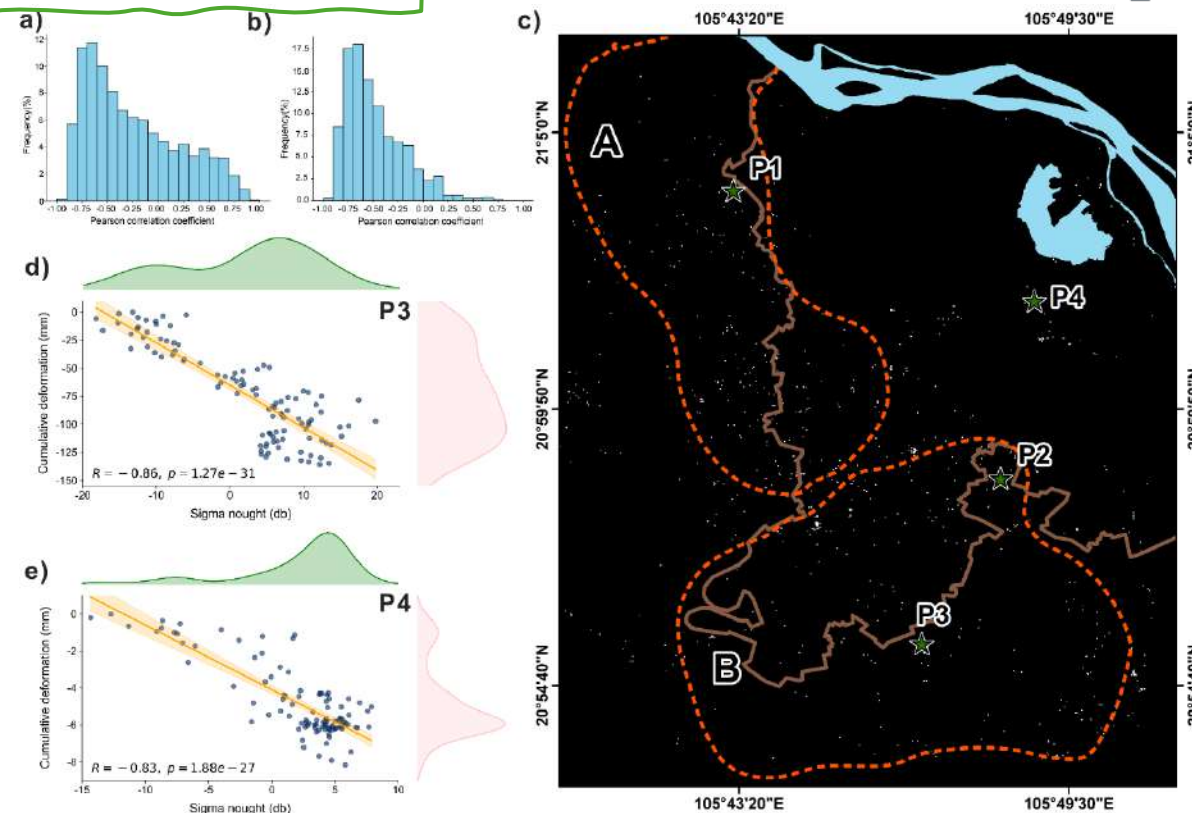
Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Correlation Analysis Between ground Subsidence and built-up grow areas in Hanoi



Optical images and SAR backscattering coefficient map



Map of the relationship between ground subsidence and the expansion of built-up area

Build-up grow areas

Extract pixels of $\sigma_{2024}^0 - \sigma_{2017}^0 > 15 \text{ dB}$

- σ^0 with 15dB increment is highly likely to be accompanied by subsidence
- 92% of such pixels are distributed in subsidence areas A and B

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



Correlation Analysis Between ground Subsidence and over-pumping groundwater

Groundwater over-pumping

1. High Groundwater Decline Areas (Q58, Q76, etc.):

- Exhibit **subsidence rates** >15 mm/year

2. Adjacent to Subsidence Bowls (Q55, Q75):

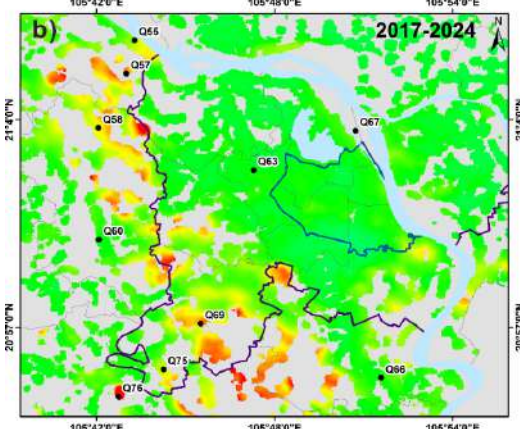
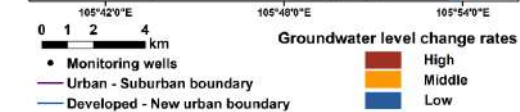
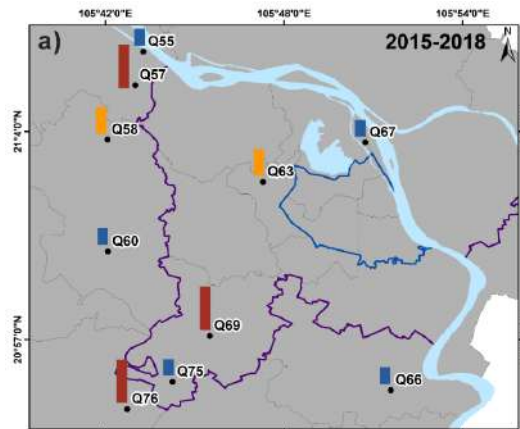
- Show **moderate subsidence** (5–10 mm/year)

3. Low Groundwater Fluctuation Zones (Q60, Q66):

- Demonstrate stable state (± 2 mm/year)

4. Anomaly Case (Q63):

- Near-zero deformation since 2018 due to:
 - ✓ Low consolidation coefficient **or**
 - ✓ Strict groundwater extraction controls



A **significant positive correlation** exists between groundwater level dynamics and subsidence rates.

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR

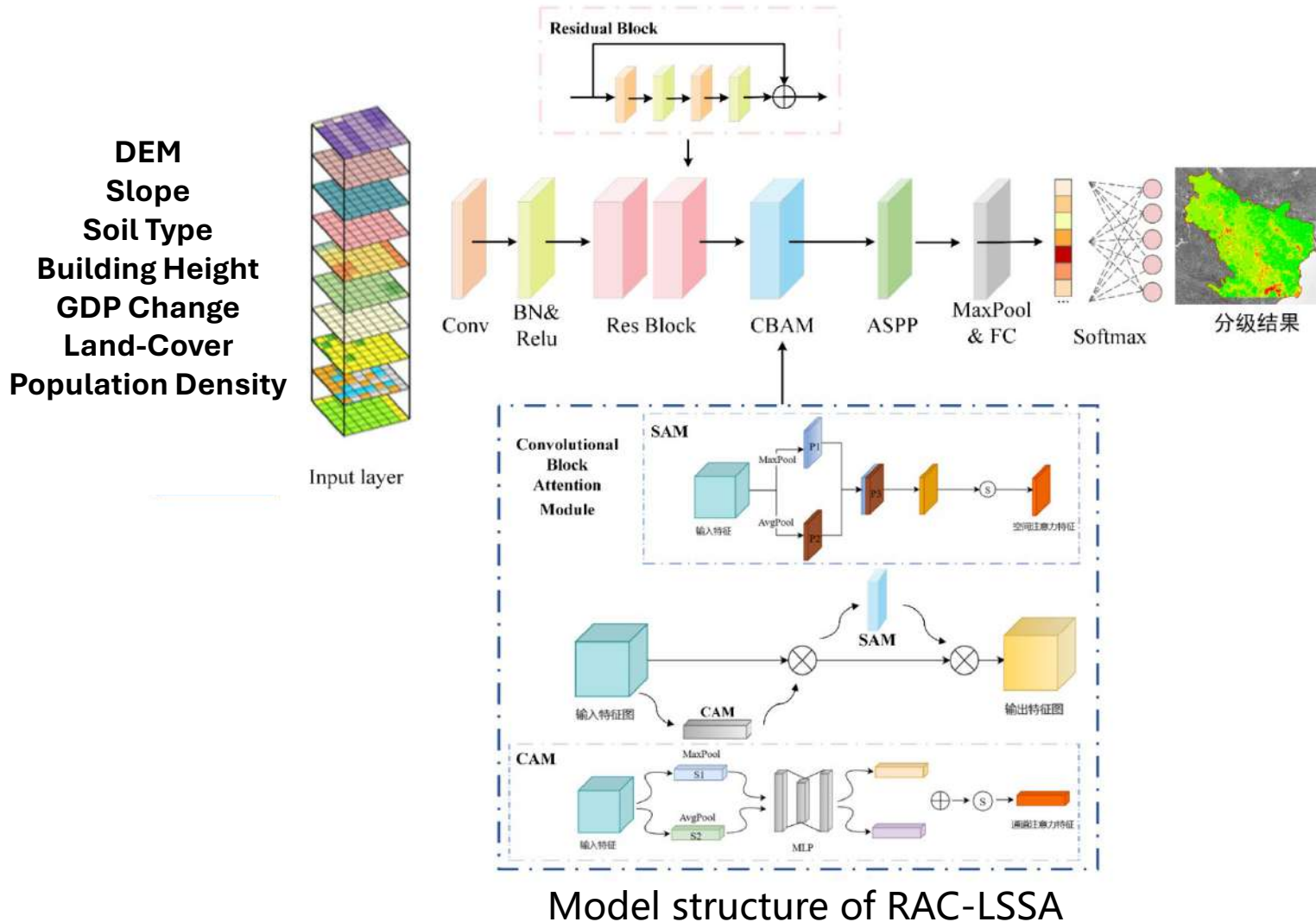


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Intelligent Susceptibility Assessment of Subsidence Based on RAC-LSSA Model



RAC-LSSA model

- Factors input
 - Natural conditions
 - Human activities
- Model training
 - ResNet
 - Attention Mechanism
 - ASPP
- Result
 - Susceptibility Risk Levels

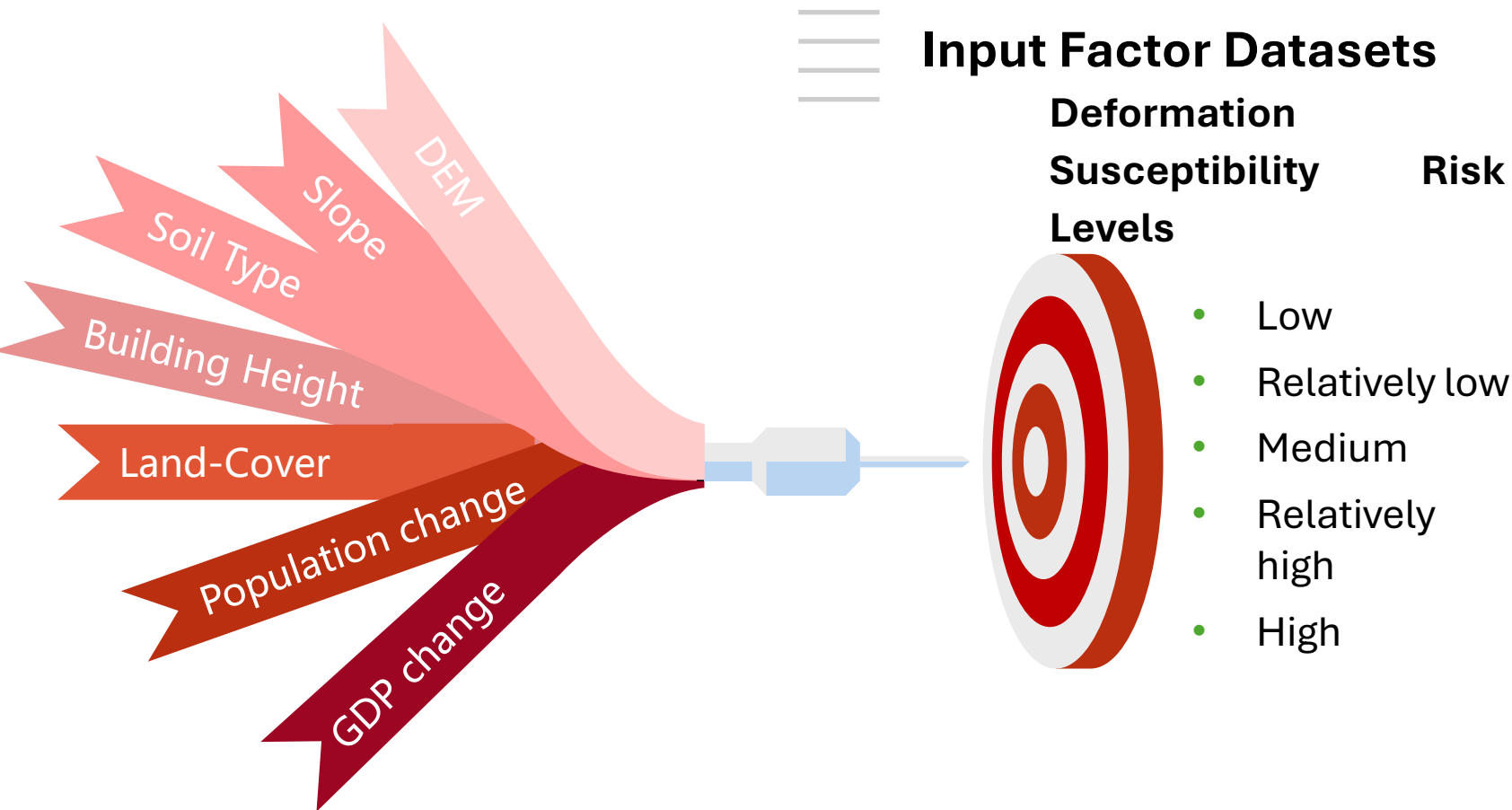
Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR



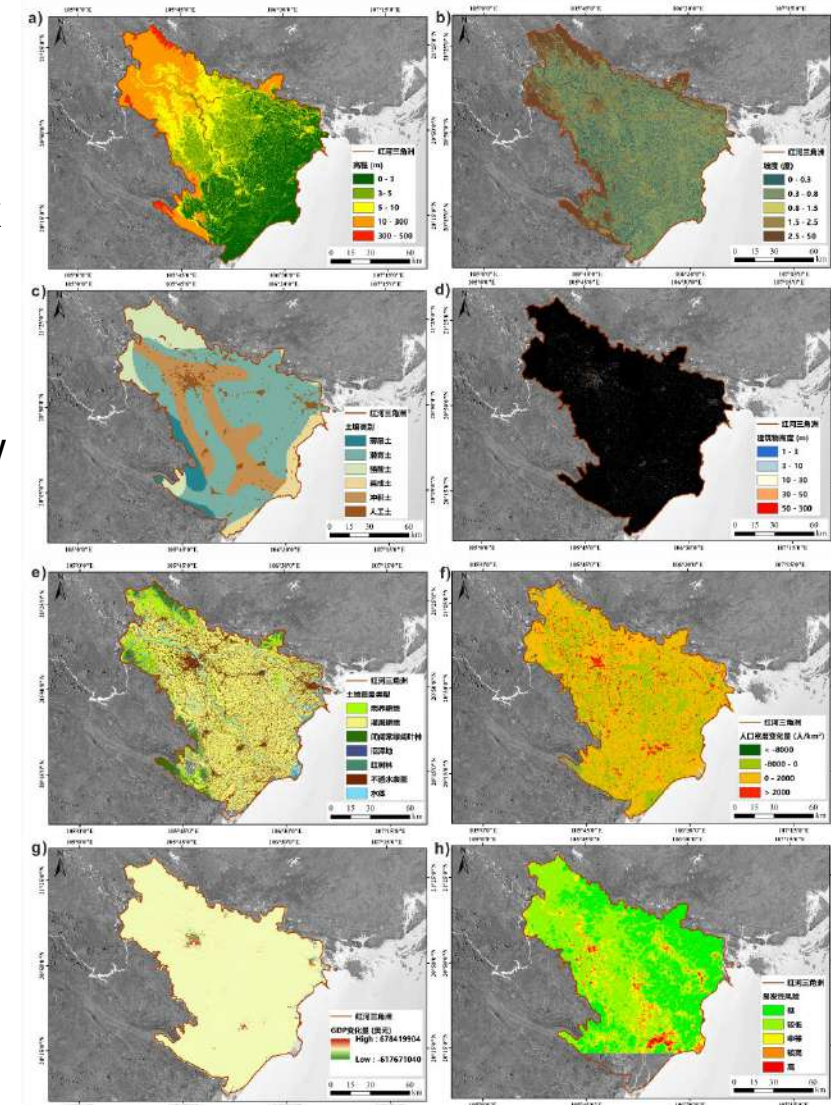
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(a) DEM (b) Slope (c) Soil Type (d) Building Height (e) Land-Cover (f) 2017 and 2023 Population Density Change (g) 2017 and 2020 GDP Changes (h) ground Subsidence Susceptibility Risk Level



Input factors

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR

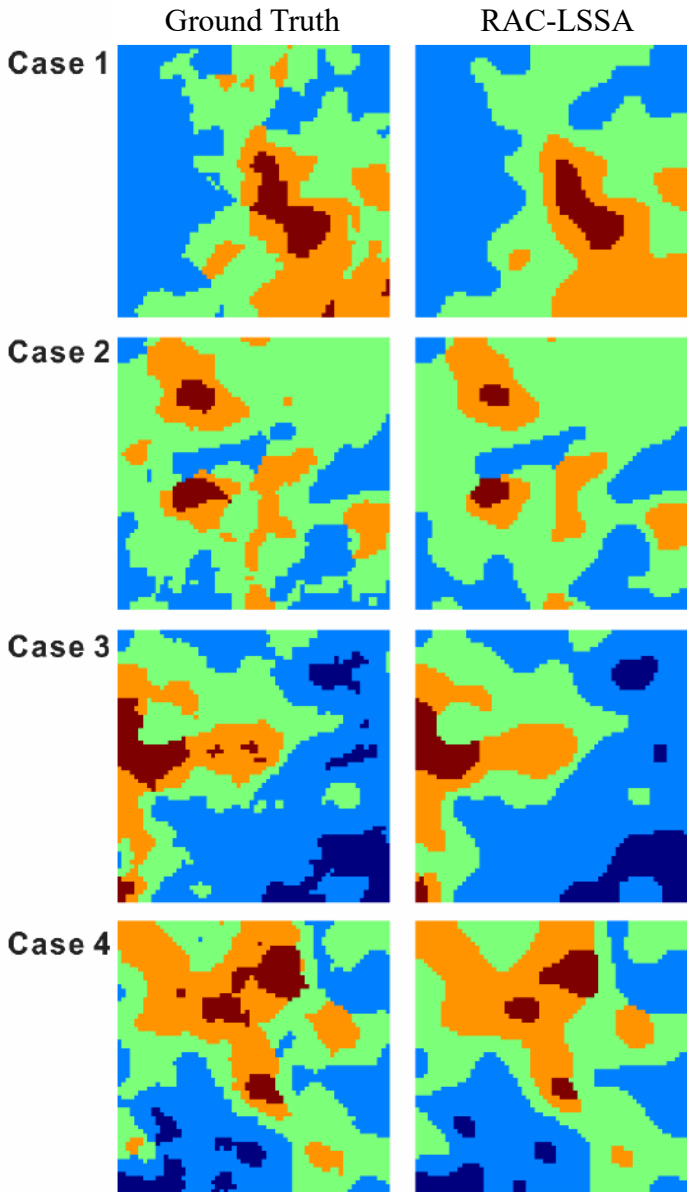


Intelligent Susceptibility
Assessment of Subsidence
Based on RAC-LSSA Model

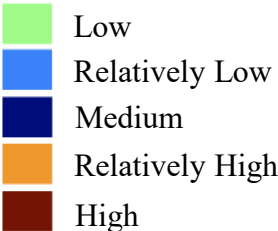
Three evaluation metrics—Precision, Recall, and F1-score—were computed for each subsidence susceptibility class.

$$Precision_c = \frac{TP_c}{TP_c + FP_c}$$
$$Recall_c = \frac{TP_c}{TP_c + FN_c}$$
$$F1_c = \frac{2 * Precision_c * Recall_c}{Precision_c + Recall_c}$$
$$Overall Accuracy = \frac{\sum_i^C TP_i}{N}$$
$$Kappa = \frac{OA - EA}{1 - EA}, EA = \frac{\sum_i^C (T_i * P_i)}{N^2}$$

Samples	Macro-Precision	Macro-Recall	Macro-F1	Kappa	Overall Accuracy
Case 1	0.89	0.88	0.88	0.85	0.89
Case 2	0.88	0.86	0.86	0.81	0.88
Case 3	0.90	0.89	0.90	0.87	0.92
Case 4	0.90	0.89	0.89	0.86	0.90



Subsidence susceptibility assessment results obtained by the RAC-LSSA model.



Results

0.8925

0.88

0.8825

0.845

0.8975

Activity 2: Delta deformation retrieval and prediction with AI-driven InSAR

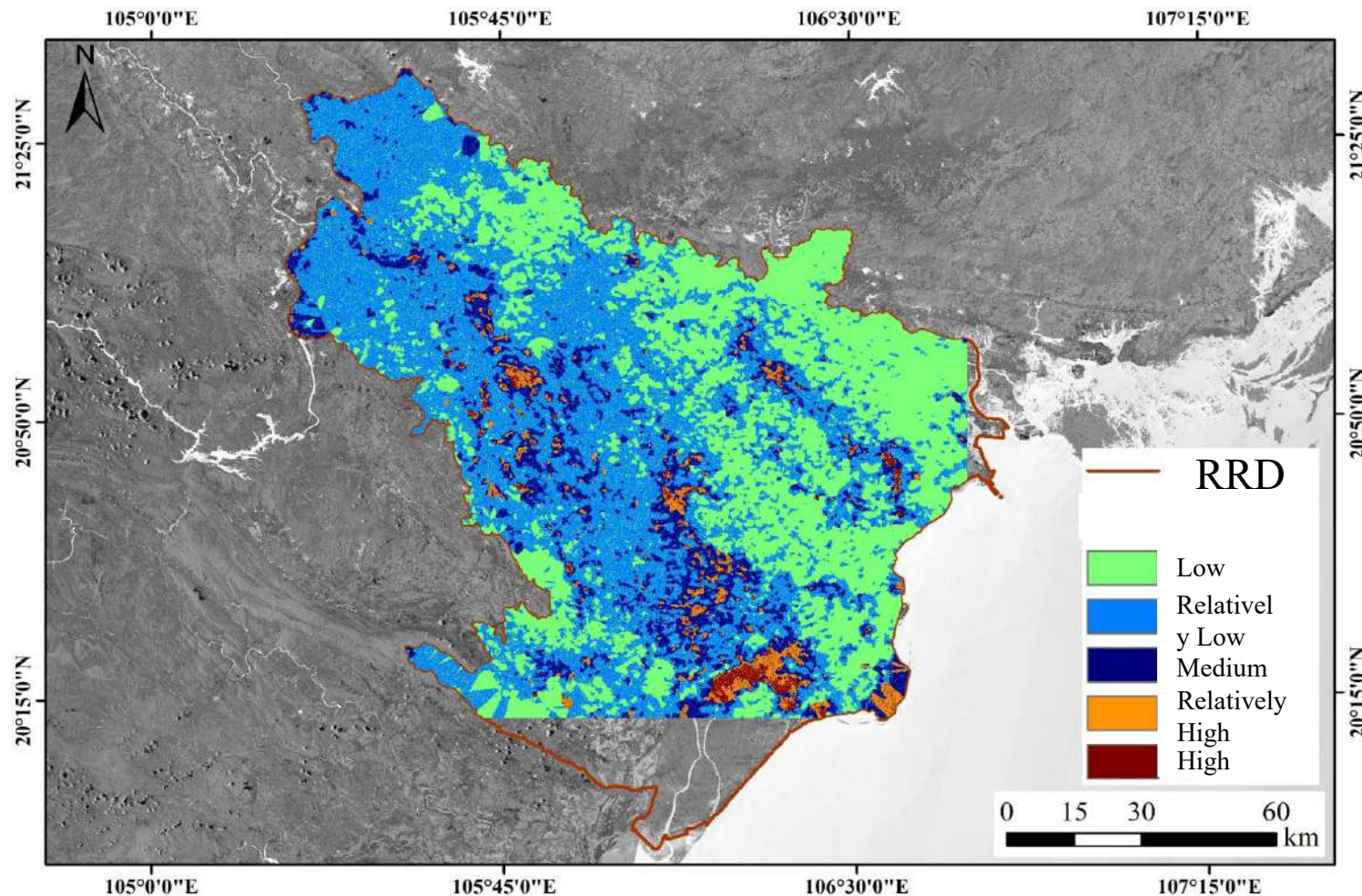


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Intelligent Susceptibility Assessment of Subsidence Based on RAC-LSSA Model



Ground Subsidence Susceptibility Risk Assessment Map of the Red River Delta.

Results

Results of the RAC-LSSA Model-
Based ground Subsidence
Susceptibility Assessment for the
Red River Delta:

- **80% of the area** exhibits **moderate or lower susceptibility risk levels.**
- **Higher and high-risk zones** are predominantly concentrated in **urban areas.**



Conclusions

1. SBAS-InSAR Retrieval of Ground Deformation in the Red River Delta

- Derived millimeter-level displacement fields (2017-2024) from **dual-satellite, three-track data**, revealing significant subsidence in **Hanoi, Hai Duong, Hung Yen, and Nam Dinh**.
- Two subsidence bowls (>20 mm/yr) formed near Hanoi's urban-rural boundary.

2. Validation of MinA Algorithm with High-Temporal-Coherence Pixels

- Optimized MinA weights through **cross-validation using TSX-LOS data**
- GPS-validated 2D deformation RMSE:
 - a) East-West: **3.2 mm** (Site 1) | **2.2 mm** (Site 2)
 - b) Vertical: **3.7 mm** (Site 1) | **2.0 mm** (Site 2)

3. Full Coherence Matrix Error Propagation Analysis

- Derived theoretical error bounds of ± 2 mm for MinA decomposition via covariance matrix propagation.

4. Influence Factor Analysis of Hanoi's Subsidence

- Dominant **vertical subsidence**
- Significant correlations with:
 - a) Population density changes
 - b) Land cover transitions (farmland $\rightarrow$ impervious surfaces)
 - c) Built-up area expansion
 - d) groundwater over pumping



Conclusions

5. RAC-LSSA Model for Susceptibility Assessment

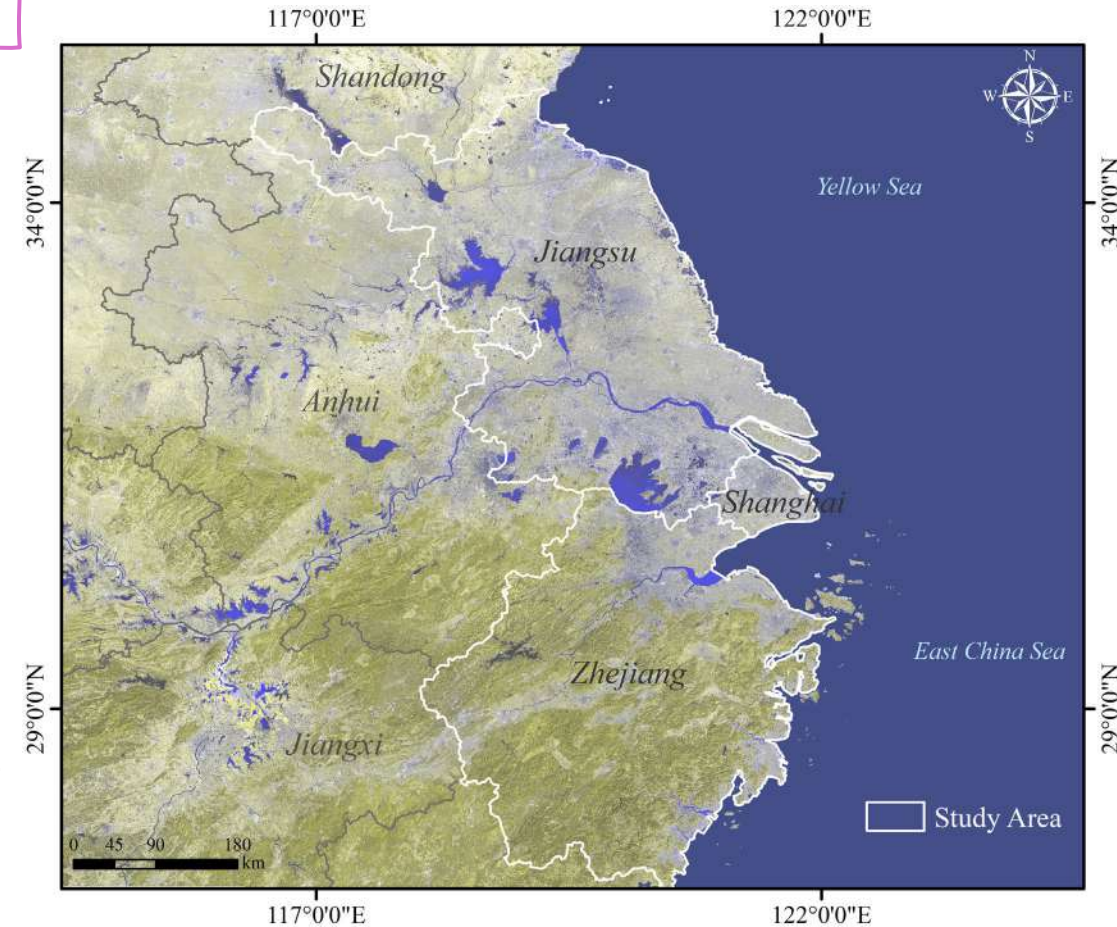
- By integrating natural factors with human activity factors, an intelligent assessment model based on residual networks and attention mechanisms is constructed to identify the subsidence susceptibility risk levels.
- The RAC-LSSA model was used to evaluate the susceptibility of Red River Delta subsidence.

Activity 3: Monitoring Coastal and Lake Environments

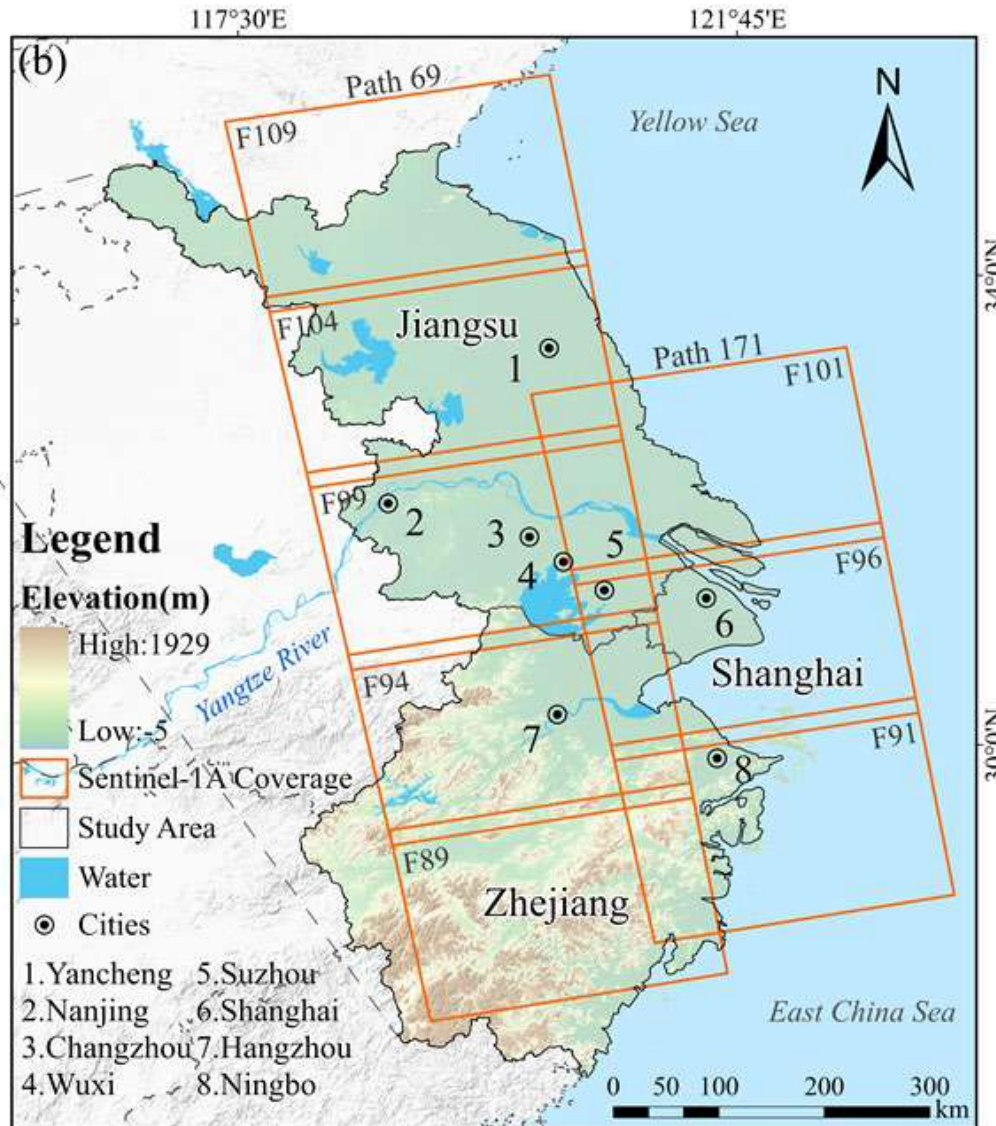


3.1 Retrieval and Prediction of Ground Deformation in the Yangtze River Delta based on Multi-source InSAR data and Multi-modal, Multi-factor Deep Learning Model

- The Yangtze River Delta (YRD) is among China's most urbanized and densely populated regions.
- Rapid urbanization, extensive infrastructure development, and prolonged overexploitation of groundwater have led to **severe ground subsidence**, resulting in direct economic losses exceeding hundreds of billions of yuan.
- Although the overall subsidence trend in the YRD has slowed in recent years, **localized areas still experience significant ground subsidence**.
- Precise monitoring and analysis of the spatiotemporal patterns of ground subsidence in the YRD, predicting future trends, are crucial for implementing targeted mitigation strategies and sustainable regional management.



Activity 3: Monitoring Coastal and Lake Environments



- **1,552 ascending track Sentinel-1 images** acquired from September 2016 to October 2023 were utilized to derive the Yangtze River Delta deformation.
- The data processing volume exceeds 8TB, and the total data volume exceeds **30TB**.

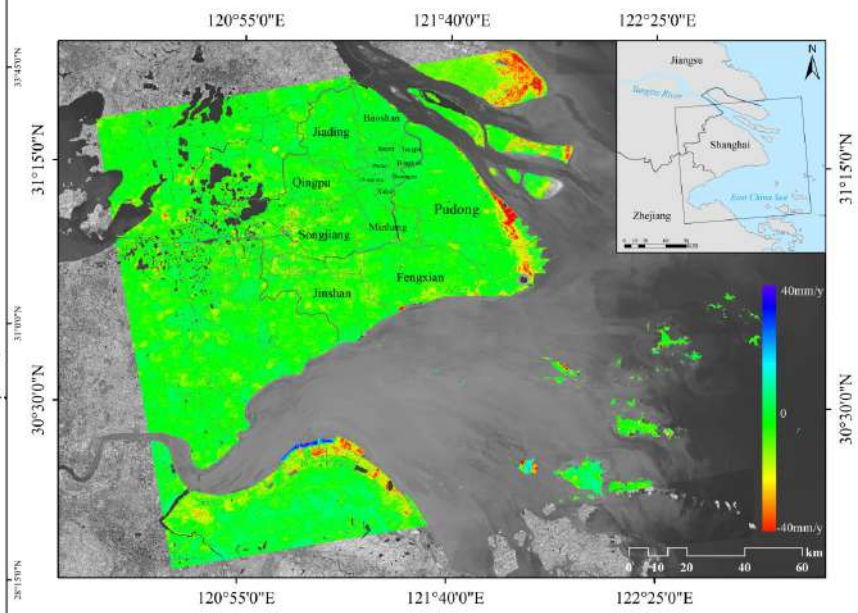
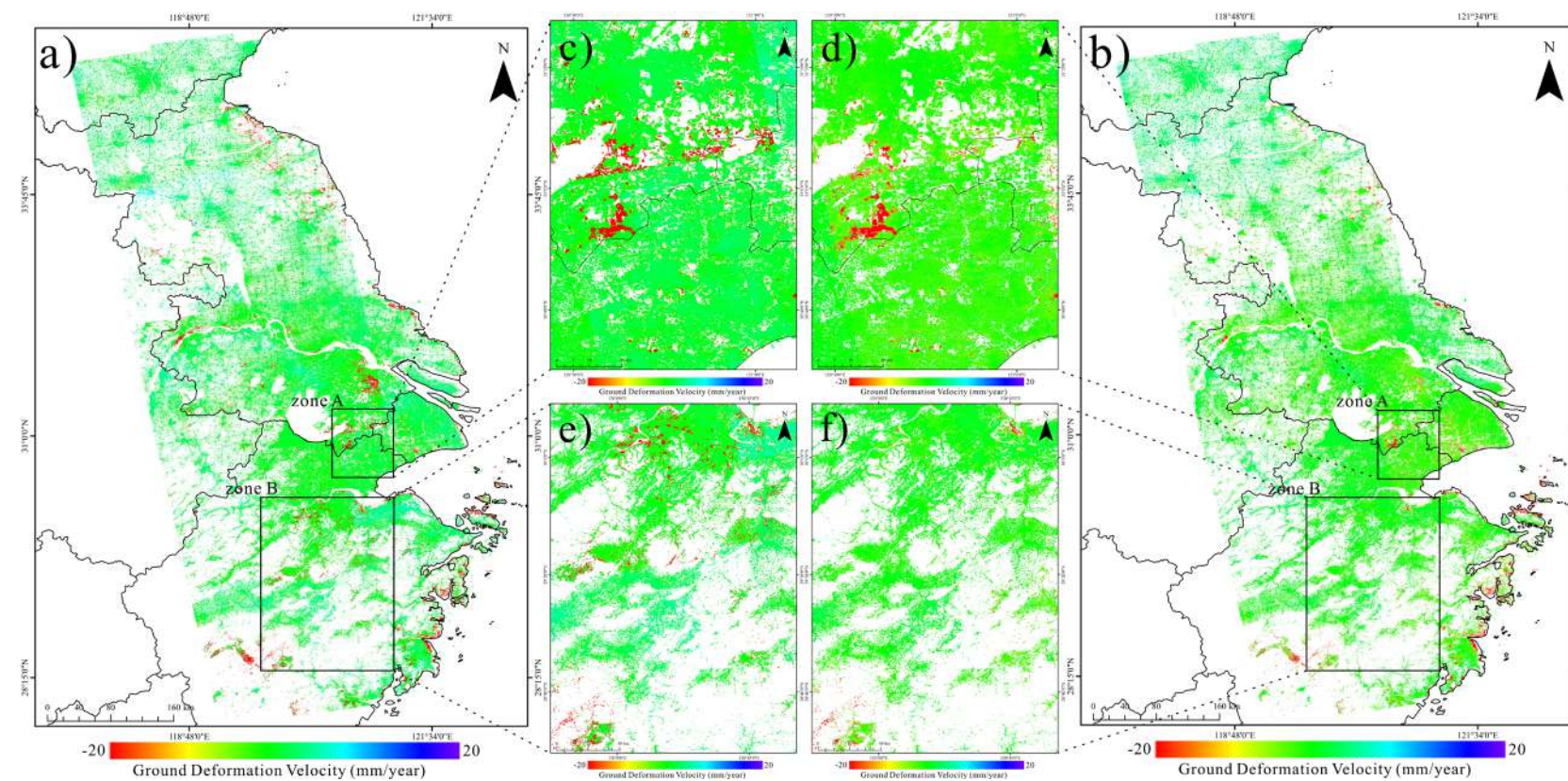
Sentinel-1 datasets

Orbital path	Orbital Frame	Acquisition time	Number of images
69	89	2017.03.07-2023.09.29	189
69	94	2016.11.16-2023.09.29	197
69	99	2017.03.28-2023.10.23	184
69	104	2017.03.27-2023.10.11	183
69	109	2017.03.16-2023.08.24	180
171	91	2016.09.12-2023.10.18	205
171	96	2016.09.12-2023.10.18	206
171	101	2016.01.16-2023.10.06	208

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3.1 Recent Ground Deformation retrieval of the Yangtze River Delta



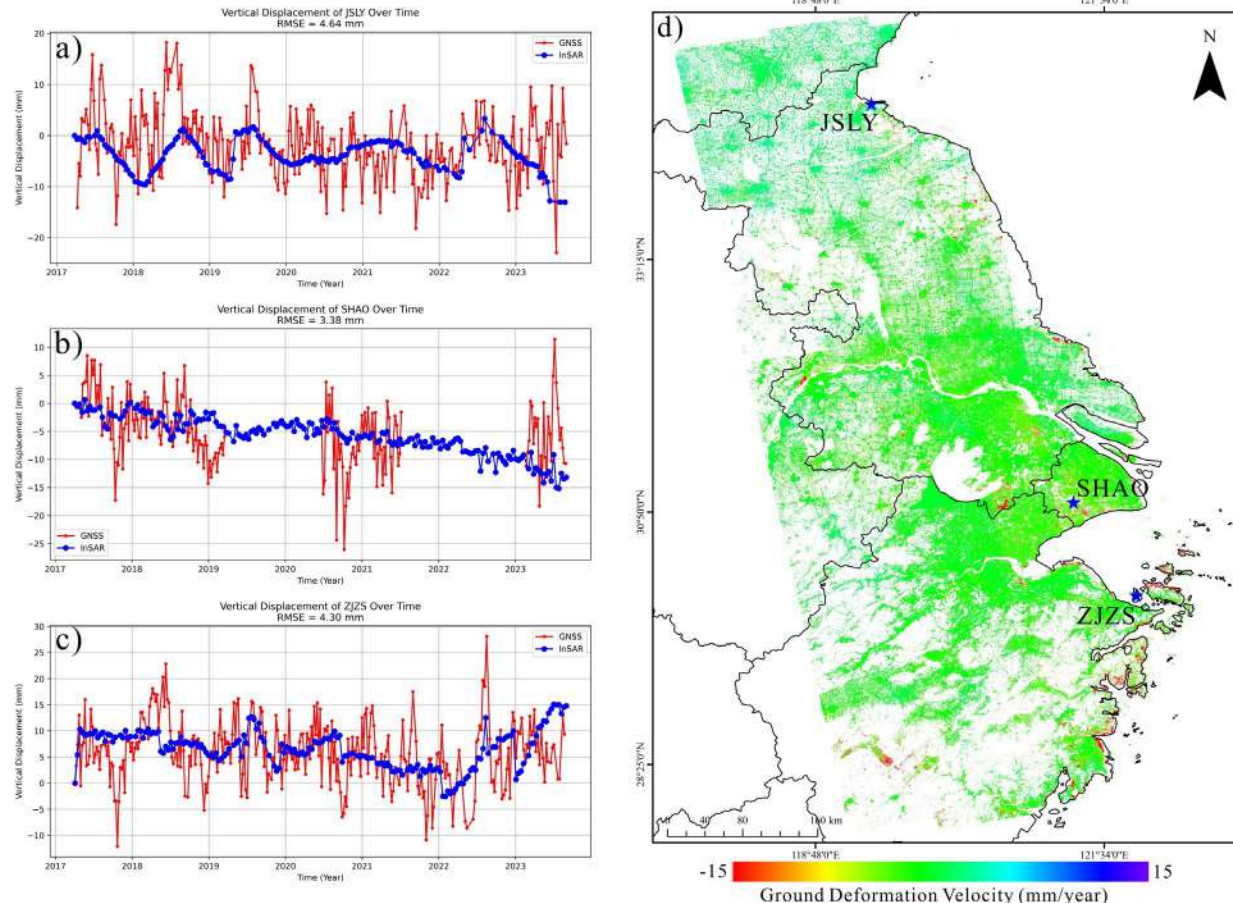
Ground deformation velocity of the Shanghai from July 2017 to July 2023

Maps of ground deformation results of YRD from 2017.3 to 2023.8 without and with block adjustment: a) map of the mean ground deformation velocity of YRD without block adjustment; b) map of the mean ground deformation velocity of YRD with block adjustment

Activity 3: Monitoring Coastal and Lake Environments



3.1 Recent Ground Deformation retrieval of the Yangtze River Delta



The main ground deformation zones:

- Coastal zones of Yancheng, Nantong, Shanghai, Hangzhou and Ningbo.
- Densely populated zones of Nanjing and Shanghai.
- Ground fracture-prone zones of Suzhou, Wuxi, and Changzhou.

Ground deformation in YRD and validation:

- The annual average deformation velocity of YRD is < 4 mm/year.
- The InSAR-derived ground deformation time series are consistent with three GNSS (JSYC, JSNT and SHAO) station monitoring results.

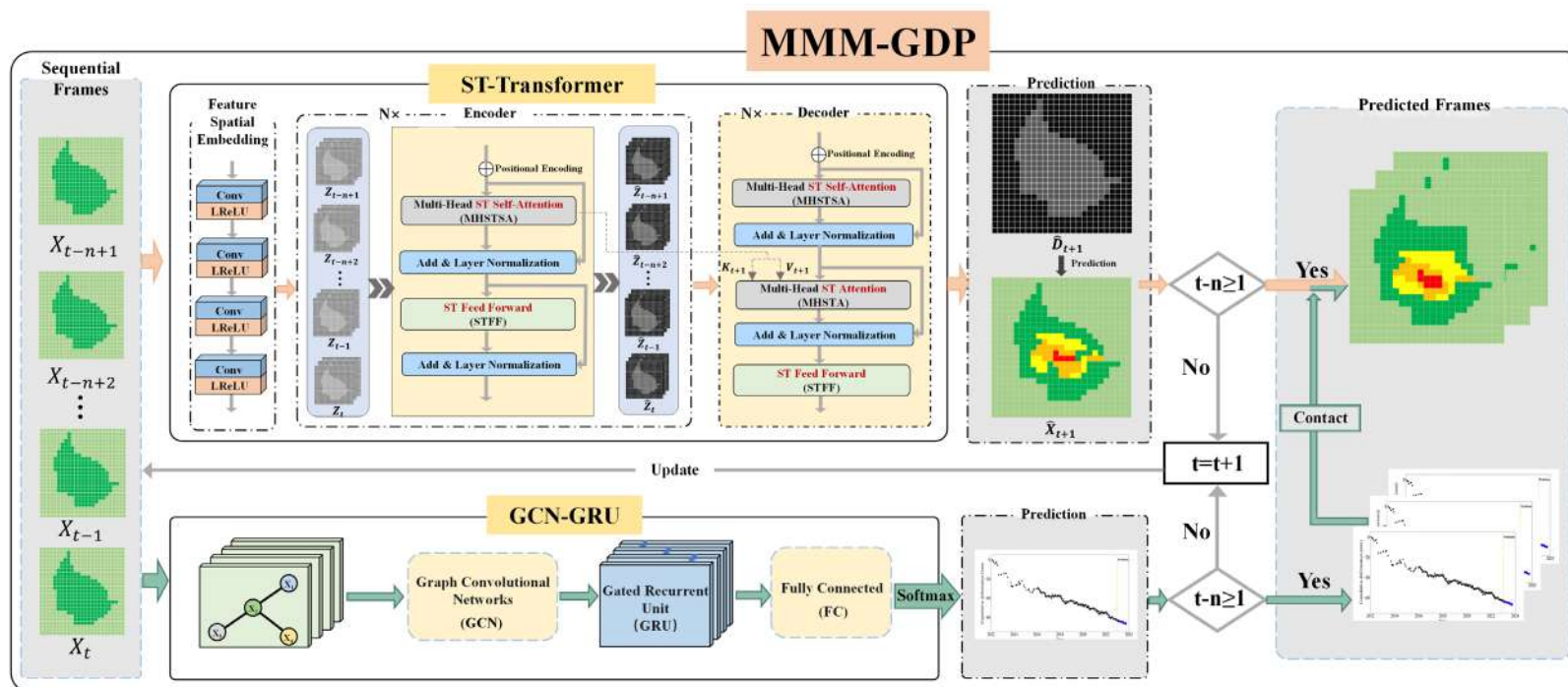
The RMSE plot of SBAS-InSAR derived subsidence time series and GNSS vertical time series from 2017 to 2023 at three GNSS stations

Activity 3: Monitoring Coastal and Lake Environments



3.2 Prediction of Ground Deformation in the Yangtze River Delta based on Multi-source InSAR data and Multi-modal, Multi-factor Deep Learning Model

- The MMM-GDP model is the Multi-modal, Multi-factor, and Multi-source Ground Deformation Prediction model.
- It integrates two branches with the ST-Transformer (Spatio-Temporal Transformer) architecture and the GCN-GRU (Graph Convolutional Network-Gated Recurrent Unit) architecture.
- Predict large-scale spatial-temporal deformation.



First Branch ST-Transformer

This Branch can effectively **capture spatial-temporal features** from sequential ground deformation data to **predict** future ground subsidence.

Second Branch GCN-GRU

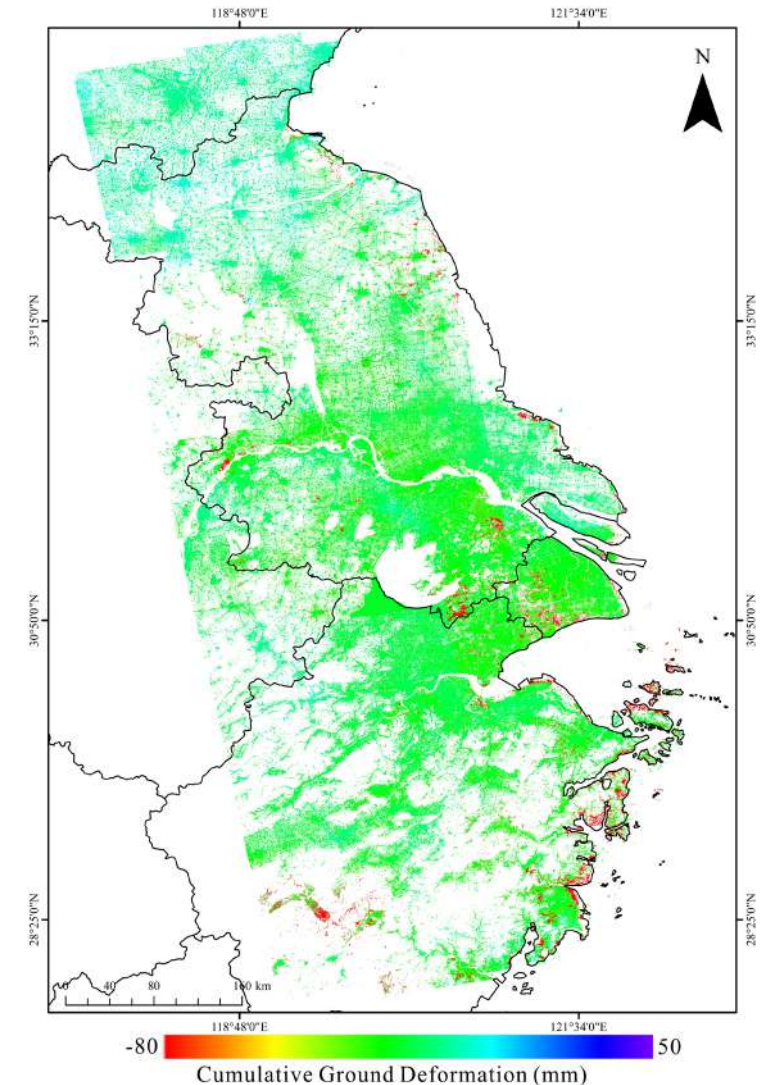
This Branch **improves the temporal prediction accuracy** of the ST-Transformer by specifically predicting subsidence in the main subsidence regions.

Activity 3: Monitoring Coastal and Lake Environments



3.1 Prediction of Ground Deformation in the Yangtze River Delta based on Multi-source InSAR data and Multi-modal, Multi-factor Deep Learning Model

- Based on the MMM-GDP model, a comprehensive prediction of ground subsidence across the Yangtze River Delta region for 2026 was conducted.
- The eastern coastal region of Jiangsu Province, the Suzhou-Wuxi-Changzhou area, the Yangtze River coastal zone, southwestern Shanghai, and the Hangzhou-Jiaxing-Huzhou Plain are projected to experience an expansion in subsidence extent, with cumulative settlement exceeding 150 mm.



Map of the predicted cumulative ground deformation of YRD from 2017.3 to 2026.8 based on MMM-GDP

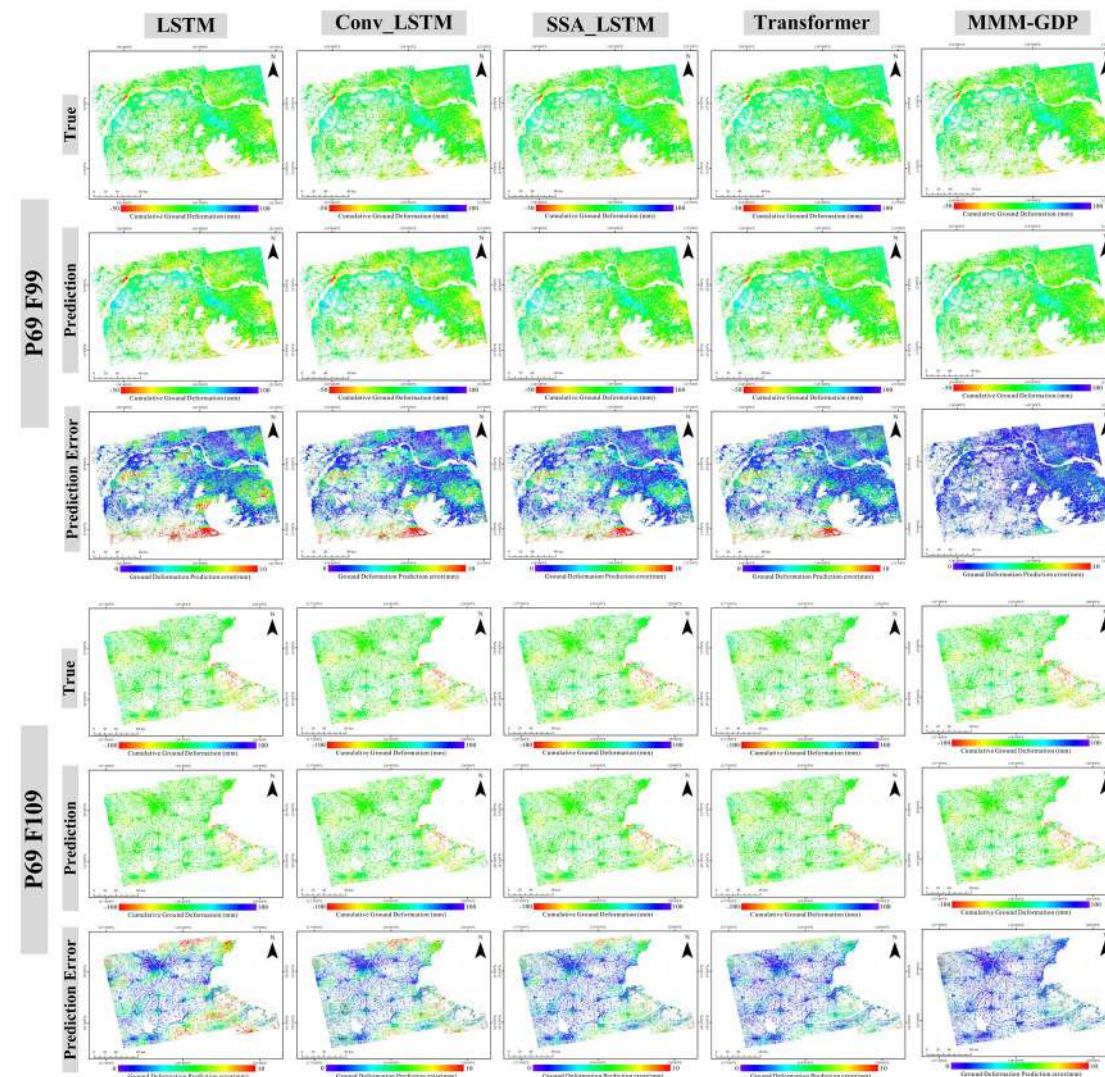
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Comparison with baseline models

- To validate the effectiveness of the MMM-GDP model, this study employs classical time-series prediction algorithms for comparative analysis.
- The MMM-GDP model outperforms all other network models across all evaluation metrics.

Model	MAE (mm)	MSE (mm)	RMSE (mm)
LSTM	3.56	7.42	2.72
Conv-LSTM	3.21	6.01	2.45
SSA-LSTM	3.07	5.88	2.42
Transformer	2.89	5.75	2.40
MMM-GDP	1.25	3.17	1.78





Conclusions

Ground deformation during 2017-2023

- This study processed **8 tracks of Sentinel-1A data (2017–2023)** to reconstruct the regional surface deformation field via the SBAS-InSAR technique.
- **Millimeter-precision ground subsidence in the Yangtze River Delta was derived using the SBAS-InSAR.**
- The results reveal that ground subsidence primarily concentrates in **three major subsidence centers**: the **eastern coastal area**, the **alluvial zone of the Yangtze River**, and the **Qiantang River**, where deformation rates exceed **–20 mm/year**.

1552
Sentinel-1 images

MMM-GDP model

- We developed the **Multi-modal, Multi-factor Ground Deformation Prediction (MMM-GDP) model**, a spatiotemporal intelligent prediction model for subsidence.
- Comparative validation demonstrates that the MMM-GDP model outperforms other subsidence prediction models, achieving a prediction error of less than **1.25 mm**, thereby proving its capability for **high-precision spatiotemporal prediction** of ground subsidence.
- The prediction results reveal an expanding subsidence trend in localized areas of the Yangtze River Delta, including:
 - The **eastern coastal region of Jiangsu Province**
 - The **Suzhou-Wuxi-Changzhou metropolitan area**
 - The **Yangtze River coastal zone**
 - **Southwestern Shanghai**
 - **Wuzhou P**

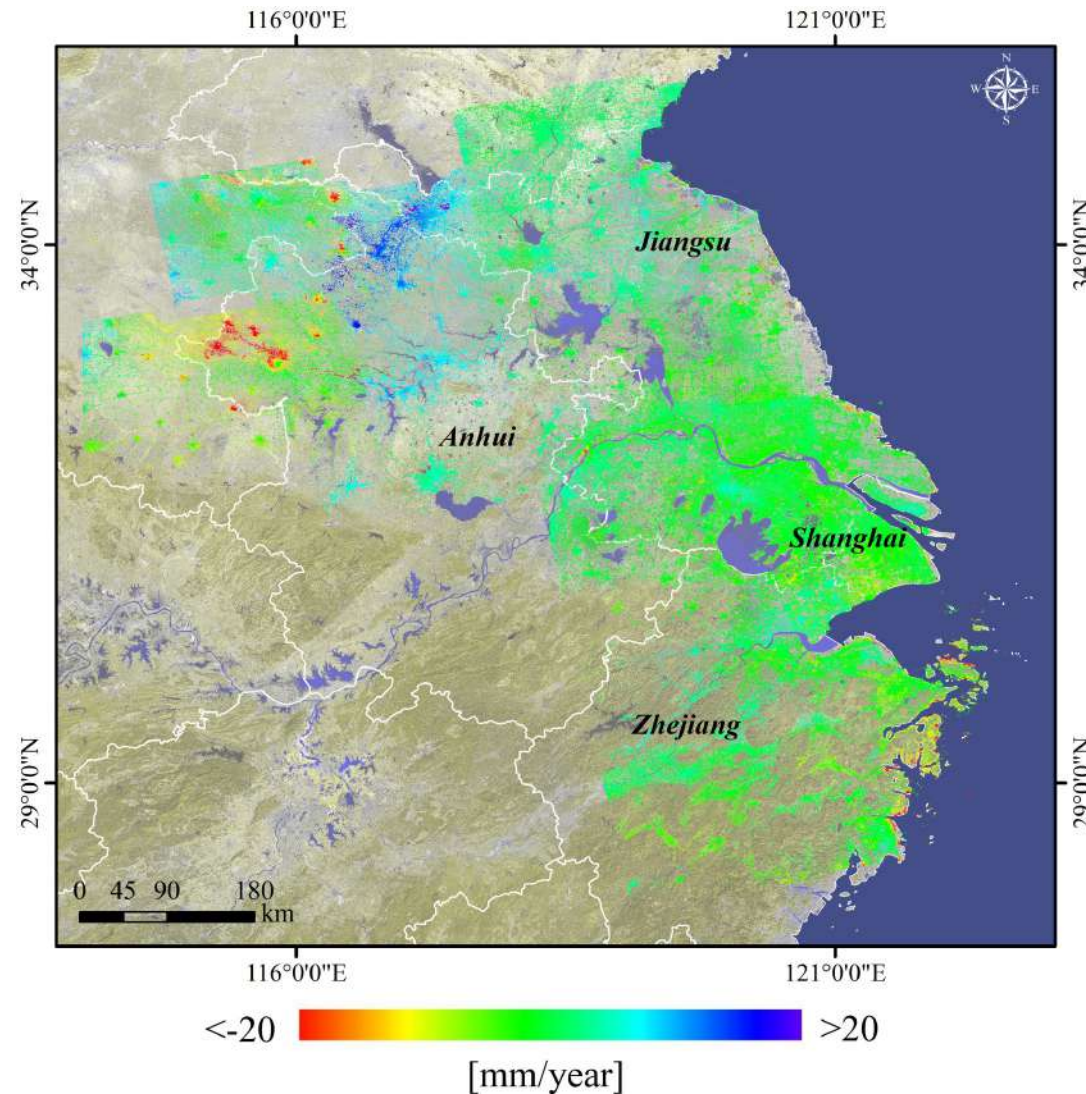
MAE
1.25mm

RMSE
1.78 mm

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3.1 Ground Deformation Monitoring in the Yangtze River Delta



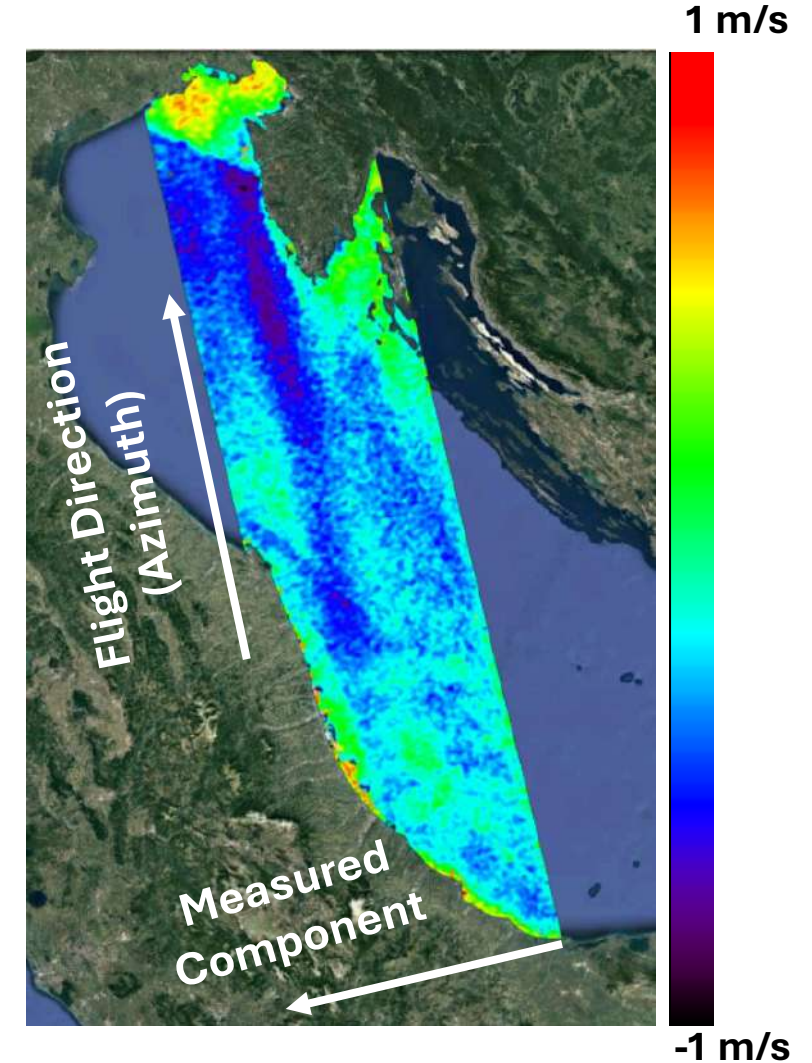
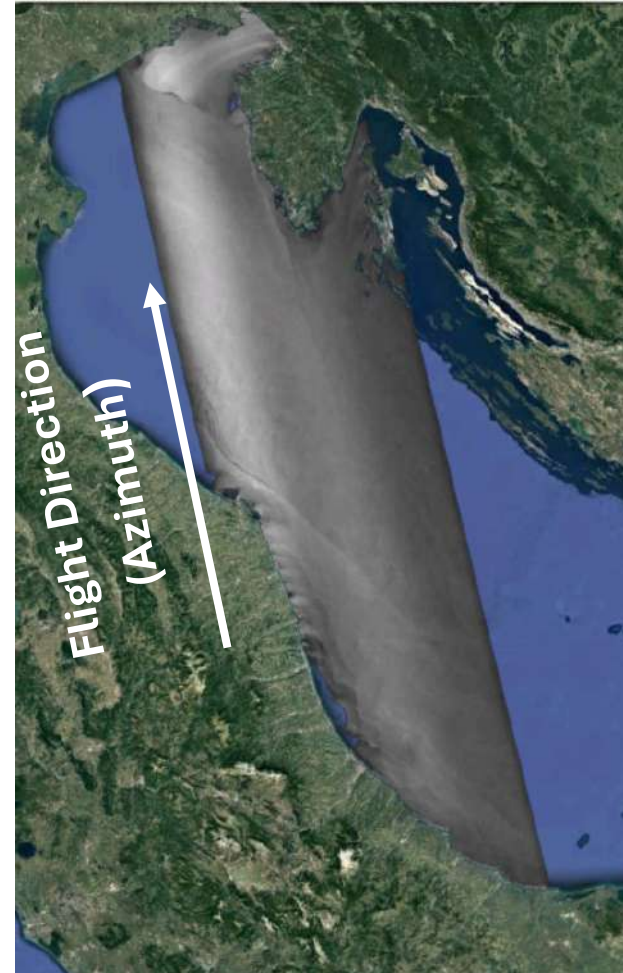
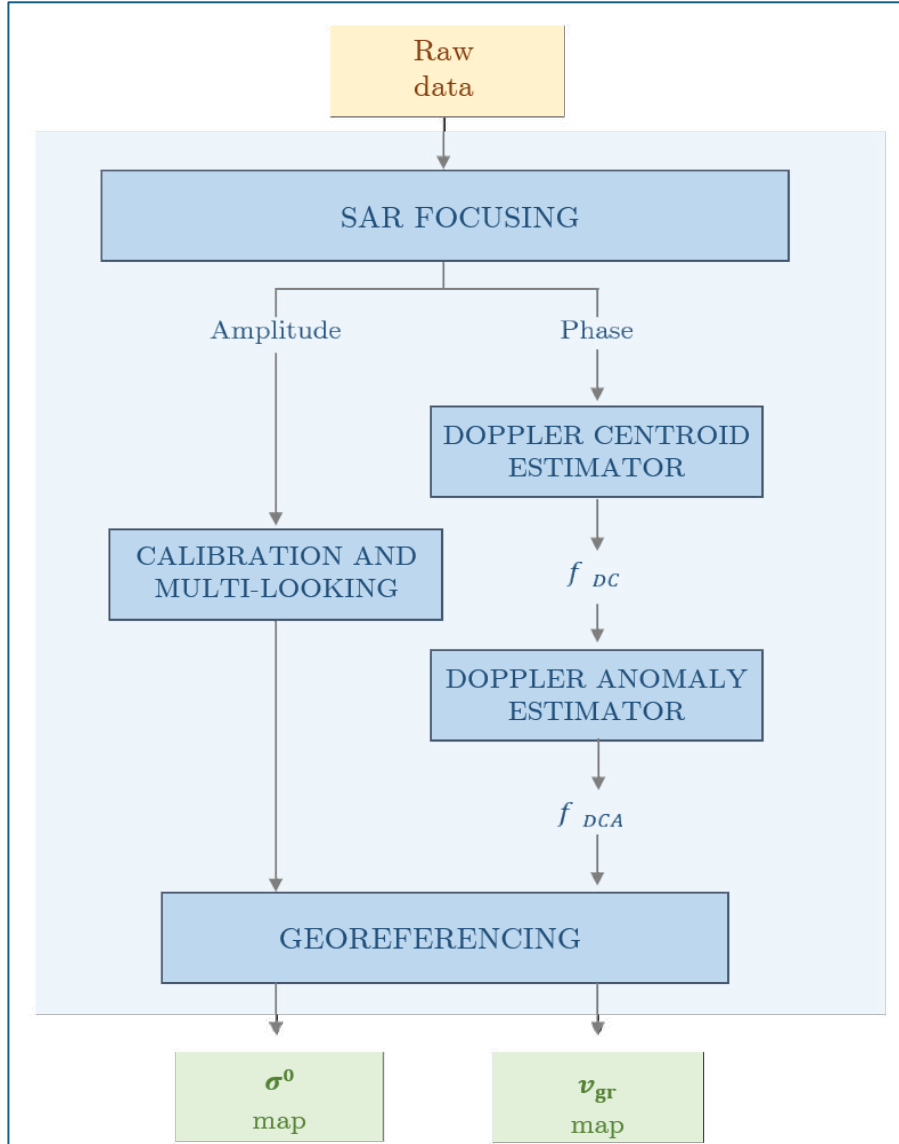
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Activity 4: Assessing the combined risks of coastal megacity



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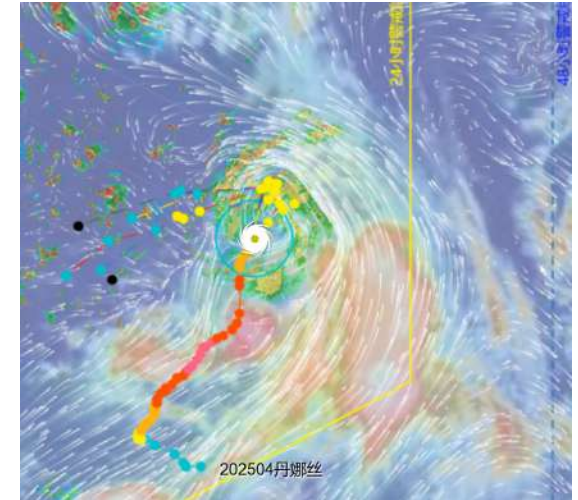
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4.1 Assessment of the Integrated Risk of Buildings and Economic Losses in Shanghai Megacity Based on Future Disaster Scenarios and Input-Output Model

- Shanghai is a megacity with an area of 6,340 km² and a population of over 24.7 million, where disaster-bearing bodies are **densely distributed**.
- Grid-based assessments are inadequate for fulfilling the requirements for the precise management of buildings.**
- Shanghai is frequently affected by **typhoon-driven storm surge disasters**.
- Shanghai has long been affected by **ground subsidence**.
- Develop an integrated risk assessment model for individual buildings** in the megacity and conduct refined risk and loss assessments under various future scenarios.



Building Density within
Kilometer Grids in Shanghai



Typhoon



Waibaidu Bridge after historical
subsidence



Waibaidu Bridge before historical
subsidence

Activity 4: Assessing the combined risks of coastal megacity

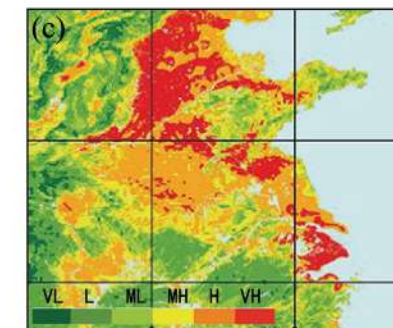
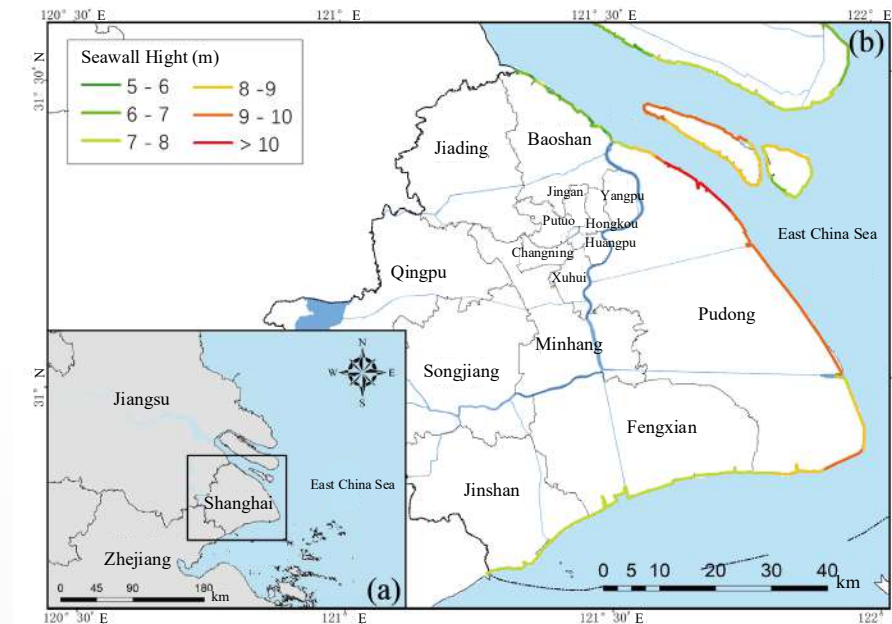


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Data Types	Data Name	Data source and description
Data for simulating disasters	Radar satellite	141 ascending Sentinel-1A images acquired over Shanghai between 2017 and 2021
	Mean sea level rise	IPCC Sixth Assessment Report
	Extreme water level data during storm surges	Extreme water level data during Typhoon 9711 (Yin et al., 2020)
Elevation	DiluviumDEM	Digital elevation datasets for global coastal areas (Dusseau et al., 2023)
Seawall	Seawall height	The elevation of the Shanghai seawall (Yin et al., 2020)
Buildings	Building distribution	High-resolution (2.5 m) building rooftop area dataset in China (CBRA)
	Building height	Building height raster dataset (CNBH-10m)
	Year of built	China annual 30 m land use dataset (1985–2022)
	Building function	Point of Interest Dataset
Population	Population dataset	Projected Population Gridded Dataset under Shared Socioeconomic Pathways(Chen et al., 2020)
Economy	GDP dataset	Projected GDP Gridded Dataset under Shared Socioeconomic Pathways(Wang et al., 2022)



(a) Shanghai seawall height distribution; (c) Map of future ground subsidence prone areas (red for high subsidence risk areas)(Herrera-Garcia et al., 2021); (d) The coverages of the Sentinel-1A data.

Activity 4: Assessing the combined risks of coastal megacity



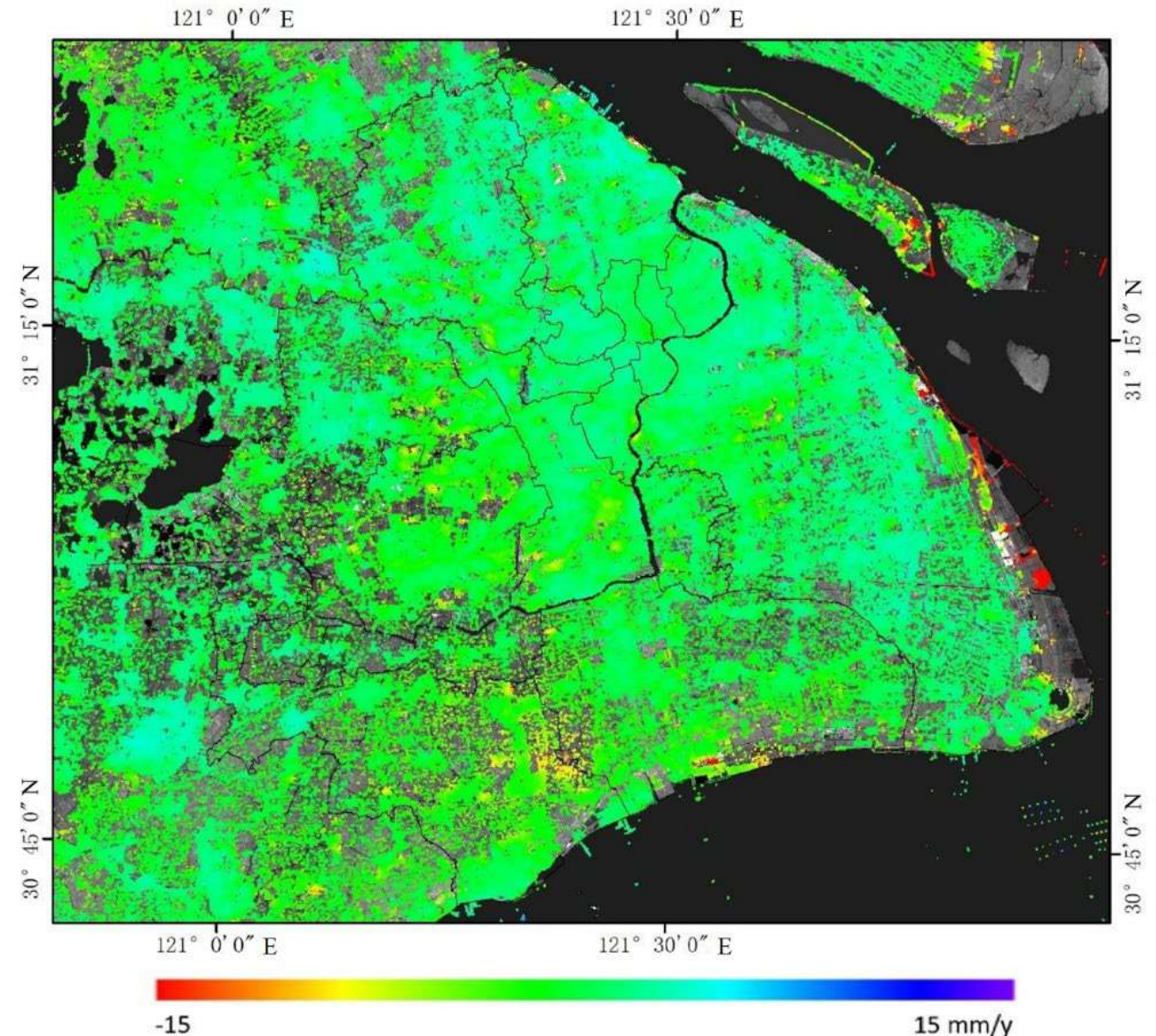
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Ground subsidence from 2017 to 2021

- During 2017-2021, the areas with significant subsidence were mainly concentrated in the coastal regions of Shanghai.
- Specifically, we observed deformation with an average annual rate exceeding 20 mm/year in the **eastern coastal area of Pudong**, which is likely due to self-weight consolidation of dredger fill.
- Notably, some seawalls also exhibit significant subsidence, compromising their protective performance and reducing coastal areas' capacity to resist storm surges and sea-level rise.



Activity 4: Assessing the combined risks of coastal megacity



Development of Extreme Storm Surge Scenarios

Based on the extreme water level data from tidal stations during Typhoon No. 9711 and the projected global mean sea level rise data from the IPCC Sixth Assessment Report, we determined the highest water level values for all tidal stations for the years **2030**, **2050**, and **2100**.

Tidal Station	Highest Tide Level	2030					2050					2030				
		SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Waigaoqiao	5.99	6.08	6.08	6.08	6.09	6.09	6.17	6.18	6.19	6.21	6.22	6.37	6.43	6.55	6.67	6.76
Wusongkou	5.99	6.08	6.08	6.08	6.09	6.09	6.17	6.18	6.19	6.21	6.22	6.37	6.43	6.55	6.67	6.76
Huangpu Park	5.72	5.81	5.81	5.81	5.82	5.82	5.9	5.91	5.92	5.94	5.95	6.1	6.16	6.28	6.4	6.49
Luchao Port	5.68	5.77	5.77	5.77	5.78	5.78	5.86	5.87	5.88	5.9	5.91	6.06	6.12	6.24	6.36	6.45
Changxing	5.88	5.97	5.97	5.97	5.98	5.98	6.06	6.07	6.08	6.1	6.11	6.26	6.32	6.44	6.56	6.65
Hengsha	5.65	5.74	5.74	5.74	5.75	5.75	5.83	5.84	5.85	5.87	5.88	6.03	6.09	6.21	6.33	6.42
Beichao	5.36	5.45	5.45	5.45	5.46	5.46	5.54	5.55	5.56	5.58	5.59	5.74	5.8	5.92	6.04	6.13
Dajinshan	5.26	5.35	5.35	5.35	5.36	5.36	5.44	5.45	5.46	5.48	5.49	5.64	5.7	5.82	5.94	6.03
Zhongjun	5.69	5.78	5.78	5.78	5.79	5.79	5.87	5.88	5.89	5.91	5.92	6.07	6.13	6.25	6.37	6.46
Tanxu island	5.9	5.99	5.99	5.99	6.0	6.0	6.08	6.09	6.1	6.12	6.13	6.28	6.34	6.46	6.58	6.67

Activity 4: Assessing the combined risks of coastal megacity

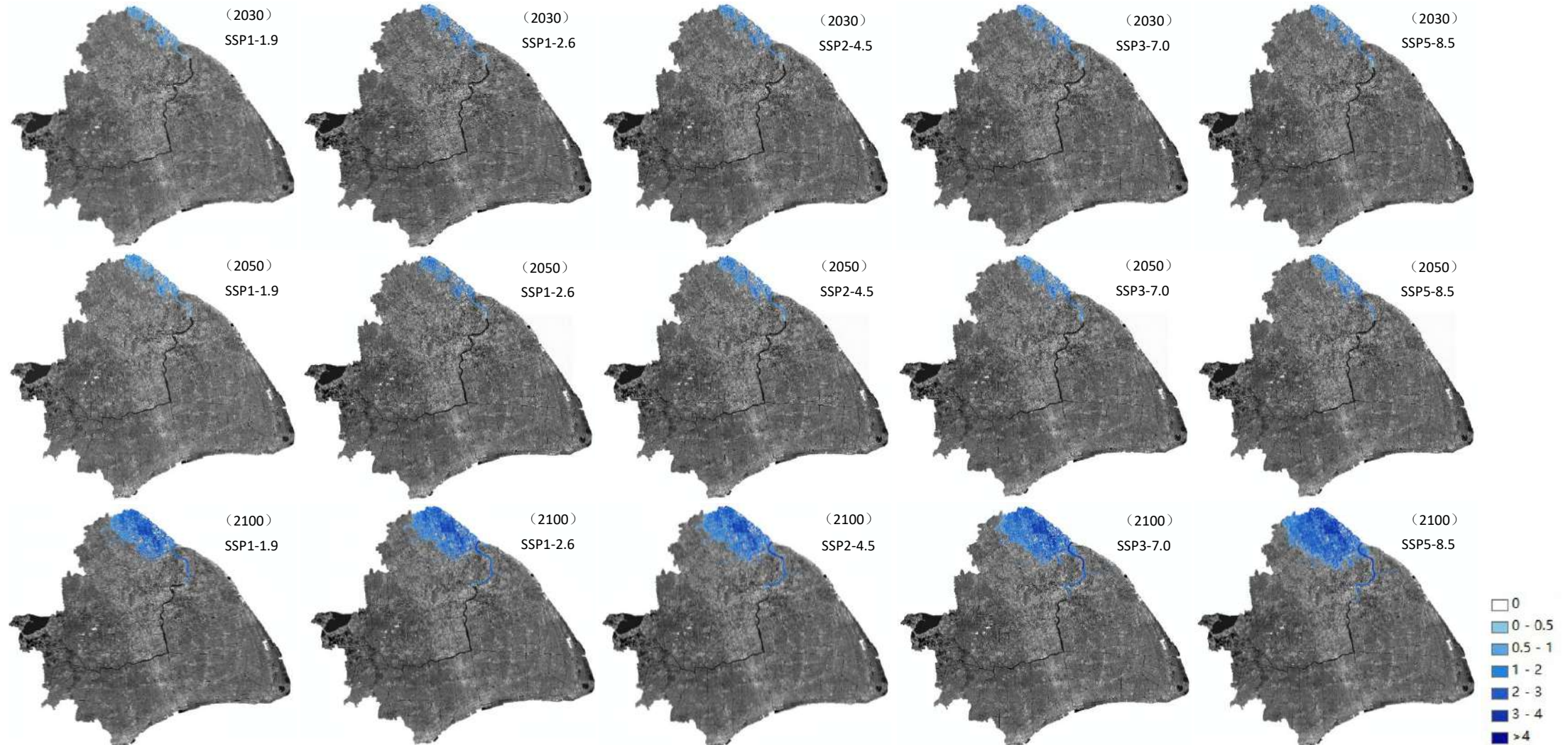


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Simulation of Coastal Flooding Induced by Wave Overtopping



Activity 4: Assessing the combined risks of coastal megacity

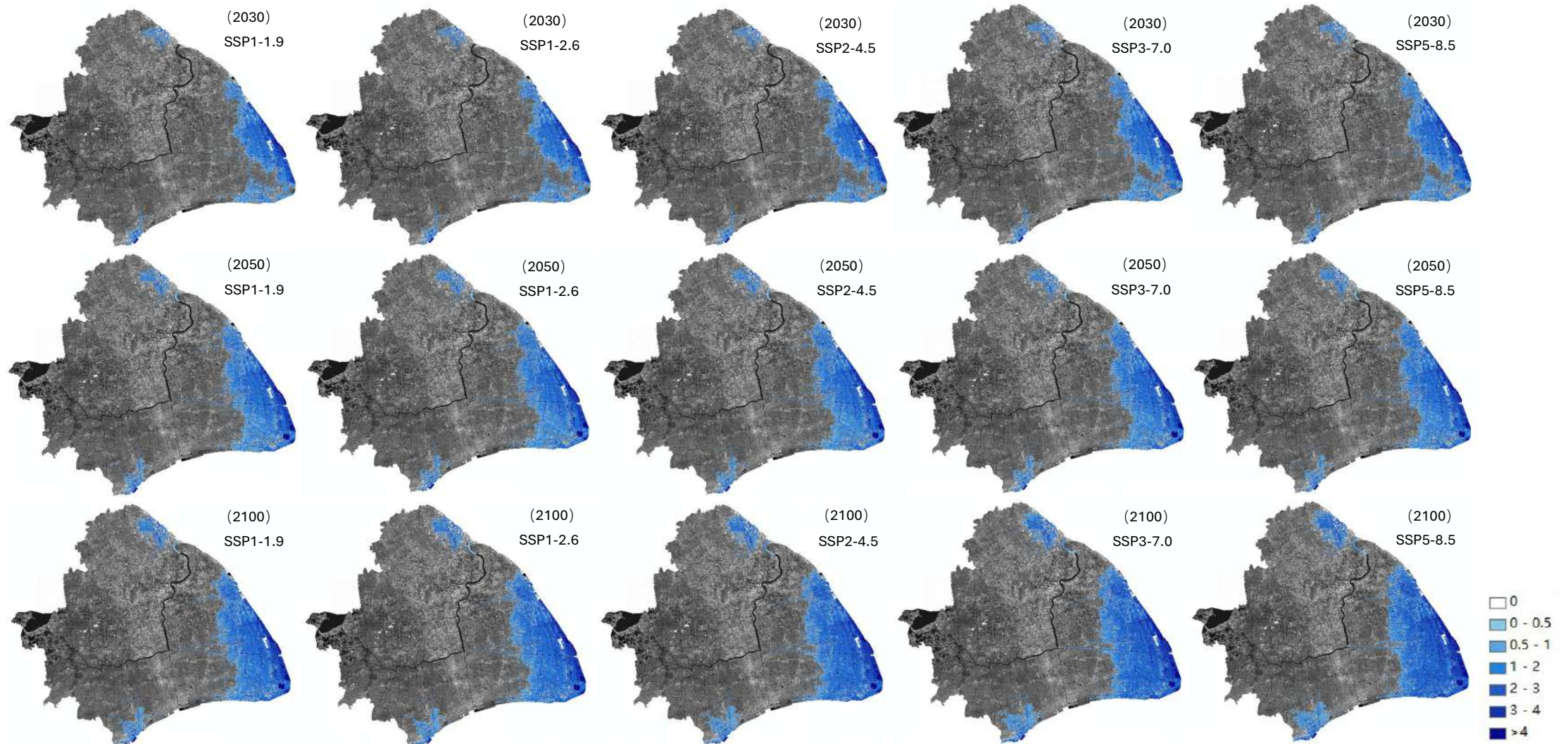


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Simulation of Coastal Flooding induced by Seawall Breaching



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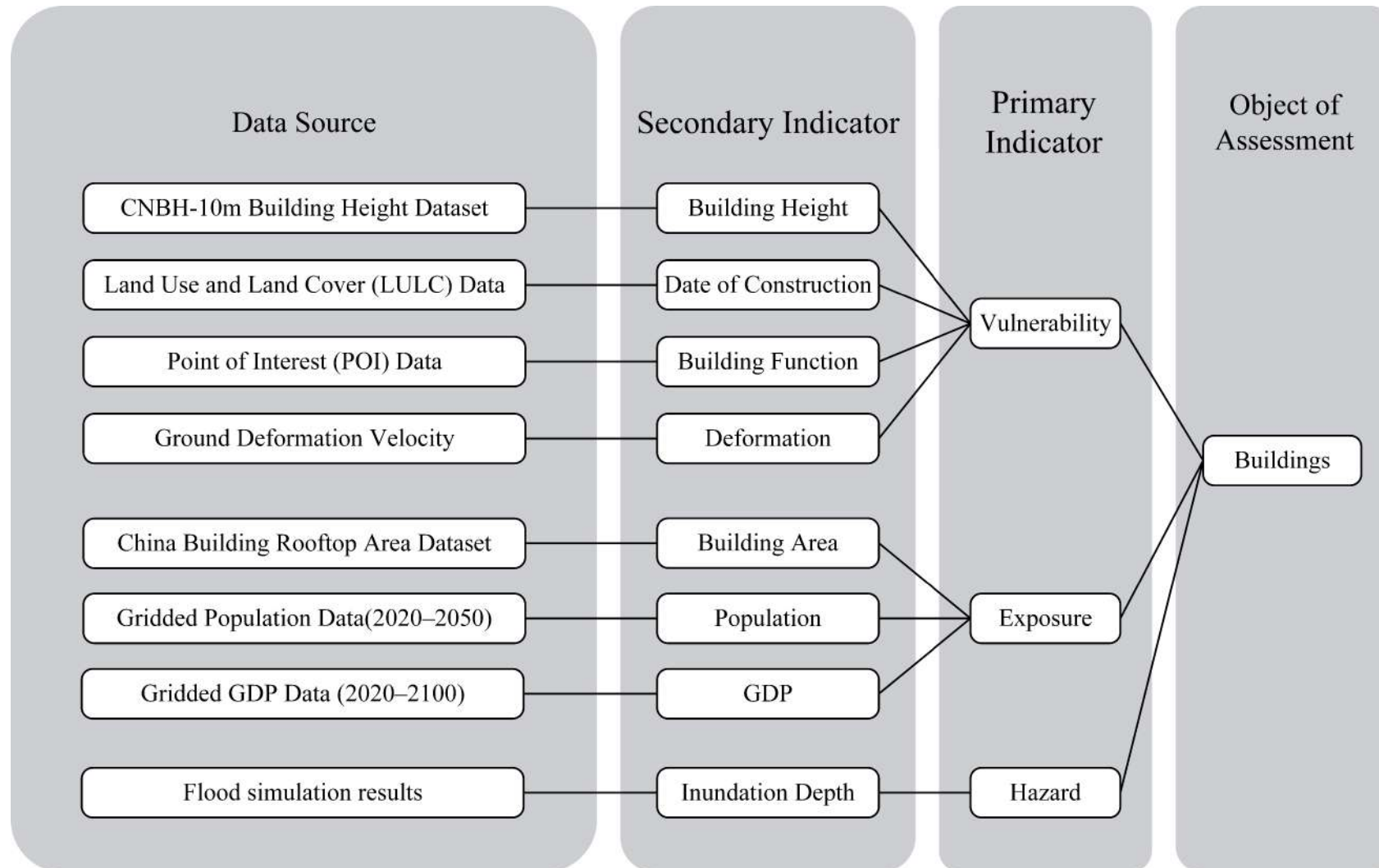


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Integrated Risk Assessment Metrics for Buildings in Megacities



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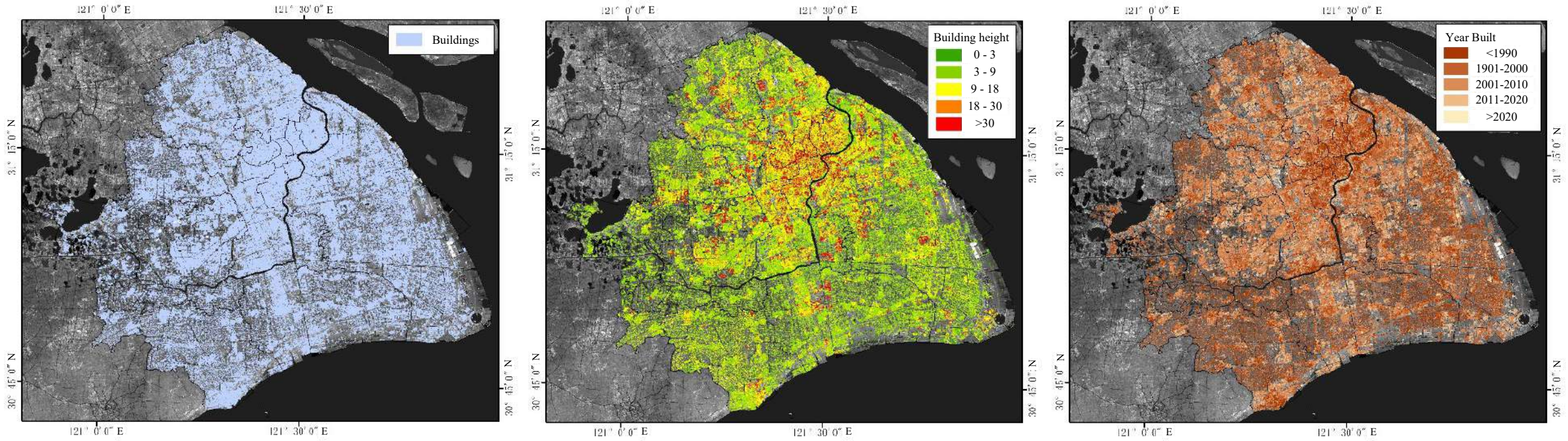


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Building Information



(a) Building polygons of Shanghai, (b) Heights of buildings, (c) Construction year of buildings in Shanghai

Activity 4: Assessing the combined risks of coastal megacity

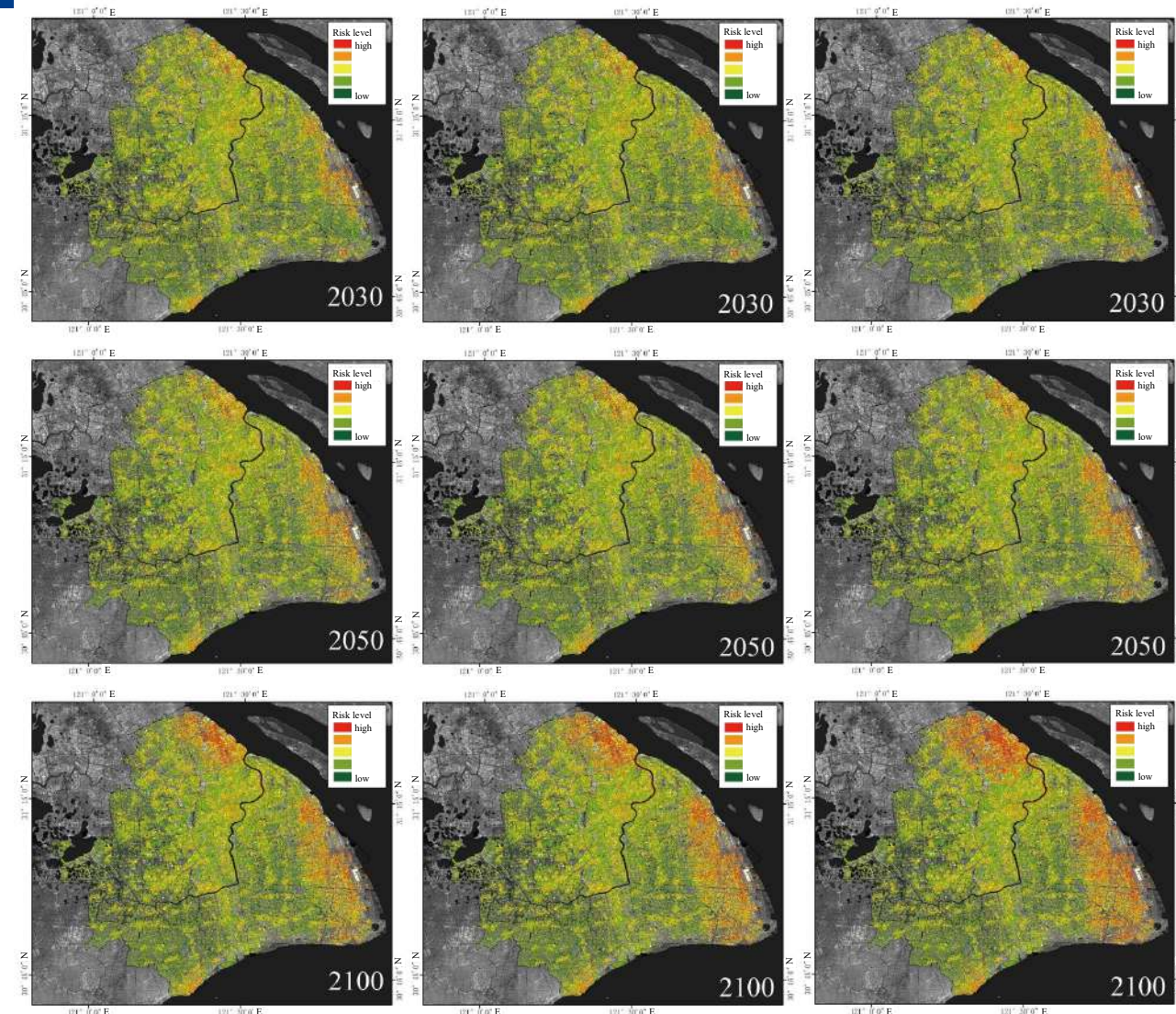


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- In 2030, there are 7,164 (SSP1 - 1.9) ~ 10,302 (SSP5 - 8.5) buildings with a high integrated risk level;
- In 2050, there are 14,647 (SSP1 - 1.9) ~ 17,164 (SSP5 - 8.5) buildings with a high integrated risk level;
- In 2100, there are 28,133 (SSP1 - 1.9) ~ 59,997 (SSP5 - 8.5) buildings with a high integrated risk level;
- Buildings with high risk levels are primarily located in high-flood-risk coastal zones, and expanding landward with increasing hazard severity over time.



Scenario-Based Projections of Integrated Risk for Individual Building in Shanghai: SSP1-1.9, SSP2-4.5, SSP5-8.5.

Activity 4: Assessing the combined risks of coastal megacity

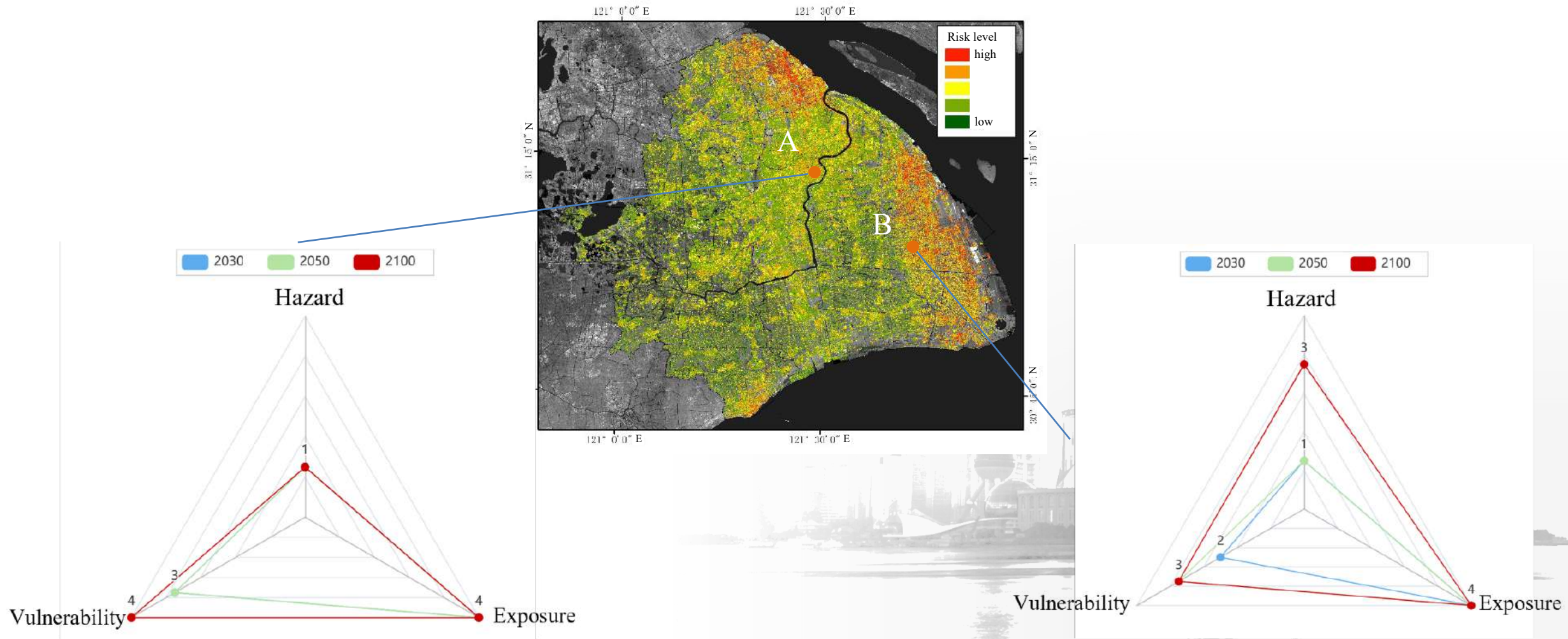


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Building-Scale Integrated Multi-Hazard Risk Assessment



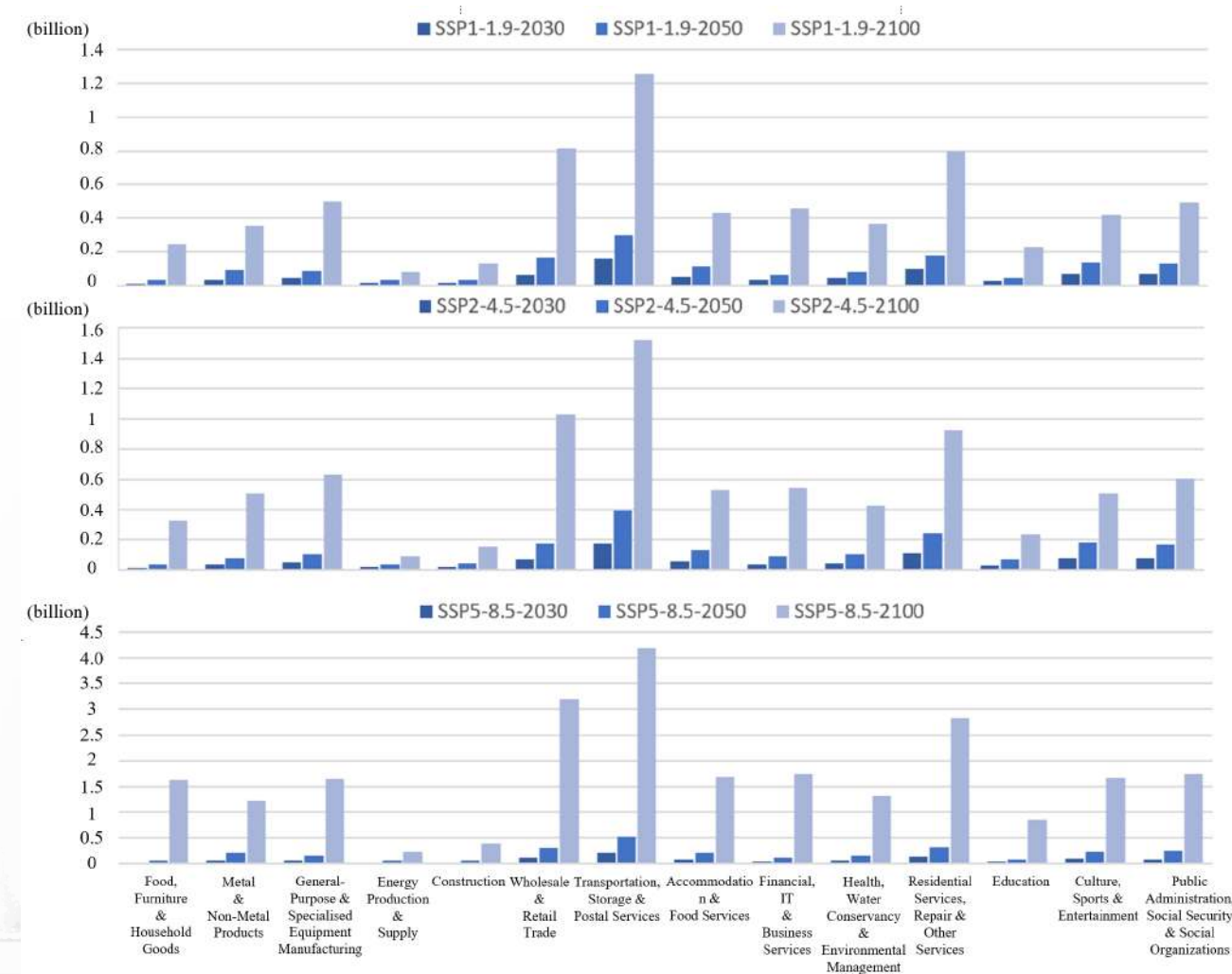
Activity 4: Assessing the combined risks of coastal megacity



Direct Economic Loss Assessment of Integrated Multi-Hazard Risk

➤ Future Overtopping Scenarios

- By **2030**, coastal flooding caused by overtopping may result in direct economic losses ranging from **745 to 893 million CNY**;
- By **2050**, these losses are projected to increase to **1.505 to 2.641 billion CNY**;
- By **2100**, losses may escalate significantly to **6.577 to 24.274 billion CNY**;
- The period between **2050 and 2100** shows particularly pronounced growth in direct economic losses;
- Sectors with the highest loss proportions include:
Transportation, Storage & Postal Services
Wholesale & Retail Trade
Residential Services, Repair & Other Services



The figures represent industry-specific statistical results of direct economic losses from coastal flooding under different overtopping scenarios

Activity 4: Assessing the combined risks of coastal megacity



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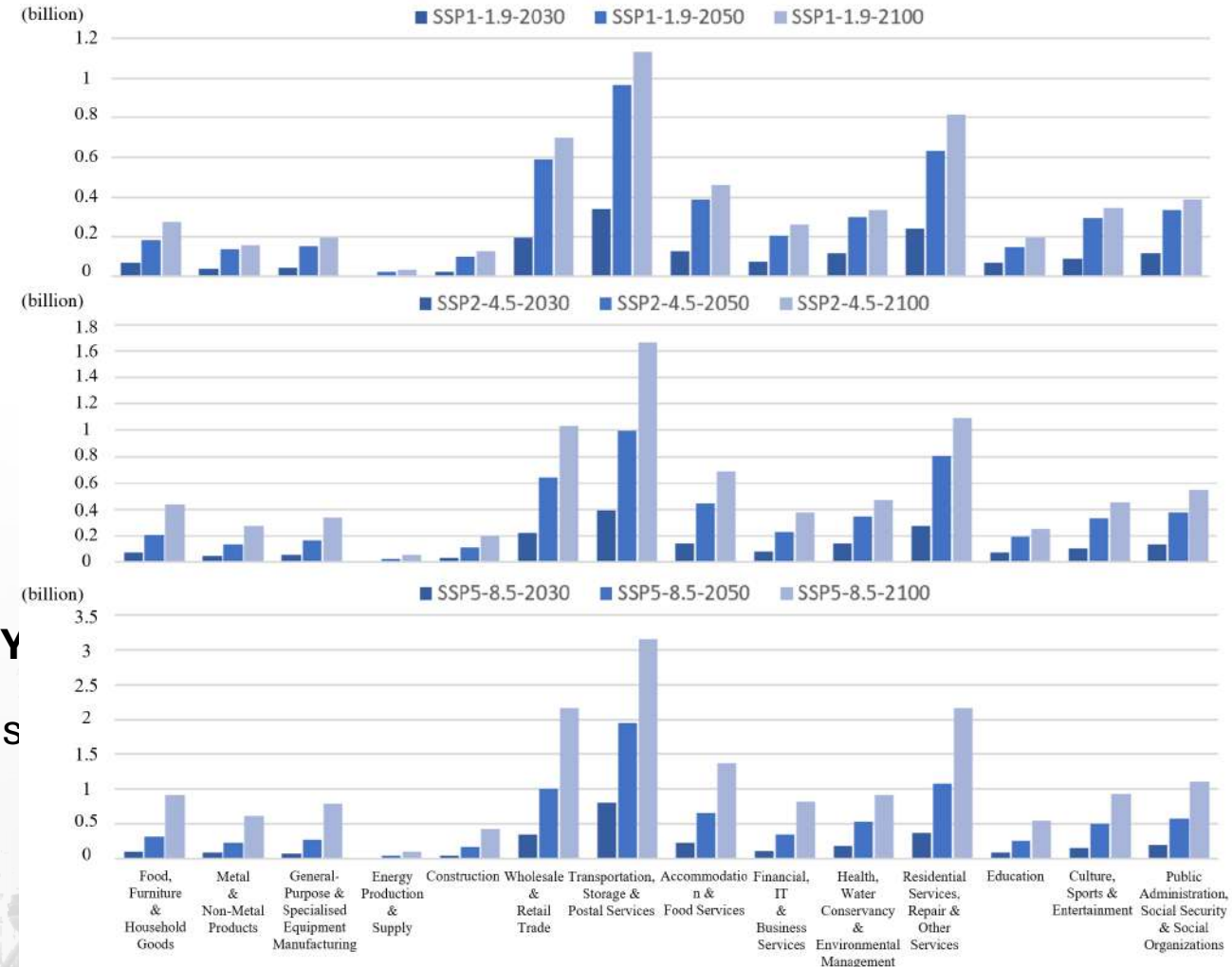


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Direct Economic Loss Assessment of Integrated Multi-Hazard Risk

➤ Future Levee Breach Scenarios

- By **2030**, coastal flooding caused by **levee breaches** may result in direct economic losses ranging from **1.551 to 2.793 billion CNY**;
- By **2050**, these losses are projected to increase to **4.616 to 7.914 billion CNY**;
- By **2100**, losses may reach **5.254 to 16.03 billion CNY**
- The most significant growth in direct economic losses occurs between **2030 and 2050**.

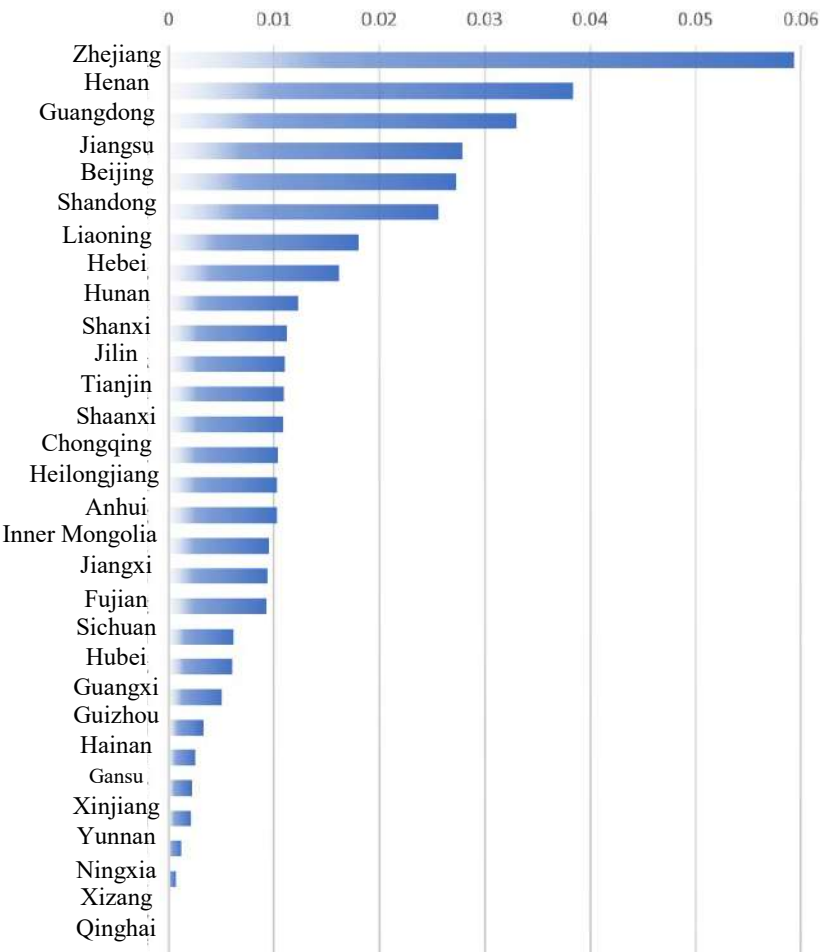


The above values represent industry-specific statistical results of direct economic losses from coastal flooding under different levee breach scenarios.

Activity 4: Assessing the combined risks of coastal megacity



Analysis of Economic Linkage Levels



Statistical Analysis of Economic Linkage Levels Between 30 Chinese Provinces/Municipalities and Shanghai (Using Shanghai as Benchmark).

Ranking of Industries with High Economic Linkage to

Rank	Province	Industry	Rank	Province	Industry
1	Zhejiang	Non-metallic Mineral Products	16	Beijing	Financial Services
2	Henan	Transportation, Warehousing & Postal Services	17	Zhejiang	Transportation, Warehousing & Postal Services
3	Henan	Non-metallic Mineral Products	18	Guangdong	Metal Products
4	Shandong	Petroleum, Coking Products & Nuclear Fuel Processing	19	Liaoning	Transportation, Warehousing & Postal Services
5	Liaoning	Petroleum, Coking Products & Nuclear Fuel Processing	20	Beijing	Information Transmission, Software & IT Services
6	Guangdong	Real Estate	21	Heilongjiang	Oil & Natural Gas Extraction
7	Hunan	Residential Services, Repair & Other Services	22	Zhejiang	Information Transmission, Software & IT Services
8	Hebei	Transportation, Warehousing & Postal Services	23	Zhejiang	Rental & Business Services
9	Jiangsu	Electrical Machinery & Equipment	24	Guangdong	Communication Equipment, Computers & Other Electronic Equipment
10	Zhejiang	Petroleum, Coking Products & Nuclear Fuel Processing	25	Jiangsu	Information Transmission, Software & IT Services
11	Beijing	Transportation, Warehousing & Postal Services	26	Shandong	Oil & Natural Gas Extraction
12	Zhejiang	Other Manufacturing	27	Tianjin	Oil & Natural Gas Extraction
13	Beijing	Technical Services	28	Guangdong	Paper & Printing, Educational & Sporting Goods
14	Shanxi	Coal Mining Products	29	Hebei	Metal Products
15	Jilin	Transportation, Warehousing & Postal Services	30	Jiangsu	Transportation, Warehousing & Postal Services

Activity 4: Assessing the combined risks of coastal megacity



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Economic Linkage Losses Assessment of Integrated Multi-Hazard Risk

➤ Future Overtopping Scenarios

Year/Economic Linkage Loss (billion)		Shanghai	Other Provinces	Total
2030	SSP1-1.9	1.157	0.347	1.504
	SSP2-4.5	1.311	0.393	1.704
	SSP5-8.5	1.549	0.461	2.01
2050	SSP1-1.9	2.343	0.695	3.038
	SSP2-4.5	2.927	0.872	3.799
	SSP5-8.5	4.099	1.216	5.315
2100	SSP1-1.9	10.193	2.958	13.152
	SSP2-4.5	12.489	3.623	16.112
	SSP5-8.5	37.672	10.798	48.47

Statistical table of economic linkage losses from coastal overtopping under different climate scenarios

Projected Economic Linkage Losses from Overtopping-Induced Coastal Flooding:

- By 2100, potential economic linkage losses range from **¥13.152 billion (SSP1-1.9)** to **¥48.47 billion (SSP5-8.5)**.
- Across all climate scenarios, linkage losses **exceed direct economic losses**, representing **over 2 times** the direct loss amounts.
- **Over 70%** of Shanghai's sectoral linkage losses originate from cascading impacts on its locally related industries.

Activity 4: Assessing the combined risks of coastal megacity

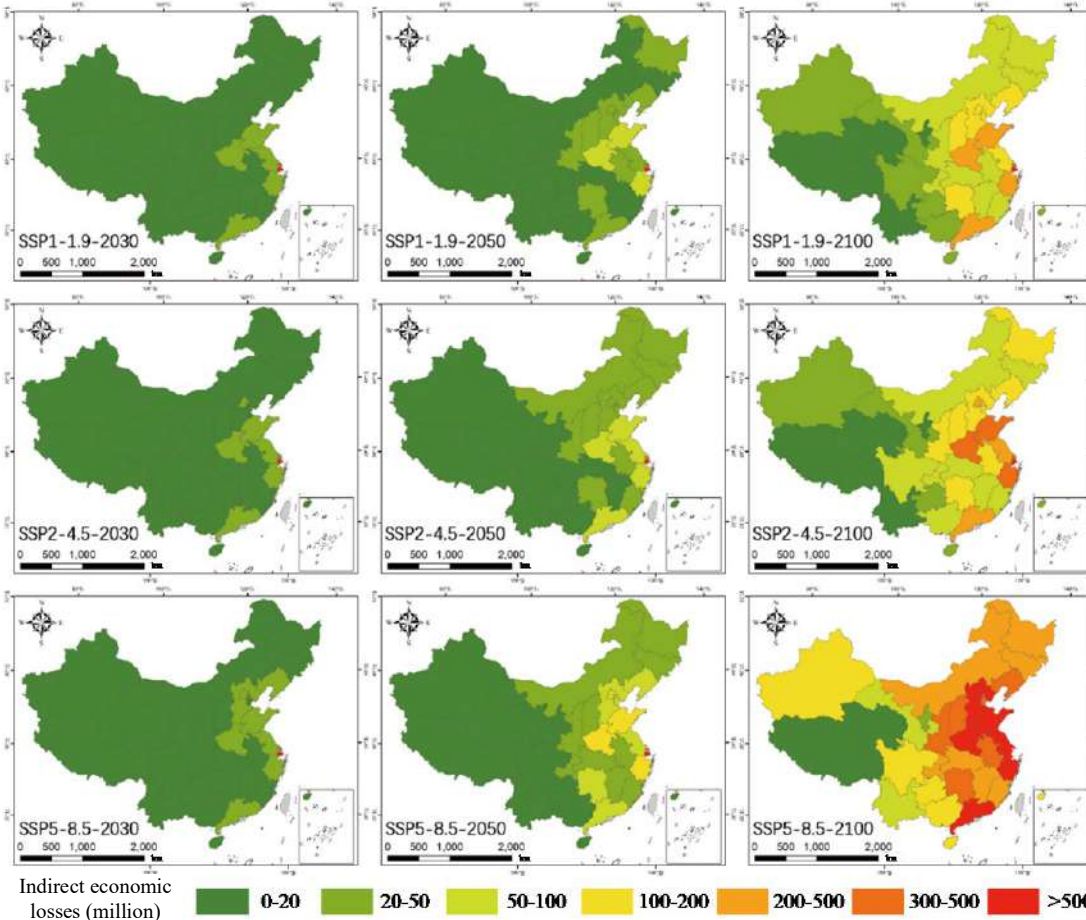


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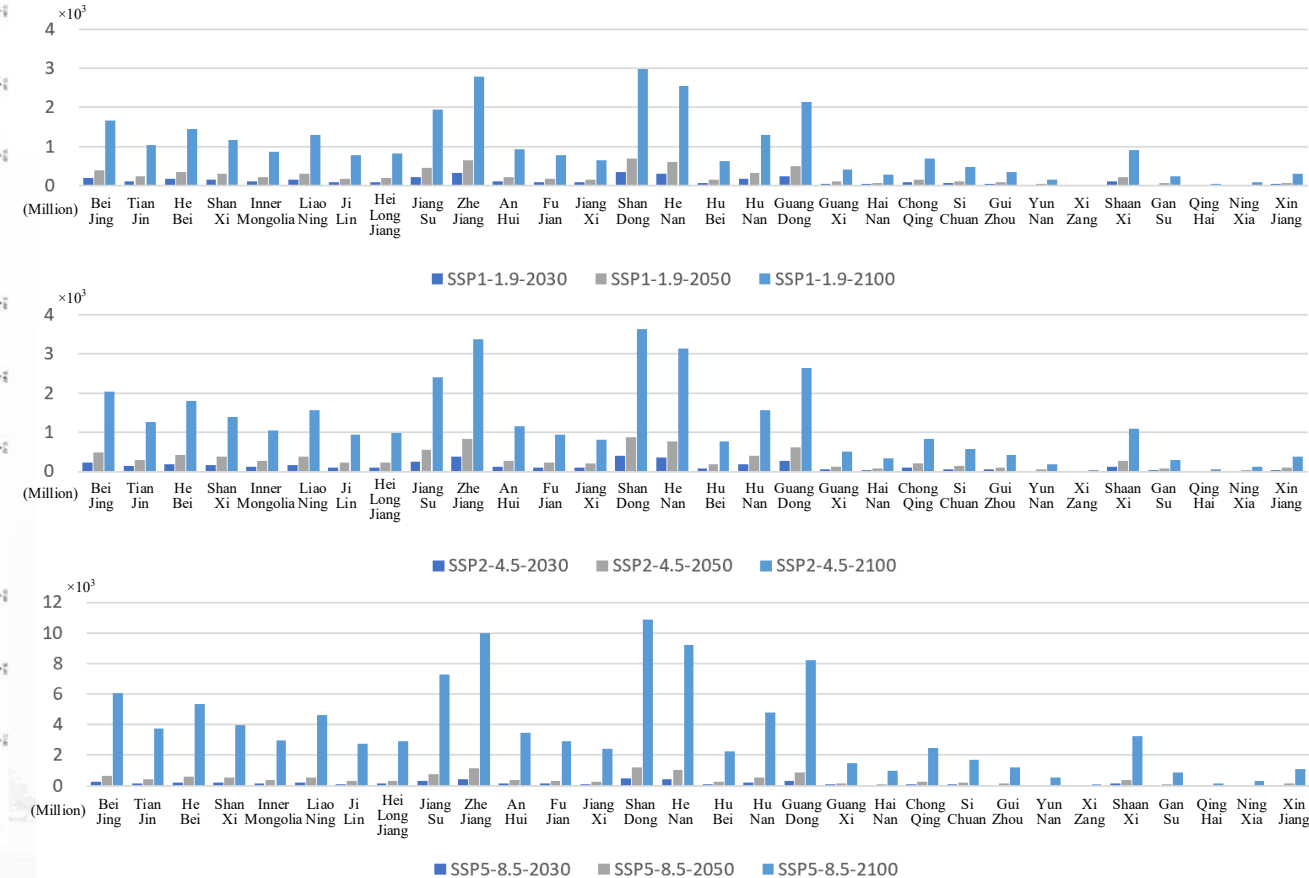


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➤ Future Overtopping Scenarios



Spatial distribution map of provincial indirect economic losses of coastal flood caused by overtopping under different scenarios



Spatial Distribution of Indirect Economic Losses Across Provinces

Activity 4: Assessing the combined risks of coastal megacity



Economic Linkage Losses Assessment of Integrated Multi-Hazard Risk

➤ Future Levee Breach Scenarios

Year/Linkage	Economic Losses (billion)	Shanghai	Other Provinces	Total
2030	SSP1-1.9	1.157	0.347	1.504
	SSP2-4.5	1.311	0.393	1.704
	SSP5-8.5	1.549	0.461	2.01
2050	SSP1-1.9	2.343	0.695	3.038
	SSP2-4.5	2.927	0.872	3.799
	SSP5-8.5	4.099	1.216	5.315
2100	SSP1-1.9	10.193	2.958	13.152
	SSP2-4.5	12.489	3.623	16.112
	SSP5-8.5	37.672	10.798	48.47

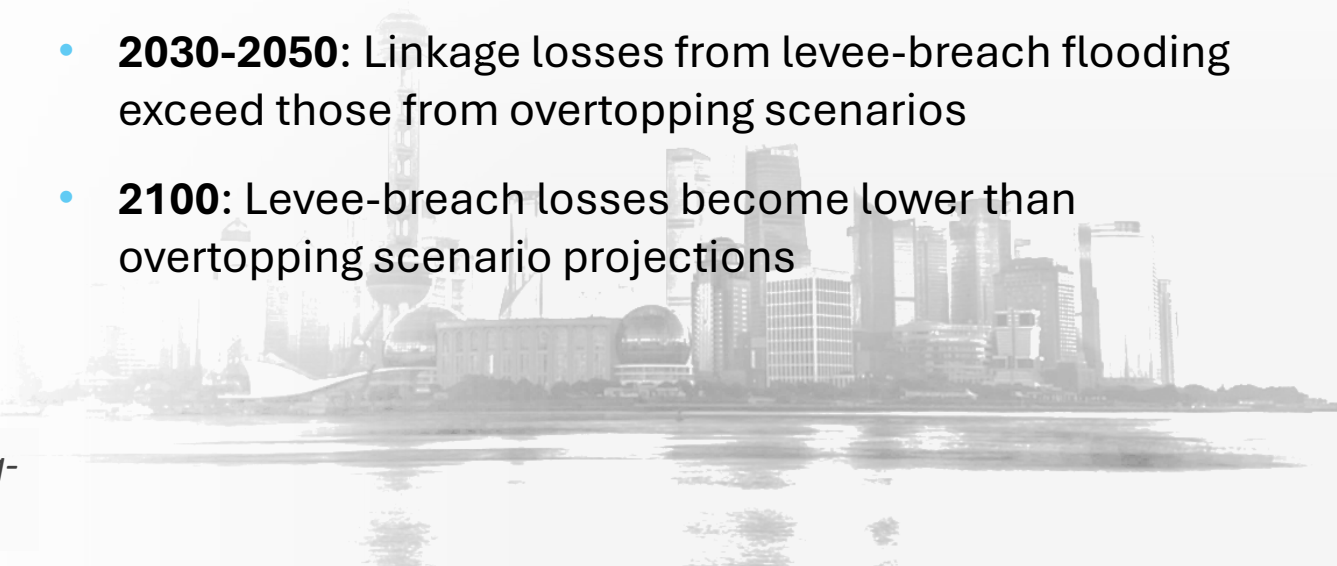
Statistics of indirect economic losses caused by coastal overtopping-induced flooding under different climate scenarios.

Projected Economic Linkage Losses from Levee-Breach Coastal Flooding:

- By 2100, potential economic linkage losses range from **¥10.581 billion (SSP1-1.9)** to **¥33.294 billion (SSP5-8.5)**.

Comparative Analysis:

- 2030-2050:** Linkage losses from levee-breach flooding exceed those from overtopping scenarios
- 2100:** Levee-breach losses become lower than overtopping scenario projections



Activity 4: Assessing the combined risks of coastal megacity

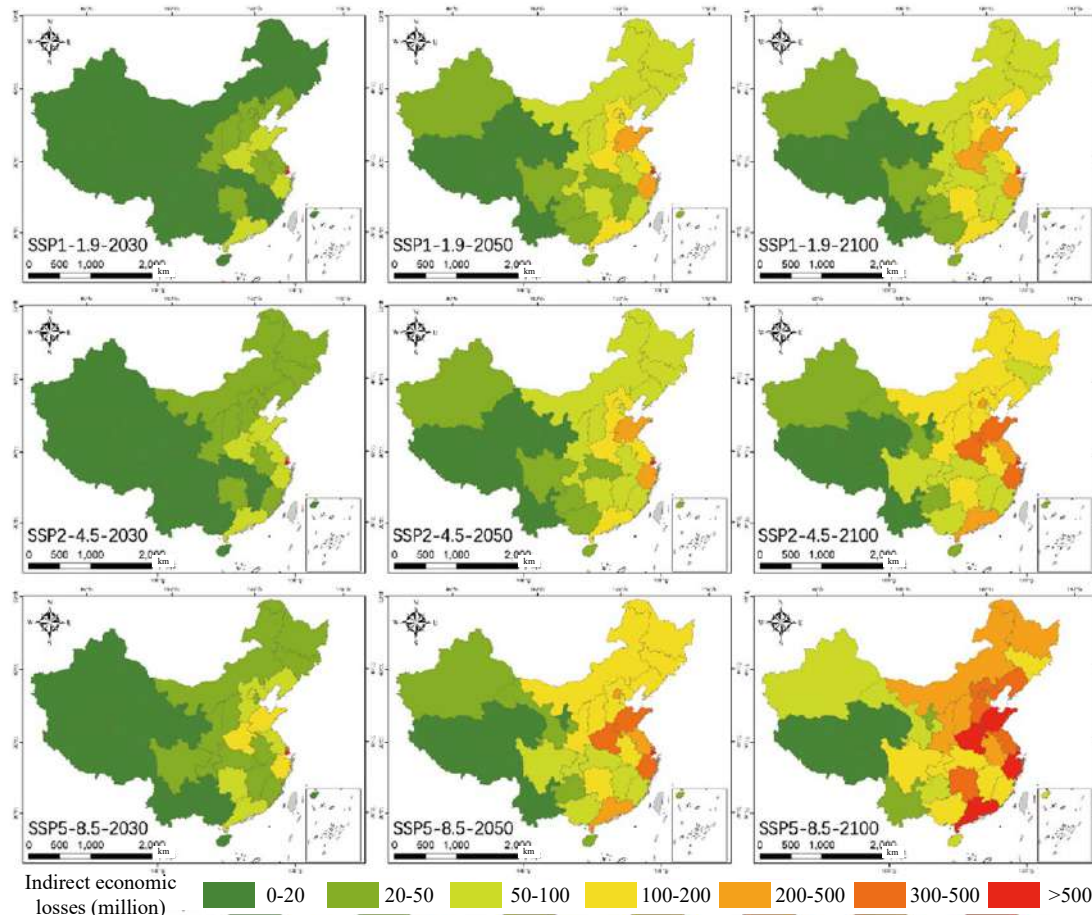


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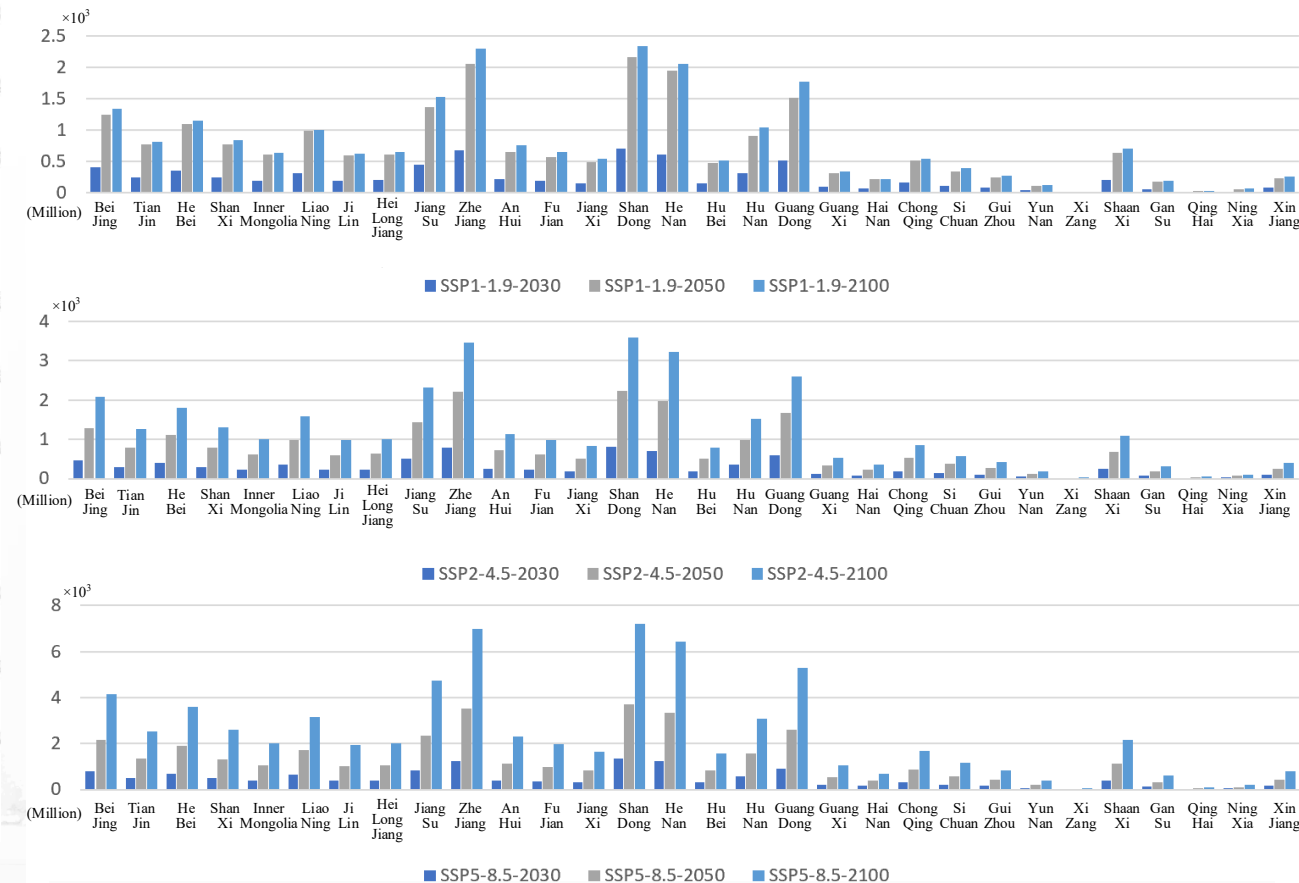


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➤ Future Levee Breach Scenarios



Provincial Distribution Maps of Economic Linkage Losses from Levee-Breach Coastal Flooding Under Different Scenarios



Spatial Distribution of Indirect Economic Losses Across Provinces

Activity 4: Assessing the combined risks of coastal megacity



Conclusions

1. Under future disaster scenarios, coastal flooding induced by overtopping would primarily inundate **Baoshan and Jiading Districts**, while levee-breach coastal flooding would mainly affect eastern coastal areas of **Pudong, Baoshan, and Jinshan District**.
2. The levee-breach scenario exhibits a greater potential inundation area and an average water depth deeper compared to overtopping.
3. Using hazard-exposure-vulnerability indicators, we developed **a megacity building-scale integrated risk assessment model**. We evaluated over 1.2 million buildings in Shanghai. Results show that from 2030 to 2100:
 - High-risk buildings will increase by 20,969 (SSP1-1.9) to 42,833 (SSP5-8.5)
 - Exposed population will grow by 367,000 (SSP1-1.9) to 588,000 (SSP5-8.5)
4. By 2100:
 - Overtopping may cause direct economic losses of ¥6.577 (SSP1-1.9) to ¥24.274 (SSP5-8.5) billion
 - Levee breaches may cause losses of ¥5.254 (SSP1-1.9) to ¥16.03 (SSP5-8.5) billion

Activity 4: Assess the combined risks of coastal megacity



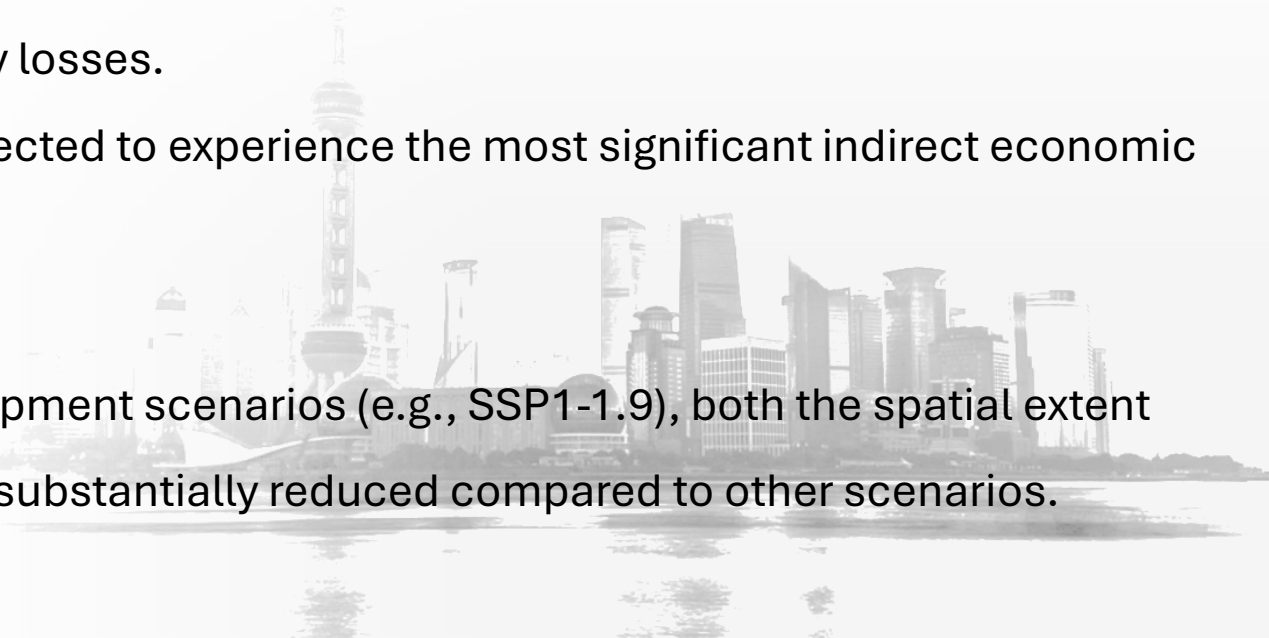
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Conclusions

5. By 2100, the potential economic linkage losses from coastal flooding are projected to be:
 - ¥13.152-48.47 billion for overtopping scenarios (SSP1-1.9 to SSP5-8.5)
 - ¥10.581-33.294 billion for levee-breach scenarios (SSP1-1.9 to SSP5-8.5)
 - Over 70% of Shanghai's linkage losses originate from cascading effects within its local industrial networks.
 - Provinces demonstrating the highest economic connectivity with Shanghai, predominantly located in eastern China, show the greatest vulnerability to secondary losses.
 - Shandong, Zhejiang, and Henan provinces are projected to experience the most significant indirect economic impacts from Shanghai's coastal flooding events.
6. Under low-emission, controlled socioeconomic development scenarios (e.g., SSP1-1.9), both the spatial extent of disaster impacts and resulting economic losses are substantially reduced compared to other scenarios.



Second Year Planning



We will extend the Land Use Land Change (LULC) analyses that are indispensable to provide suitable information to various decision support systems. Consolidated and Novel SAR change detection (CD) methods will be complemented with Interferometric SAR (InSAR) techniques.

The combined risks will be assessed at broad scales.

SO1.1: Assessing urban patterns through SAR-based indicators.

SO1.2: Develop novel algorithms to assess NBS.

SO1.3: Broad exploitation of InSAR methods, including BOI/MAI algorithms, to evaluate/characterize disaster risk conditions in different contexts.

We plan to publish papers on ISI journals and participate/attend other meetings.

A plan for the European Young Scientist activities will be designed and sent to ESA (by June 2026)

A plan of cooperation between CNR and ECNU is foreseen.

Dragon 6 EO Data Delivery



ESA /Copernicus Missions	No. Scenes
1. Sentinel-1	> 2500
2. Sentinel-2	100
3.	
4.	
5.	
6.	
Total: 2600	
Issues: We are collecting and processing SAR data in different environmental contexts and purposed (InSAR and Change Detection) to have then a base for further developments of AI methods that can be used to interpret the data/products. We are mostly using S-1 SAR data.	

ESA Third Party Missions	No. Scenes
1. TerraSAR-X	30
2.	
3.	
4.	
5.	
6.	
Total: 30	
Issues: TerraSAR-X is primarily used for research on ground subsidence and change detection. The other datasets are products based on satellite data or obtained with satellite data as auxiliary inputs, and they have laid the foundation for our in-depth research.	

Chinese EO data	No. Scenes
1.	
2.	
3.	
4.	
5.	
6.	
Total:	
Issues: These datasets, published by Chinese researchers, include thematic products derived from satellite data or generated using satellite data as auxiliary inputs, as well as in situ observational data.	

European Young Scientists contributions in Dragon 6



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Name	Institution	Poster title	Contribution including period of research
Pietro Mastro	IREA-CNR	ID256: Advancing Geohazard Monitoring with Remote Sensing Technologies	Combination of co- and cross-pol data aids in distinguishing information sources. Furthermore, building on this foundation, our work explores the integration of multi-polarization data as a transformative approach to enhancing the detection, analysis, and forecasting of geohazard events. Our methodology involves combining multi-pol SAR data. On the other hand, further works are still needed to test the feasibility of the EMCF approach for multi-pol SAR data.

Chinese Young Scientists contributions in Dragon 6



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Name	Institution	Poster title	Contribution including period of research
Yuhan Wan	East China Normal University	ID195: Identifying and interpreting patterns of ground deformation in Huaibei Plain during 2017-2023 based on MT-InSAR and Independent Component Analysis	This study derived ground deformation results for the Huaibei Plain during 2017-2023. We then identified six distinct deformation patterns and revealed that variations in groundwater storage, soil bulk density, and precipitation are the principal drivers of ground deformation.
Zhen Li, Jingjing Wang	East China Normal University	ID182: Assessment of the Comprehensive Risk of Buildings and Economic Losses in Megacity Based on Future Disaster Scenarios and Input-Output Model	To match the refined disaster risk management in Shanghai, this study focuses on the coupled disaster chain, innovatively conducting risk assessments at the individual-building level, and applying a multi-regional input-output (MRIO) model to assess indirect economic losses.
Weiwei Fang, Taotao Zheng	East China Normal University	ID183: Building Change Detection Based on a Dual-Stream Network with Adaptive Feature Fusion and Cross-Attention Guidance Using SAR and Optical Remote Sensing Imagery	This study proposed an urban building change detection method based on SAR and optical data. In the proposed ADDNet, we developed a dual-stream architecture and introduced cross-attention and self-attention mechanisms as well as ASPP module, which improved the accuracy of change detection to a certain extent.



Advancing Geohazard Monitoring with Remote Sensing Technologies

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Introduction

Satellite-based Synthetic Aperture Radar (SAR) remote sensing has fundamentally transformed the monitoring of Earth environments and geohazards, providing high-resolution data on inundation, land movement, and risk exposure that are essential for disaster response and planning [1], [2], [3]. In such context, several multi-temporal Interferometric synthetic aperture radar (MT-InSAR) techniques have been developed and successfully applied, mostly for the analysis of independently processed single-pol SAR datasets. To mitigate the noise effects in the differential SAR interferograms, several noise-filtering techniques have been proposed, most of them working independently on single interferograms. Subsequently, new efforts have been made to extend these methods to include space-time information [4], [5], [6]. The method in [6] complemented the extended minimum cost flow (EMCF) space-time phase unwrapping operations with an additional processing step that allowed an increase in the signal-to-noise ratio of a set of multi-temporal multi-looked interferograms by computing a set of optimized phases. The growing availability of SAR data, including dual-pol and full-pol datasets from current and future constellations, supports integrating polarimetric InSAR techniques to enhance interferogram coherence by leveraging spatial, temporal, and polarimetric information. Combining co- and cross-pol data further aids in distinguishing information sources. Furthermore, building on this foundation, our work explores the integration of multi-polarization data as a transformative approach to enhancing the detection, analysis, and forecasting of geohazard events. The problem we address is the inherent complexity in accurately characterizing and predicting geohazard phenomena due to challenges inherent to traditional remote sensing approaches. Our methodology involves combining multi-pol SAR data with high-resolution optical imagery. This general approach allows us to extract more detailed information on surface changes and environmental dynamics. By integrating diverse data sources, we overcome limitations of using a single sensor type, achieving a more comprehensive and nuanced understanding of dynamic Earth processes [1], [2], [3], [7].

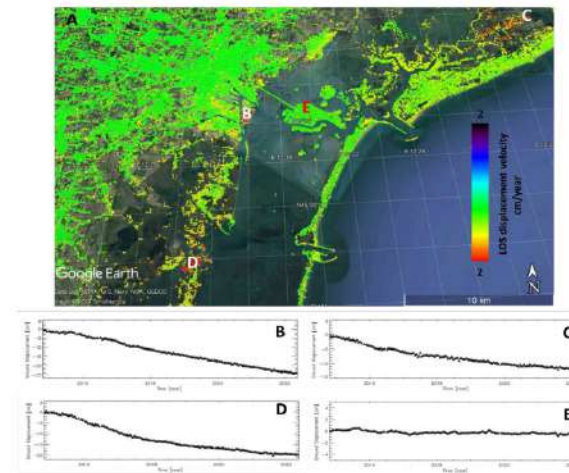


Figure 2. (A) 2014-2022 Mean deformation velocity map of the Venice Lagoon. (B-D) time series of deformation of areas of the north, center and south of Venice lagoon. (E) Time series of deformation of Venice city.

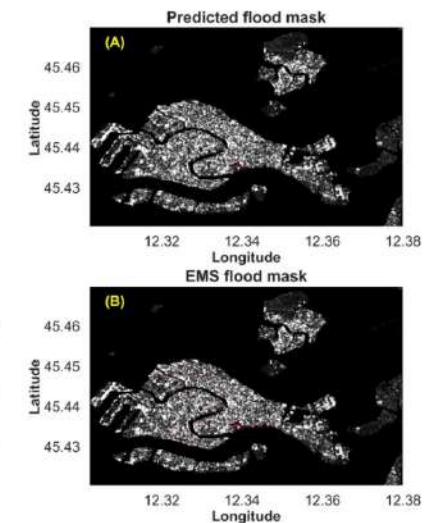


Figure 3. The flood map was determined (A) by the RF-based algorithm and (B) by the EMS. The flood maps are red-coloured and superimposed on an S1 amplitude map of Venice.

Overview of Chinese YSs research



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Identifying and interpreting patterns of ground deformation in Huaibei Plain during 2017-2023 based on MT-InSAR and Independent Component Analysis

Huaibei Plain

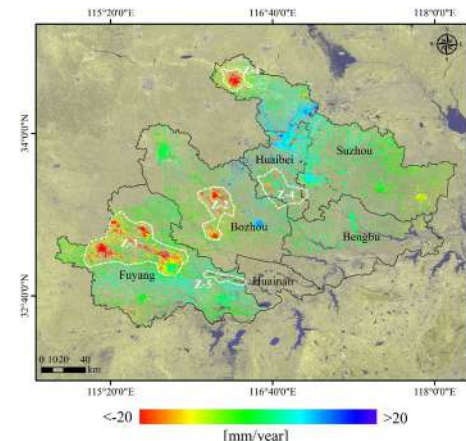
- Major Area affected by land subsidence in China
- In recent years, the region has implemented a series of subsidence control measures.
- It is urgent to conduct continuous monitoring of ground deformation, and analyze the ground deformation patterns in different regions.

1. InSAR and ICA decomposition Results

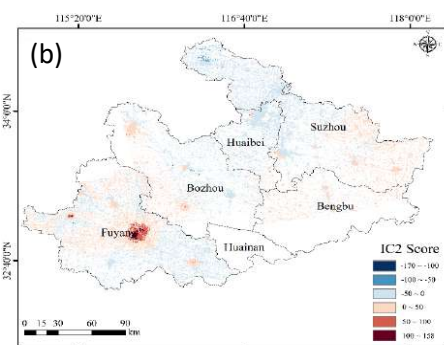
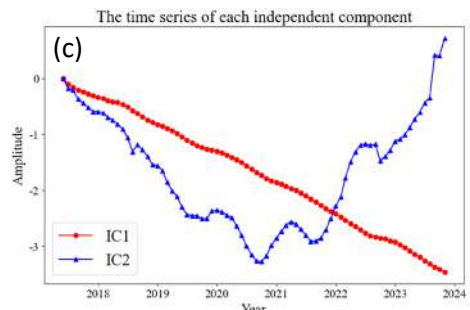
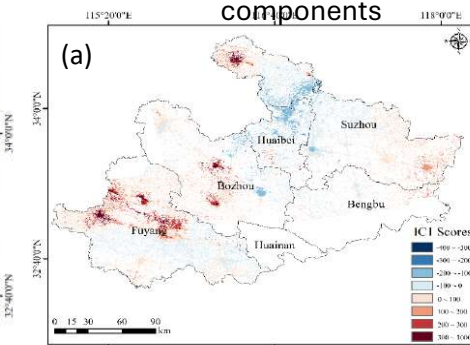
(1) Ground deformation results (2) Independent Component Analysis(ICA)

- Approximately 400 Sentinel-1A images
- During 2017-2023

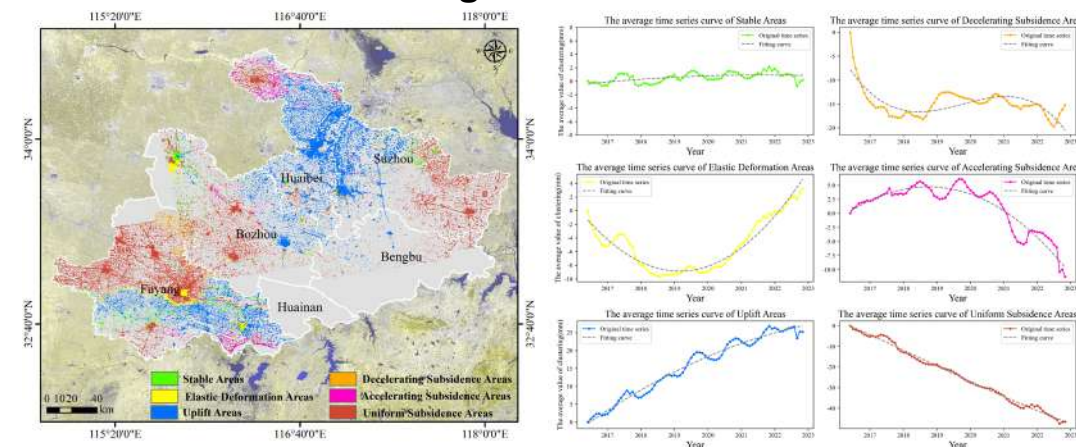
- decompose the deformation data into elastic (reversible) and inelastic (permanent) components



Conclusion1: The rebound trend of the ground deformation reflected by IC2 may be related to the rise of groundwater level.



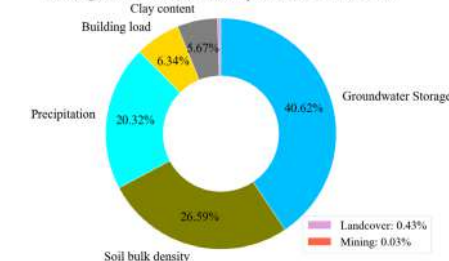
2. Times series clustering Results



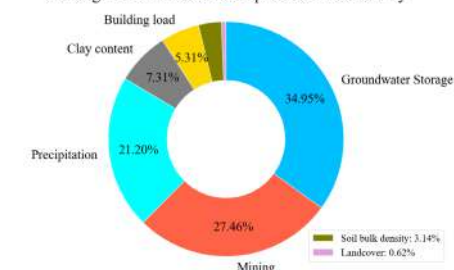
Conclusion2: There are six typical ground deformation patterns in Huaibei Plain. We analyzed their spatial and temporal distribution patterns and alerted the accelerating subsidence areas.

3. Geo-detector Results

Ranking of the influence factor q values in Huaibei Plain



Ranking of the influence factor q values in Huaibei City



Conclusion3: Groundwater storage, soil bulk density, and precipitation were the main influencing factors for the ground deformation in Huaibei Plain.



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Identifying and interpreting patterns of ground deformation in Huaibei Plain during 2017-2023 based on MT-InSAR and Independent Component Analysis

PROJECT ID: 95316 POSTER ID: 195

Yuhan Wan^{1,2,3}, Qing Zhao^{1,2,3,*}, Tianliang Yang^{4,5}, Jinlu Wang⁶, Xiaojun Kang⁶

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6 FUYANG GEO-ENVIRONMENTAL MONITORING CENTER, FUYANG, ANHUI 236000, CHINA



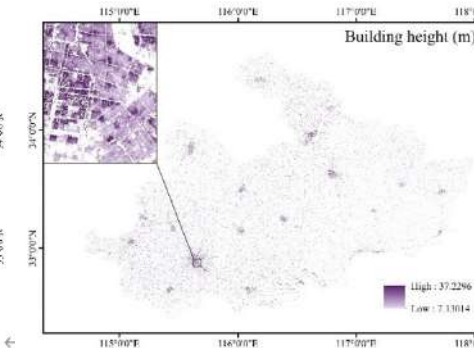
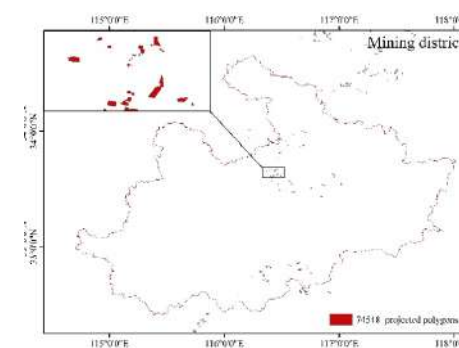
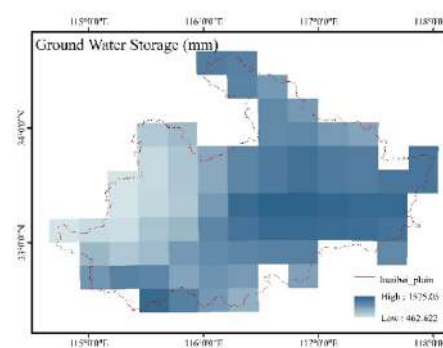
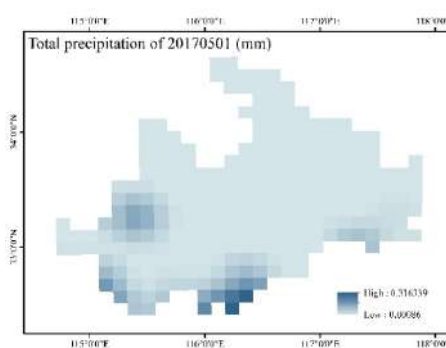
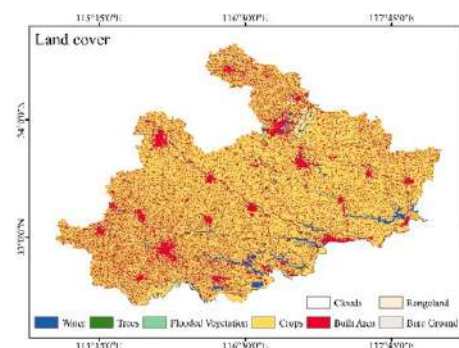
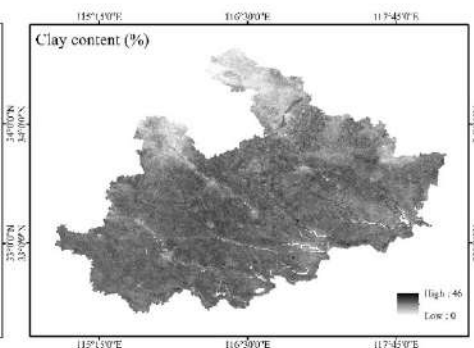
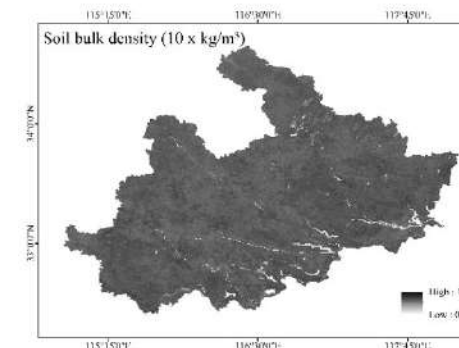
Figure 2. Location of the study area, Sentinel-1 data coverage



We utilized 382 Sentinel-1 data and collected other geographical data related to ground deformation.

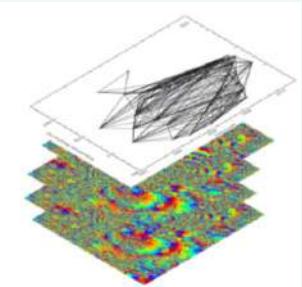
Sensors	Number of images	Path; Frame	Polarization	Acquisition time
Sentinel-1A	192	40; 102	VV	May 2017~October 2023
	190	142; 106		

Type	Influencing Data	Spatial resolution	Source
Geology	Soil bulk density	250m	OpenLandMap
	Clay content	250m	OpenLandMap
Land cover	Land cover	10m	ESRI Land Cover 10 m
Climate	Precipitation	0.1°	ERA5-Land
Underground water	Underground water	0.25°	GLDAS-2.2_CLSM-F2.5
Mining district	Mining district	Polygon	Liang et al.(2021)
Building load	Building height	10m	Wu et al.(2023)





Small Baseline Subset InSAR(SBAS-InSAR)

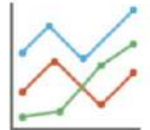
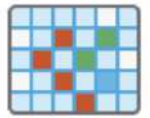


SBAS-InSAR reduces the influence of decorrelation and topographic phase by selecting SAR image subsets with small spatio-temporal baselines for interference processing.

(Berardino et al. 2002)

Time Series Similarity Clustering Analysis

Time series similarity clustering analysis in this study is based on the contour correlation of time series. These similar time series tend to be proportional to each other, and their values increase and decrease meanwhile.



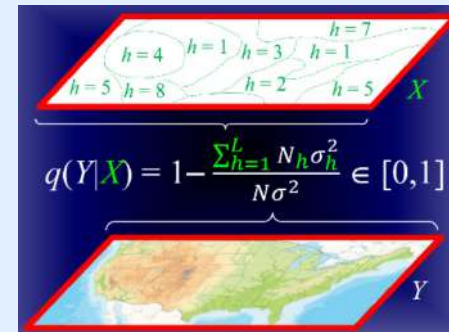
Independent Component Analysis(ICA)

ICA is a blind source signal separation method, which can separate independent signals from mixed signals without prior information. In the ground deformation analysis, ICA can decompose the deformation data into elastic (reversible) and inelastic (permanent) components.

(Comon. 1994)

(Chaussard and Farr. 2019)

Geo-detector



Geo-detector is a spatial analysis method for detecting spatial heterogeneity and revealing the underlying driving forces.

(Wang et al. 2016)



InSAR and ICA decomposition Results

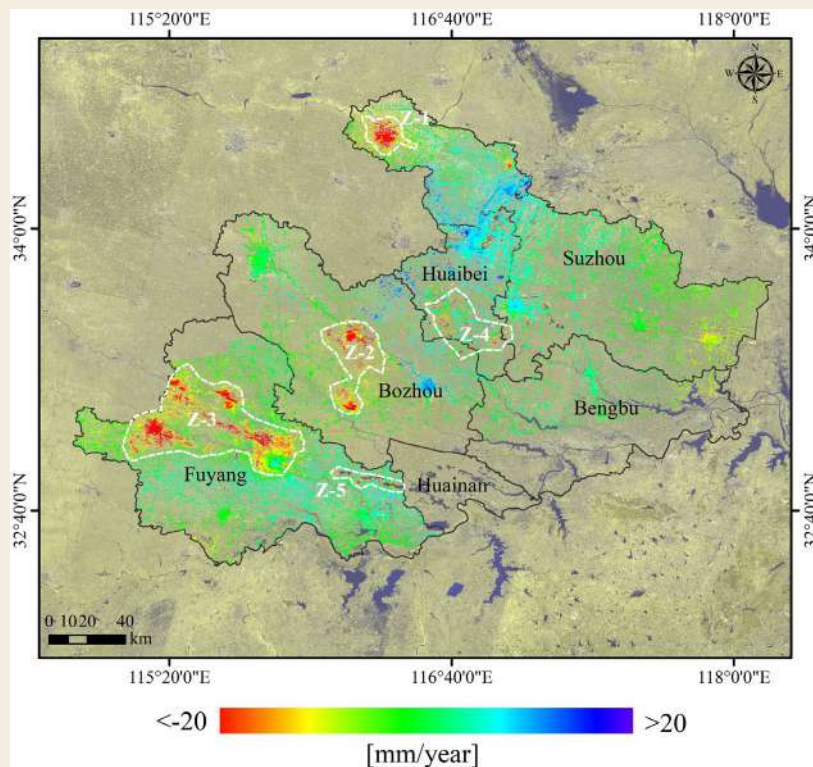


Figure 3. Ground deformation velocity map of the Huaibei Plain, Anhui Province from May 2017 to October 2023.

ICA
decomposition

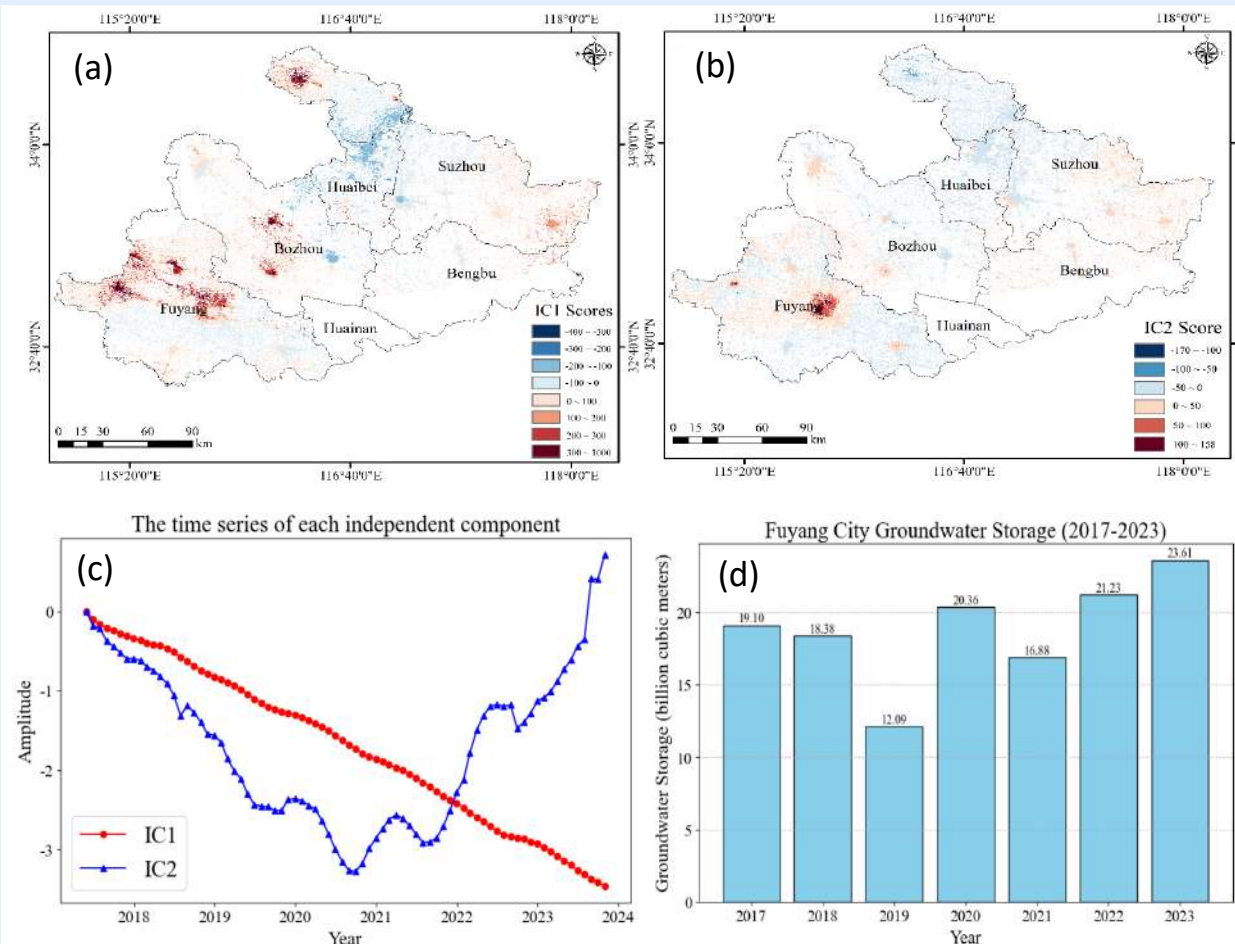


Figure 4. ICA decomposition results of the time series ground deformation: (a) Spatial distribution of IC1; (b) Spatial distribution of IC2; (c) The time series of each independent components; (d) Annual groundwater storage in Fuyang City from 2017 to 2023.

Using the ICA decomposition method, we found that the ground deformation signals could be decomposed into two main components: the linear and the rebound. And the IC2 may be related to the rise in groundwater level.



Clustering Results --- different ground deformation patterns in the Huaibei Plain

The time series clustering algorithm was used to obtain six typical ground deformation patterns in the Huaibei Plain.

The minority

Stable

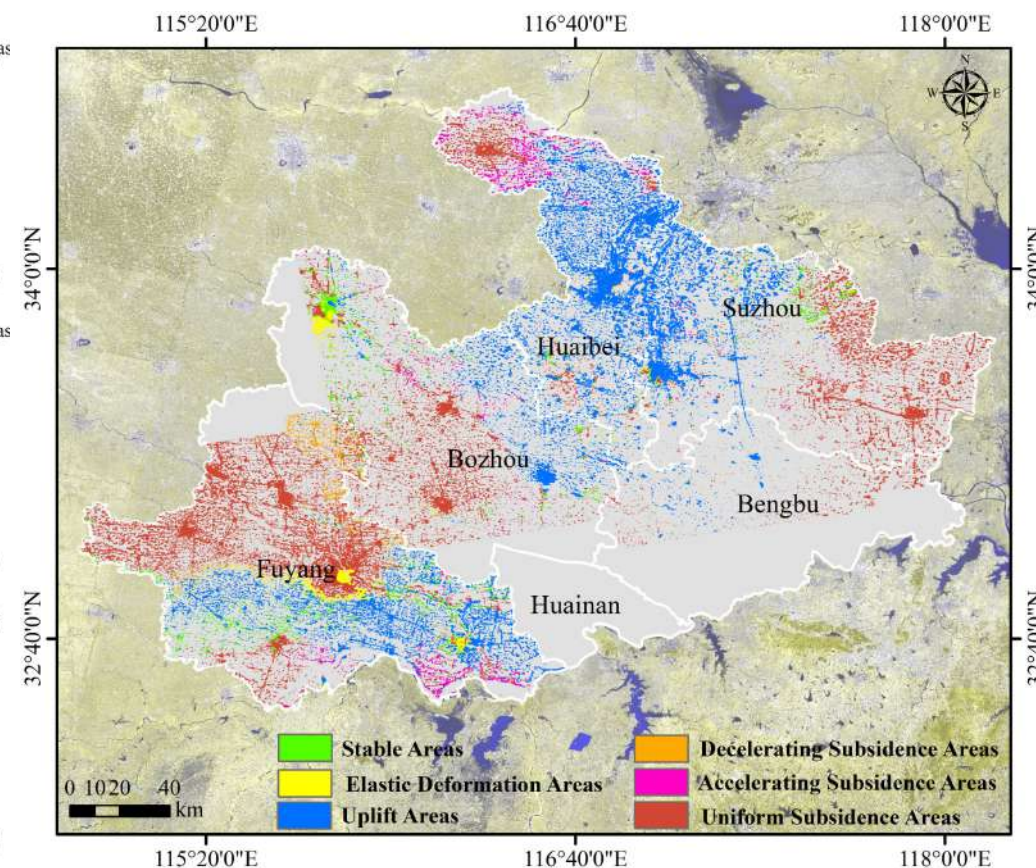
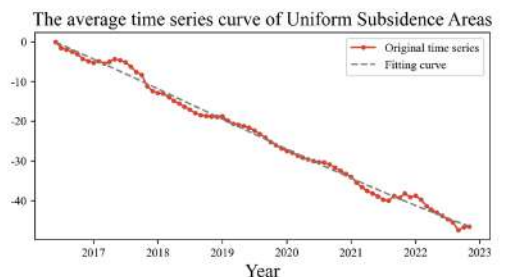
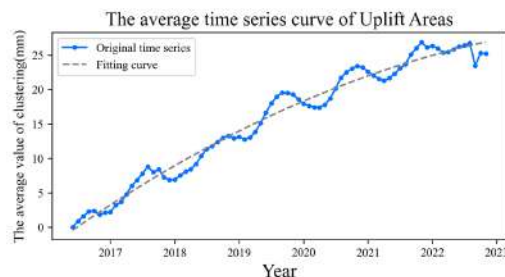
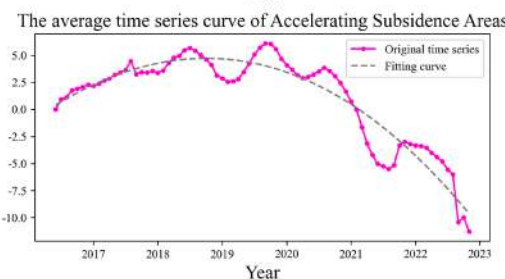
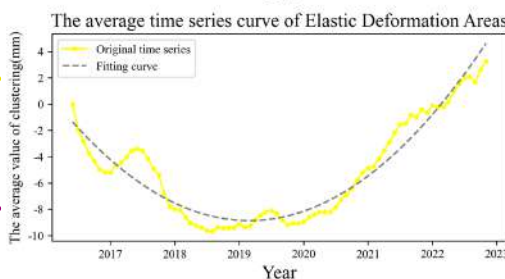
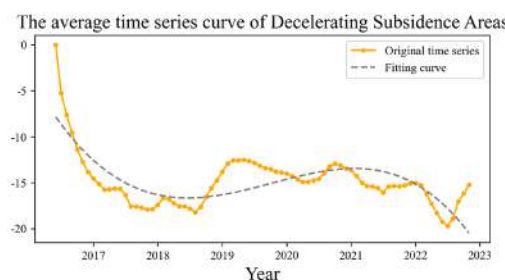
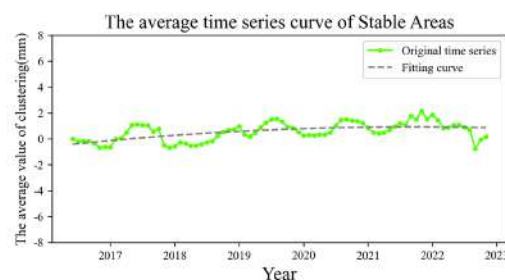
Decelerating
Subsidence

Elastic
Deformation

Accelerating
Subsidence

Uplift

Uniform
Subsidence



The majority

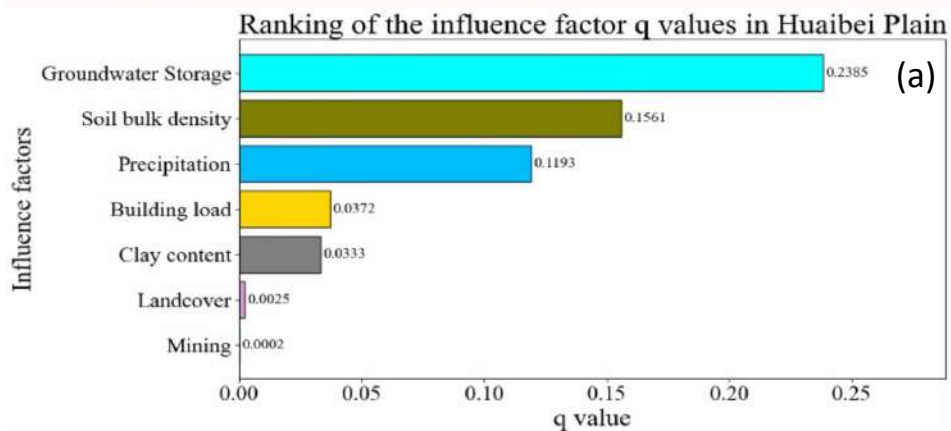
Figure 5. The spatial distribution and time series curves of six ground deformation patterns in the Huaibei Plain, Anhui Province from May 2017 to October 2023.



Geo-detector Results --- main influencing factors for the ground deformation

Huaibei Plain

- Geo-detector results show that **groundwater storage, soil bulk density and precipitation** were the main influencing factors for the ground deformation in the Huaibei Plain.



VS

Huaibei City

- We also conducted a study on the **Huaibei City, which is severely mined**. Groundwater storage, mining and precipitation were the main influencing factors in the Huaibei City.

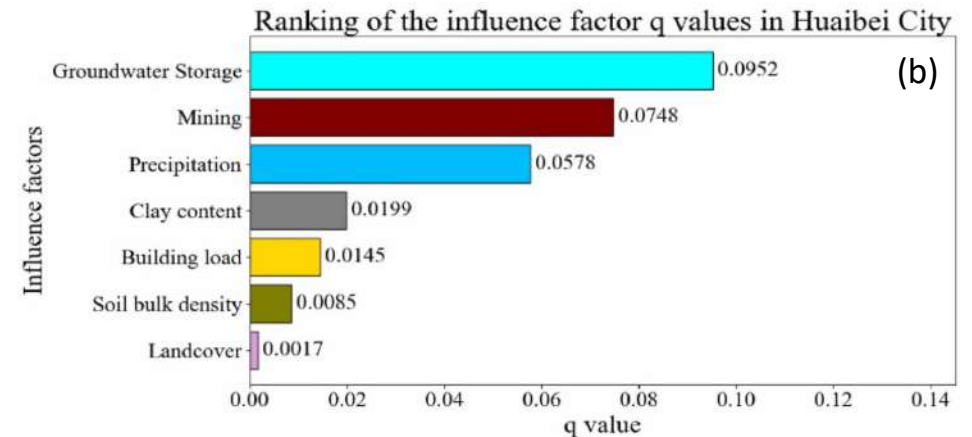


Figure 6. Geographic detector results. (a) Ranking of the influence factor q values in the whole Huaibei Plain; (b) Ranking of the influence factor q values in Huaibei City, which is severely-mined.



01 Ground Deformation Monitoring

Applied **SBAS-InSAR** to map ground deformation in Huaibei Plain during 2017 -2023.

02 Ground Deformation Signal Decomposition

- Used **ICA** to separate elastic and inelastic signals.
- Linked **elastic uplift in Fuyang City** to **groundwater recovery**.

03 Temporal Pattern Recognition

Identified **six deformation patterns** using time-series similarity analysis.

04 Driving Factor Analysis

Found **groundwater storage, soil bulk density, and precipitation** as key drivers.

This research not only helps to understand the mechanisms of ground deformation but also holds significant importance for the prevention and control of ground subsidence disasters.



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Overview of Chinese YSs research



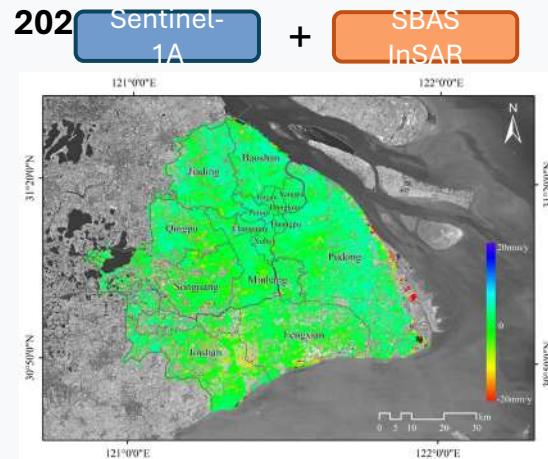
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Assessment of the Comprehensive Risk of Buildings and Economic Losses in Megacity Based on Future Disaster Scenarios and Input-Output Model

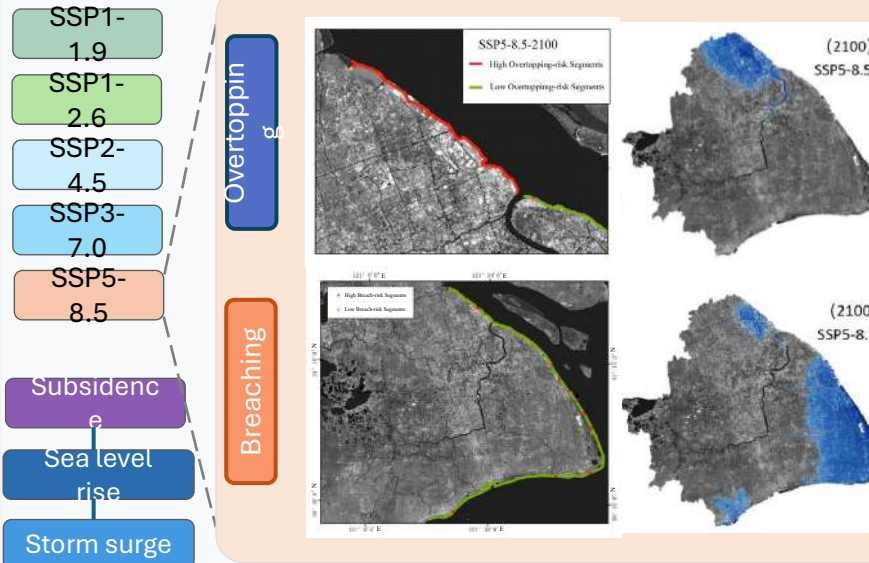
1. Surface subsidence during 2017-2022



High-deformation zones:

Eastern coastal zone of Pudong;
Some areas near the seawalls.

2. Coastal Flood Simulation

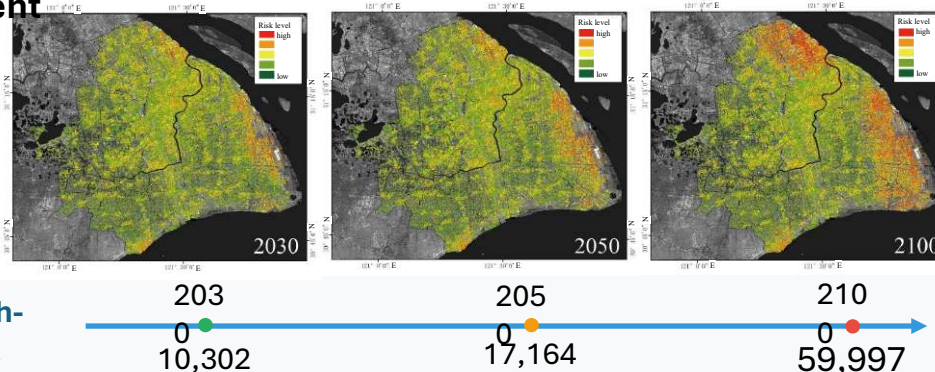


3. Comprehensive Risk Assessment



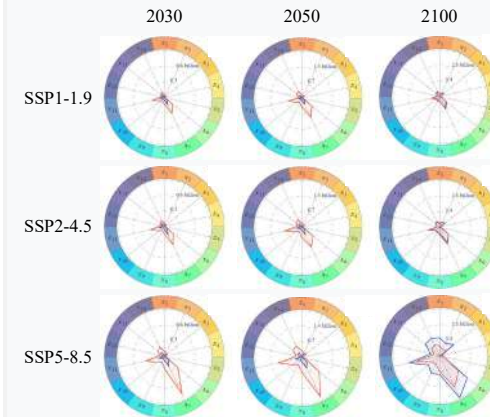
SSP5-8.5

High-risk Building



4. Economic Loss Assessment

➤ Direct economic losses:



Total economic loss: Overtopping

	SSP1-1.9	SSP5-8.5
2030	0.74 billion	0.89 billion
2050	1.5 billion	2.64 billion
2100	6.57 billion	24.27 billion

Breaching

	SSP1-1.9	SSP5-8.5
2030	0.91 billion	2.79 billion
2050	4.61 billion	7.91 billion
2100	5.25 billion	16.03 billion

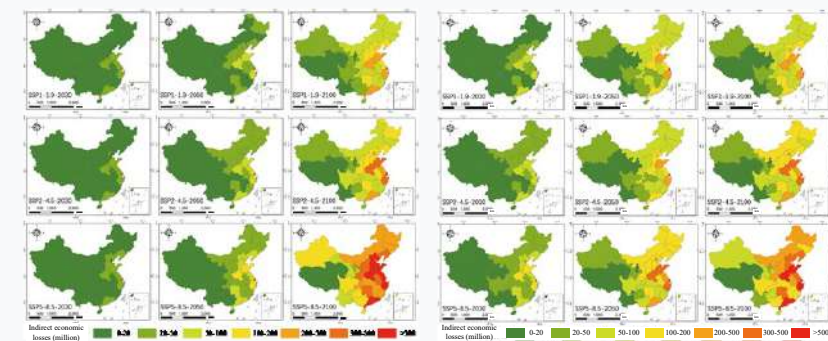
The industries with highest loss:

Transportation, Storage & Postal Services

➤ Indirect economic losses:

The province with high indirect economic losses:

Shandong, Zhejiang, and Henan





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Assessment of the Comprehensive Risk of Buildings and Economic Losses in Shanghai Based on Future Disaster Scenarios and Input-Output Model

[PROJECT ID. 95316] [POSTER ID. 182]

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Research Background and Significance



Study Area

Shanghai, located in the Yangtze River Delta, has long been affected by typhoons and ground subsidence.

Future

With the continuous rise of the sea level, the coastal flood risk in Shanghai is increasing.

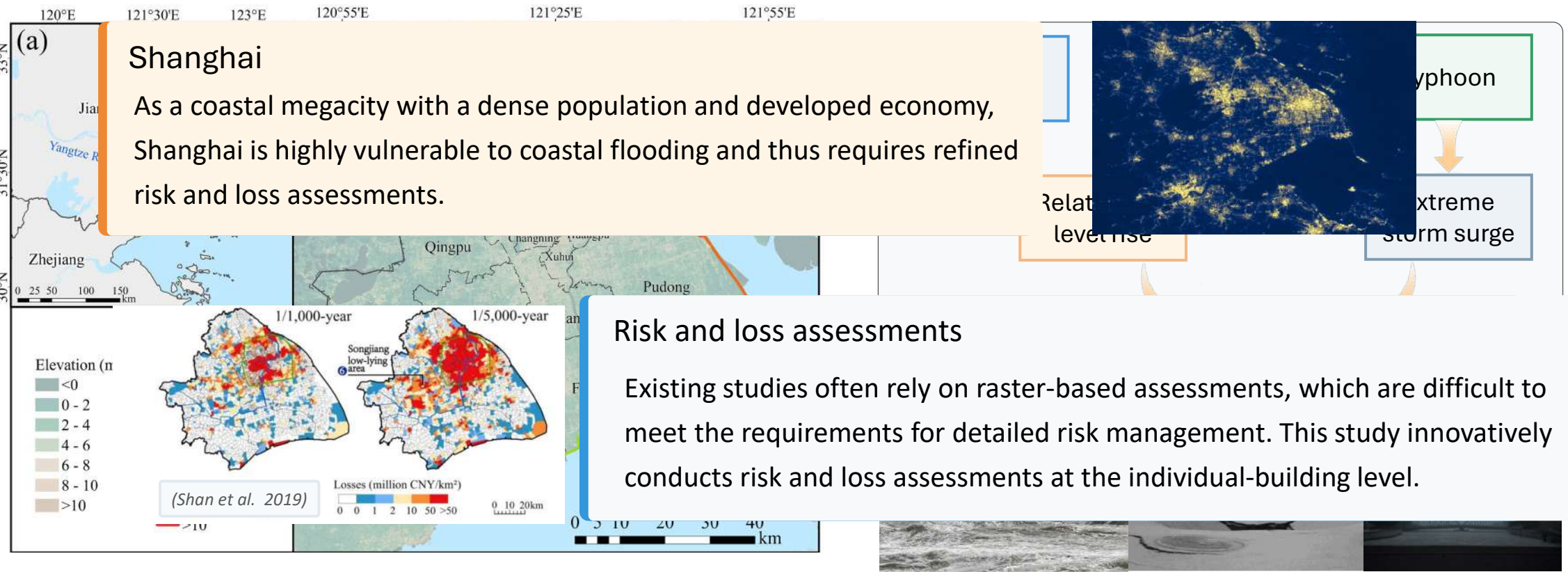


Figure 1. Location of Shanghai

(Berardino, 2002)

Small Baseline Subset InSAR

$$\begin{aligned}\Delta\varphi_k(x,r) &= \varphi(t_j,x,r) - \varphi(t_i,x,r) \\ &\approx \frac{4\pi}{\lambda} [d(t_j,x,r) - d(t_i,x,r)] \\ A\varphi &= \Delta\varphi \\ d(x,r) &= \frac{\lambda}{4\pi} \varphi(x,r)\end{aligned}$$

Ground deformation

(Bates, 2010)

Hydrodynamic model

$$\frac{\partial q}{\partial t} + \frac{gh\partial(h+z)}{\partial x} + \frac{gn^2q^2}{R\frac{4}{3}h} = 0$$

$$q_{t+\Delta t} = \frac{q_t - gh_t\Delta t \frac{\partial(h_t+z)}{\partial x}}{\left(1 + gh_t\Delta tn^2 q_t/h_t^{10/3}\right)}$$

Coastal flood inundation

Risk assessment index system

Vulnerability $v = \sum_j^n (v_j \cdot w_j)$

Exposure $e = \sqrt[n]{\prod_j^n e_j}$

Hazard	Inundation depth
1	0.5m
2	1.0m
3	1.5m
4	2.0m
5	2.5m
6	3.0m
7	3.5m
8	4.0m
9	4.5m
10	5.0m
11	5.5m
12	6.0m
13	6.5m
14	7.0m
15	7.5m
16	8.0m
17	8.5m
18	9.0m
19	9.5m
20	10.0m

Flood risk of buildings

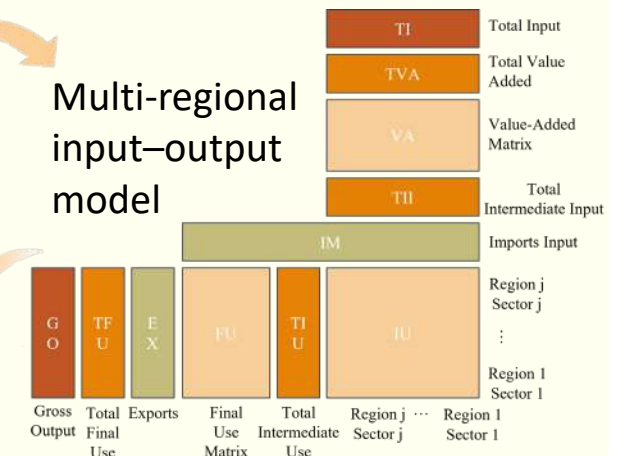
(Lenzen et al. 2018)

Direct losses

$$d(a) = \frac{h_f}{h_b} \cdot e_a$$

Multi-regional input-output model

Indirect losses





• Ground deformation during 2017-2021

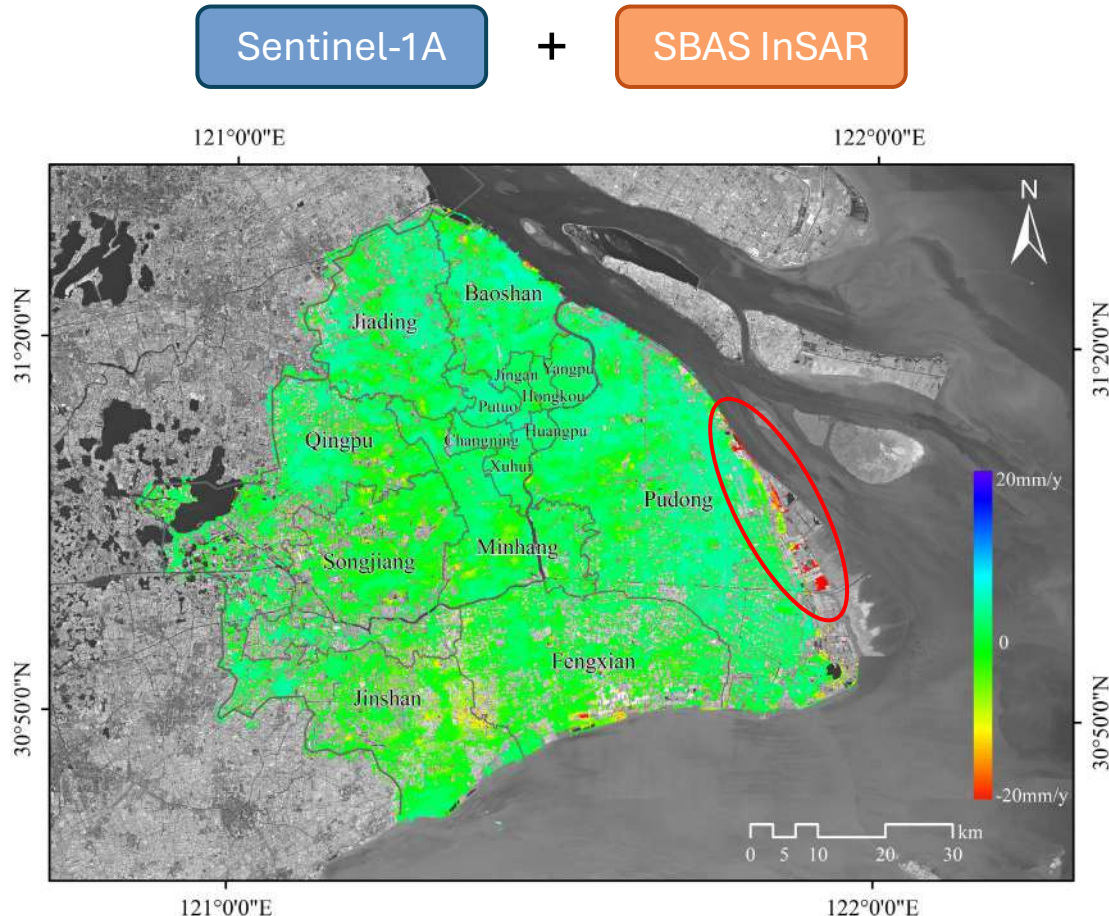


Figure 2. Maps of vertical deformation velocity of Shanghai

Based on 141 ascending Sentinel-1A images, we derived the ground deformation velocity of Shanghai during 2017-2021.

High-risk zones:

Eastern coastal zone of Pudong

- The mean deformation velocity reaches **20 mm/year**.
- This area hosts **critical infrastructure**, such as Shanghai Pudong International Airport.

Some areas near the seawalls.

- The protective performance of seawalls and coastal areas' capacity to resist storm surges and sea-level rise will be reduced.



• Coastal Flood Simulation

Develop future hazard scenarios by integrating data on ground deformation, sea level rise, and storm surge levels.

Sea level rise

- The data under different SSP scenarios obtained from IPCC Sixth Assessment Report.

Year/Sea-level Rise(m)	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	0.09	0.09	0.09	0.10	0.10
2050	0.18	0.19	0.20	0.22	0.23
2100	0.38	0.44	0.56	0.68	0.77

Storm surge

- Storm surge water level data obtained from historical disaster records.

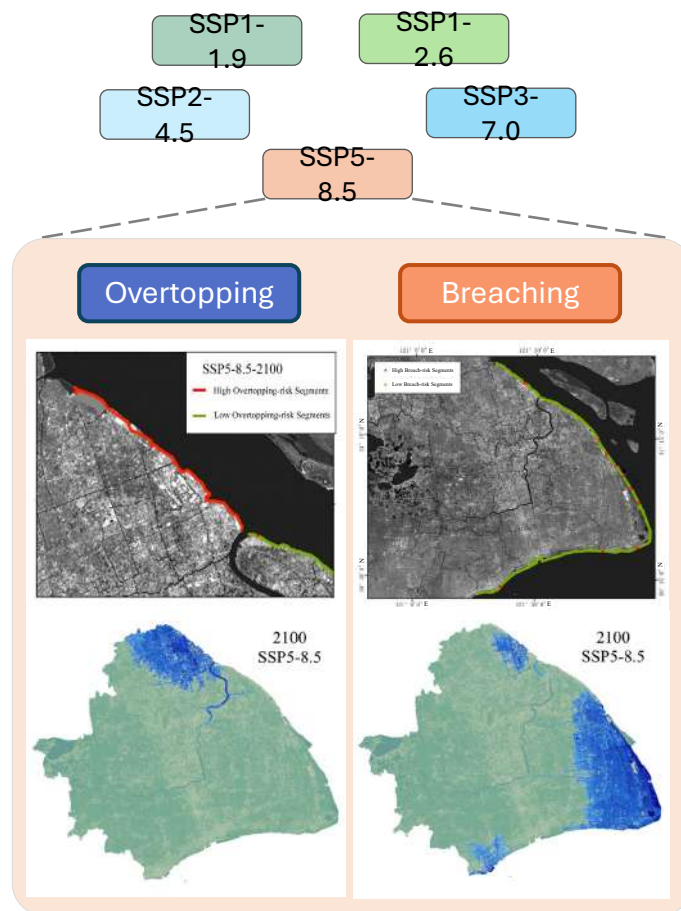
Tidal Station	Waigaoqiao	Wusongkou	Huangpu Park	Luchao Port	Changxing
peak water level	5.99	5.99	5.72	5.68	5.88
Tidal Station	Hengsha	Beichao	Dajinshan	Zhongjun	Tanxu island
peak water level	5.65	5.36	5.26	5.69	5.9





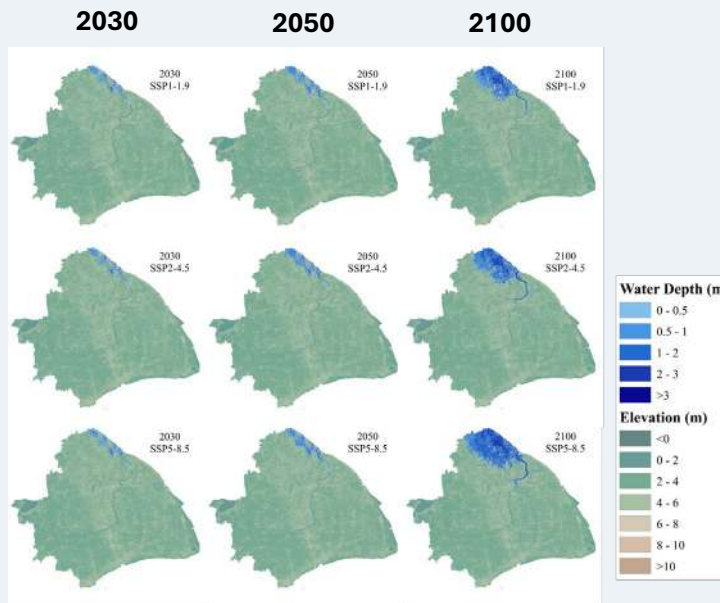
Coastal Flood Simulation

Simulated future coastal flooding caused by seawall overtopping and breaching using the LISFLOOD model.



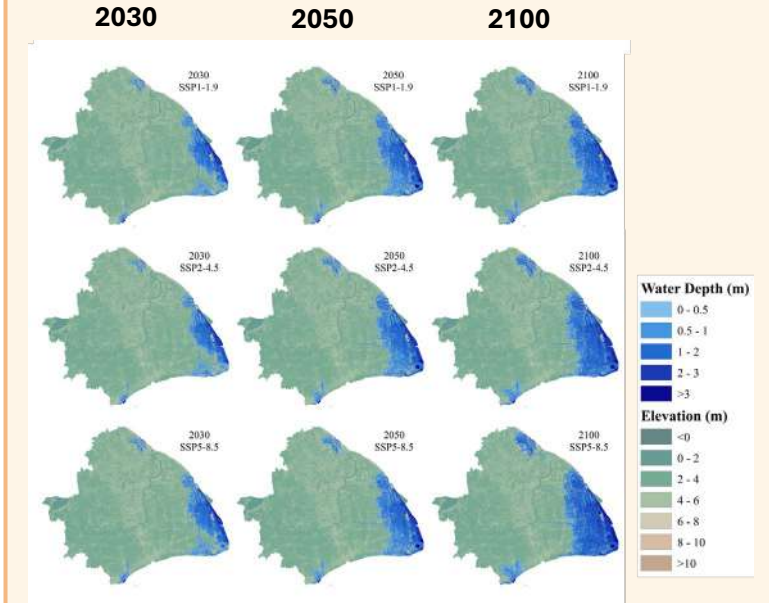
Overtopping

Inundation zones caused by overtopping are mainly concentrated in the **northern** part of Shanghai



Breaching

Flooding caused by breaching chiefly affects the **southeastern** part of Shanghai, produces both a **larger inundation extent** and a **greater flood depths**.

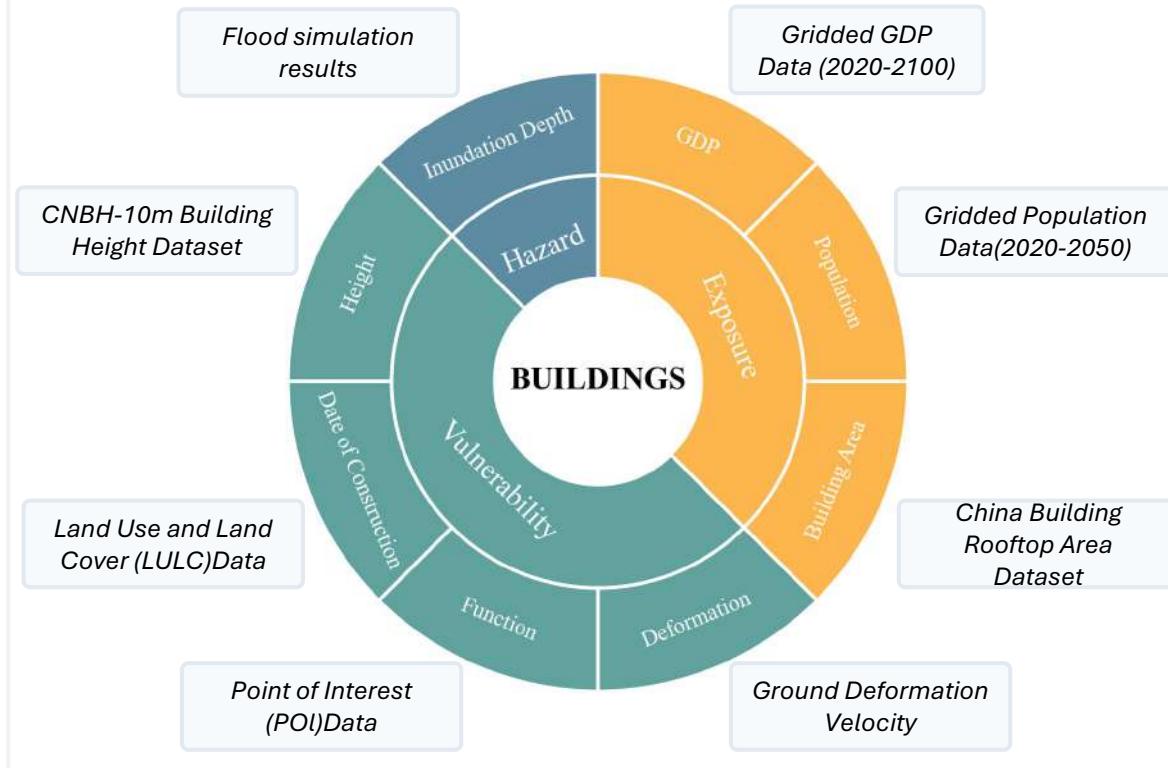




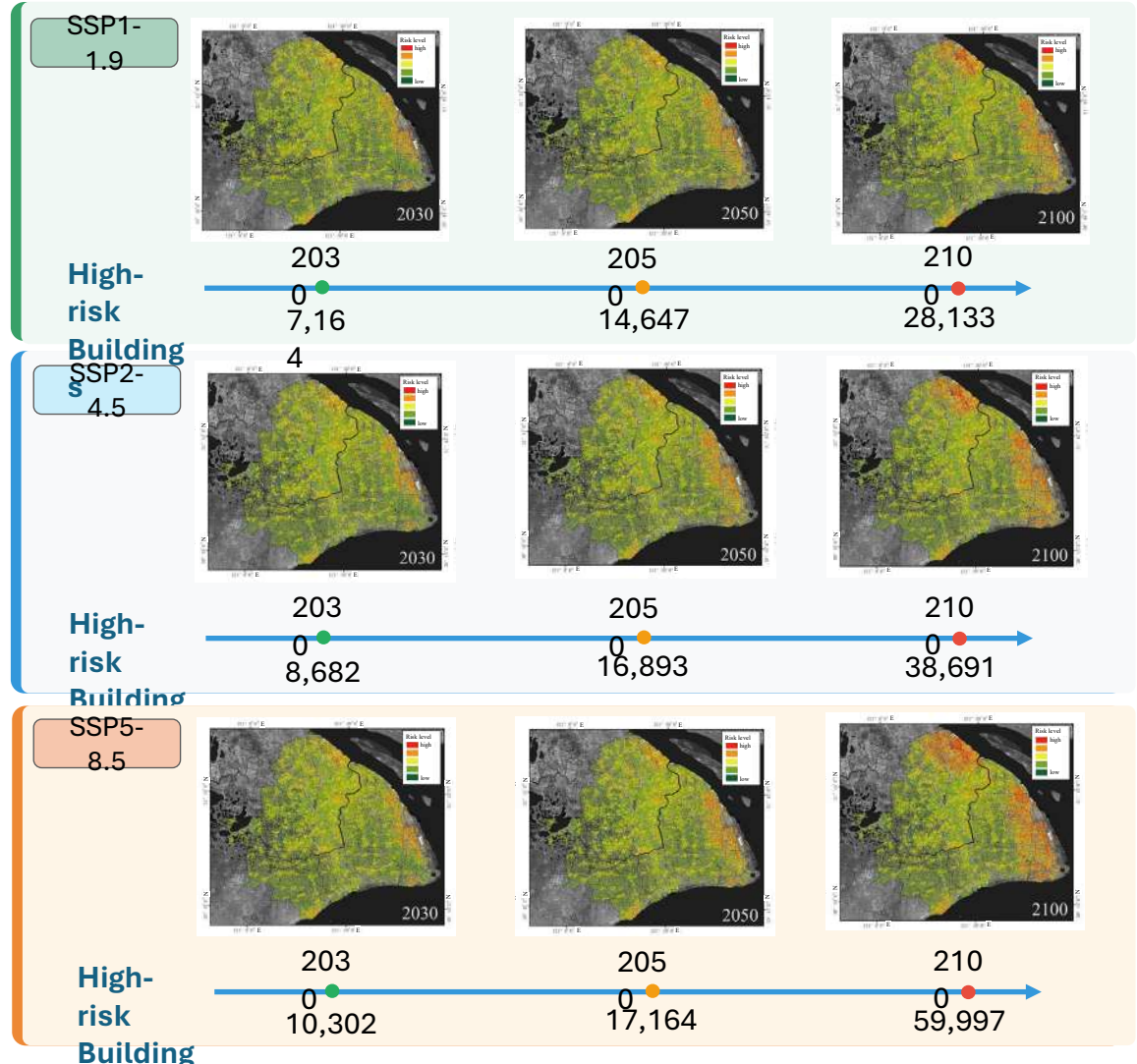
Comprehensive Risk Assessment

Develop a risk-assessment framework based on the three dimensions of hazard, vulnerability, and exposure.

We processed the collected data to derive various indicators and then classified them.



Risk assessment results





• Economic Loss Assessment

Direct economic losses

Calculate the direct economic losses via a flood loss function, and count the losses in different industries.

Flood loss function

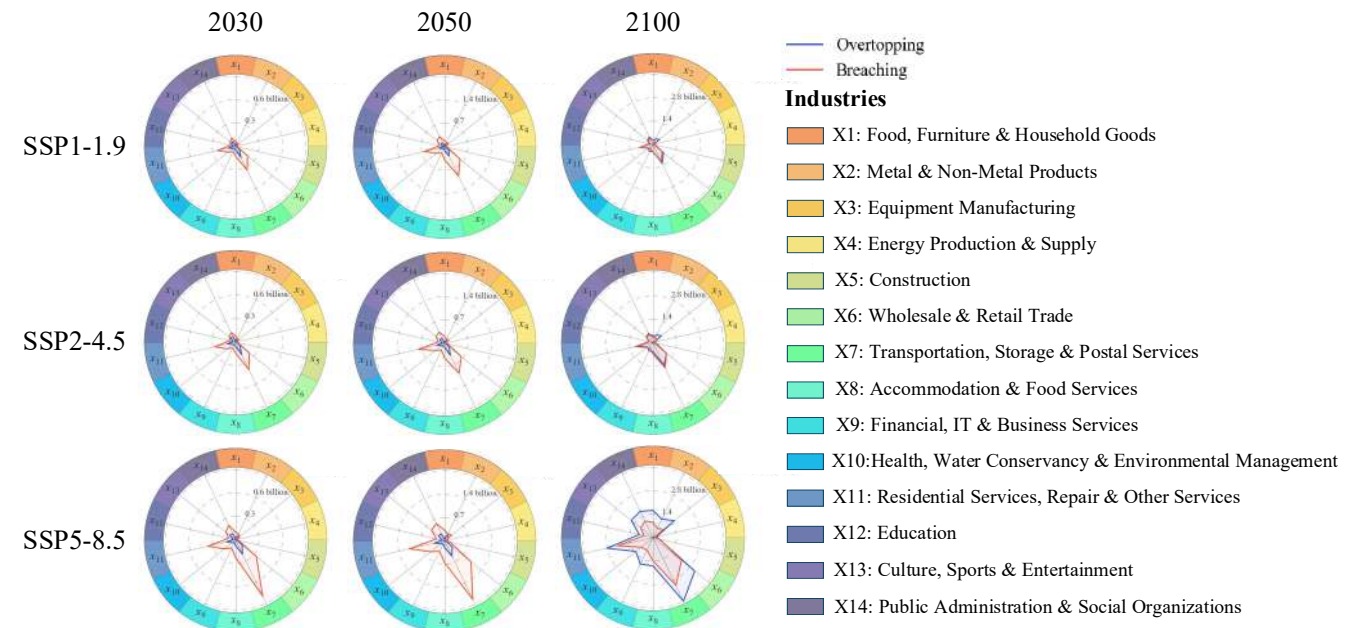
$$d(a) = \frac{h_f}{h_b} \cdot e_a$$

Total economic losses

Overtopping				
	SSP1-1.9	SSP5-8.5		
2030	0.74	0.89	billion	
2050	1.5	2.64	billion	
2100	6.57	24.27	billion	

Breaching				
	SSP1-1.9	SSP5-8.5		
2030	1.55	2.79	billion	
2050	4.61	7.91	billion	
2100	5.25	16.03	billion	

Direct economic losses (by industry)



The industries with high losses:

Transportation, Storage, and Postal Services



Economic Loss Assessment

Indirect economic losses

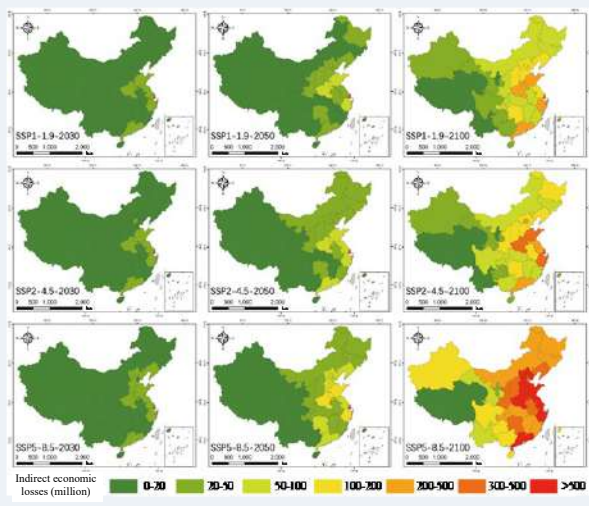
Multi-regional input-output model

Use the input-output model to estimate indirect economic losses at the provincial level.

Overtopping

Indirect economic losses are higher than direct economic losses, exceeding them by more than twice.
Of these losses, over 70% are borne by Shanghai itself.

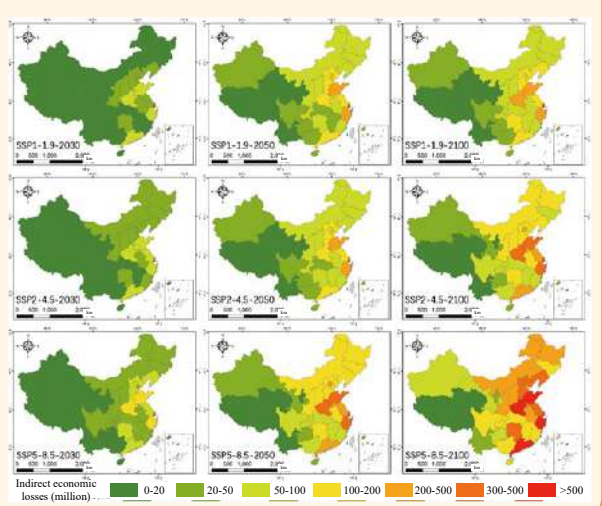
Overtopping			
	SSP1-	SSP5-	
2030	1.9	8.5	billion
2050	3.04	5.32	billion
2100	13.15	48.47	billion



Breaching

The indirect economic losses from floods due to breaching are higher than those from overtopping in 2030 and 2050, but are lower in 2100.
Of these losses, over 70% are borne by Shanghai itself.

Breaching			
	SSP1-	SSP5-	
2030	1.9	8.5	billion
2050	9.44	16.2	billion
2100	10.58	33.29	billion



The provinces with the largest indirect losses are mainly located in eastern China.



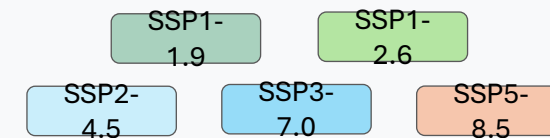
Ground deformation during 2017-2021

Investigated the ground deformations of Shanghai in recent years, high-risk zones are primarily located along the coast.

141
*Sentinel-1A
images*

Coastal Flood Simulation

Completed the simulation of coastal flooding under different scenarios using the LISFLOOD model.



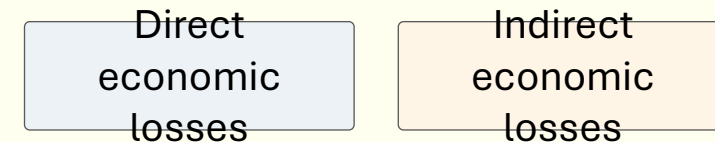
Comprehensive Risk Assessment

Completed the detailed assessment of individual-building risk in Shanghai, high-risk buildings are mainly concentrated along the coast.

1.2
million buildings

Economic Loss Assessment

The economic loss assessment was conducted using the flood loss function and the input-output model.



This research can provide a scientific basis for Shanghai's refined risk management.



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Thank You for Your Attention!



Overview of Chinese YSs research



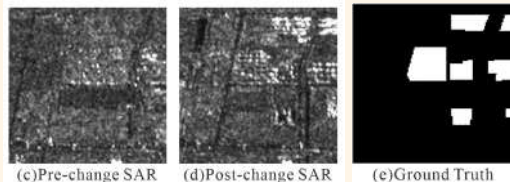
Building Change Detection Based on a Dual-Stream Network with Adaptive Feature Fusion and Cross-Attention Guidance Using SAR and Optical Remote Sensing Imagery

1. Research Data

To improve the accuracy of building change detection, we integrated SAR and optical data.

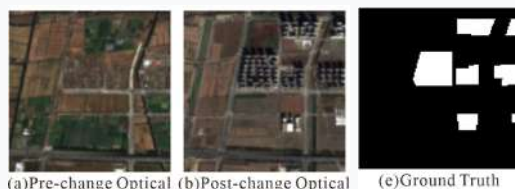
Sentinel-1 (SAR)

- Data acquisition is not affected by weather conditions.
- Distinguish buildings from other land-cover feature effectively.



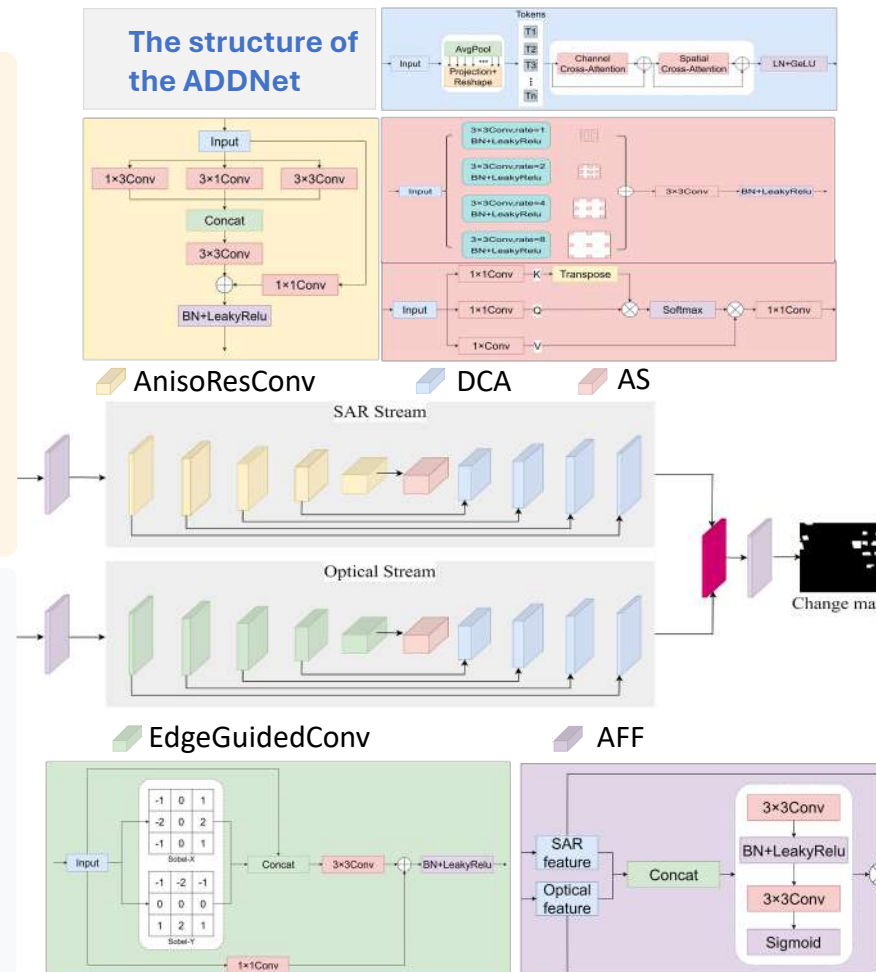
Sentinel-2 (optical)

- Provide abundant building texture and spectral information.



2. Change Detection Model (ADDNet)

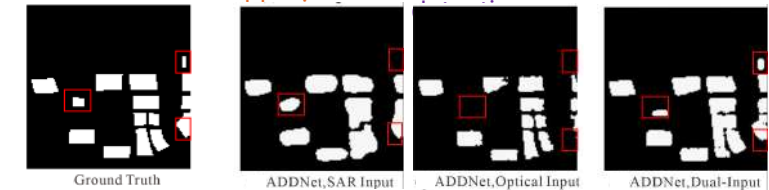
We constructed 5,820 samples to train and validate the model.



3. Results and Accuracy

Comparative analysis of the results

- Results of different input data (ADDNet with SAR, Optical or Dual)



- Results of different model (ADDNet and Unet)



Accuracy

Overall, ADDNet with dual data sources outperforms the other models in the comparison.

Method	Input	Precision	Recall	F1	IoU	Accuracy
U-Net	Optical, SAR	0.8434	0.8282	0.8258	0.7187	0.9904
ADDNet	Optical	0.9374	0.7296	0.8081	0.6941	0.9899
	SAR	0.8287	0.7925	0.8034	0.6844	0.9894
	Optical, SAR	0.8920	0.8843	0.8855	0.7985	0.9927



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Building Change Detection Based on a Dual-Stream Network with Adaptive Feature Fusion and Cross-Attention Guidance Using SAR and Optical Remote Sensing Imagery

Project ID: 95316; Poster ID: 183

Authors: Weiwei Fang^{1,2,3}, Taotao Zheng^{1,2,3}, Qing Zhao^{1,2,3,*}

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²School of Geographic Sciences, East China Normal University, Shanghai 200241, China;

³Key Laboratory of Spatial-Temporal Big Data Analysis and Application of Natural Resources in Megacities, Ministry of Natural Resources, Shanghai 200241, China





**Building
Change
Detection**



Urban planning

Land use change
analysis

Shanghai

- High building density
- rapid urban transformation

Multi-source remote sensing

- The backscattering intensity of SAR can clearly reflect building information.
- Optical imagery clearly captures the textural details of buildings.

This study proposes a novel urban building change detection method based on the fusion of SAR and optical remote sensing data in Shanghai.



Optical image



SAR image

Building
change

Experimental Data



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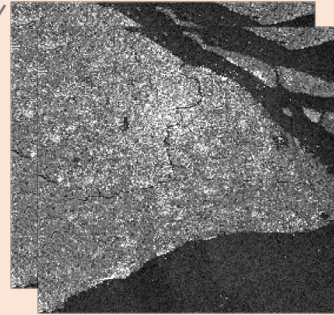


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- This study acquired Sentinel-1 (SAR) and Sentinel-2 (optical) satellite image pairs from Shanghai, covering pre-change and post-change phases, **the acquisition time** of the data is listed in the table.

Sensors	Time
Sentinel-2	20211124
	20241228
Sentinel-1	20211121
	20241223

The acquisition time of the data



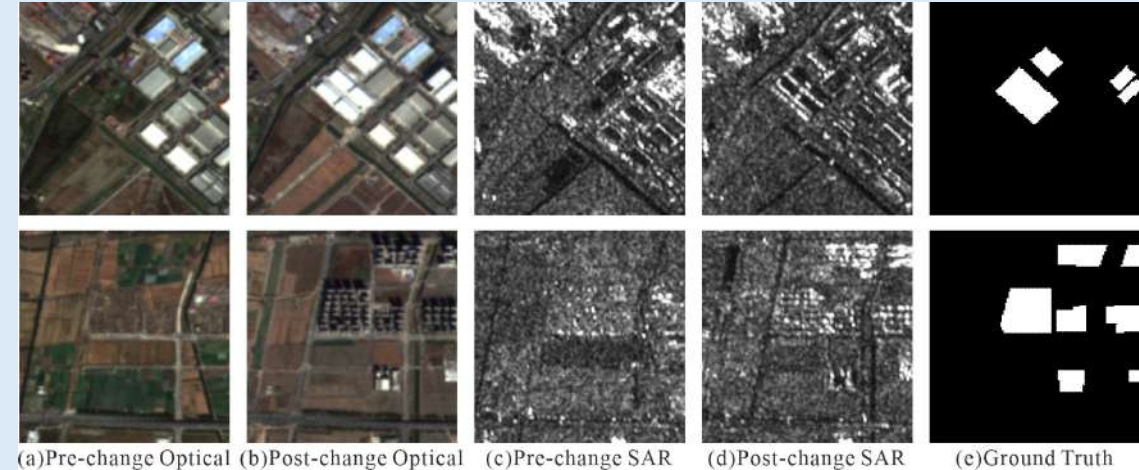
Sentinel-1



Sentinel-2

Data
Processing

- Sentinel-1 SLC(Single Look Complex) data were processed with multi-looking, geocoding and cropping to extract intensity information, while Sentinel-2 data were processed with atmospheric correction, radiometric calibration and cropping.



Visualization of the dataset

- This study constructed **5,820** samples.
- These samples were split into training, validation, and test sets at a **10:1:1** ratio.

Approach

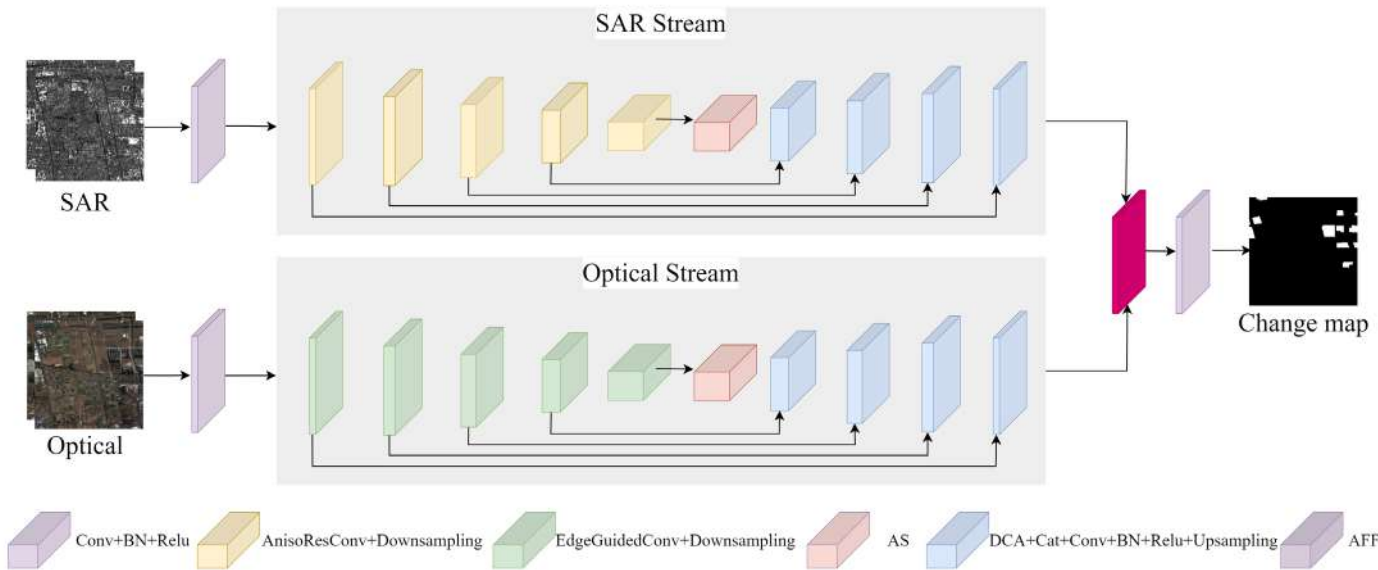


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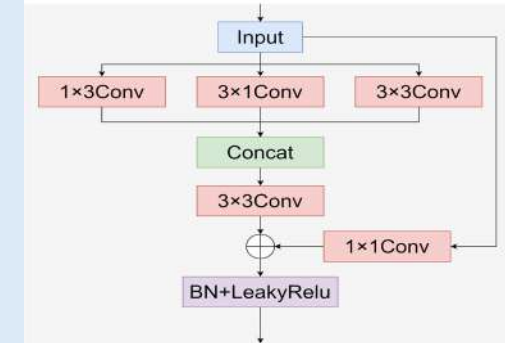
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Each stream is based on an **encoder-decoder** structure



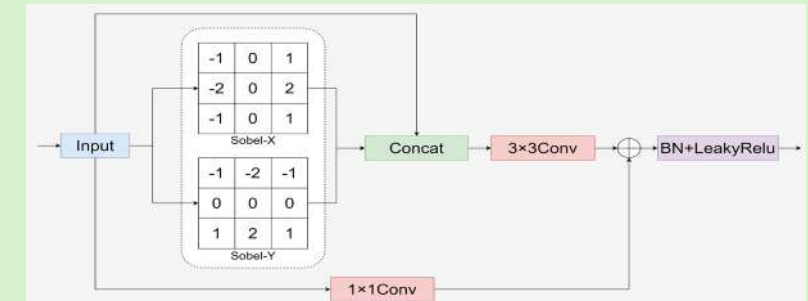
- During the encoder stage, the **AnisoResConv** and **EdgeGuidedConv** modules are specifically designed to extract features from SAR and optical data, respectively.
- The ASPP-SelfAttention (**AS**) Module and a Dual Cross-Attention (**DCA**) module are used to capture comprehensive local-global features.
- The SAR and optical stream features are adaptively fused through an Adaptive Feature Fusion (**AFF**) Module to generate the final change map.

Extracting SAR features while suppressing speckle noise.



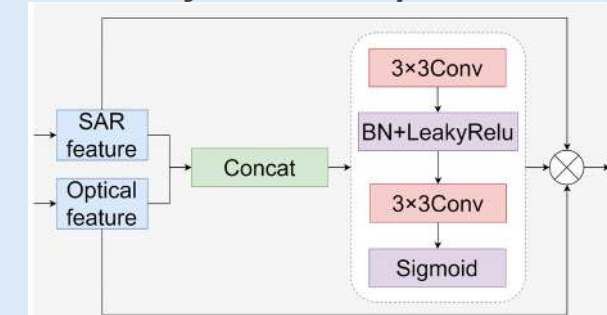
The structure of the AnisoResConv

Edge extraction of buildings



The structure of the EdgeGuidedConv

Dynamic Fusion of SAR and Optical Features



The structure of the AFF



Six evaluation metrics (as shown in the table below) were selected for quantitative analysis.

- The quantitative results demonstrate that ADDNet significantly outperforms the others when inputting both optical and SAR data, achieving superior performance
- U-Net exhibits balanced but lower metrics under dual-input conditions, highlighting ADDNet's enhanced capability in leveraging multi-source data for change detection.

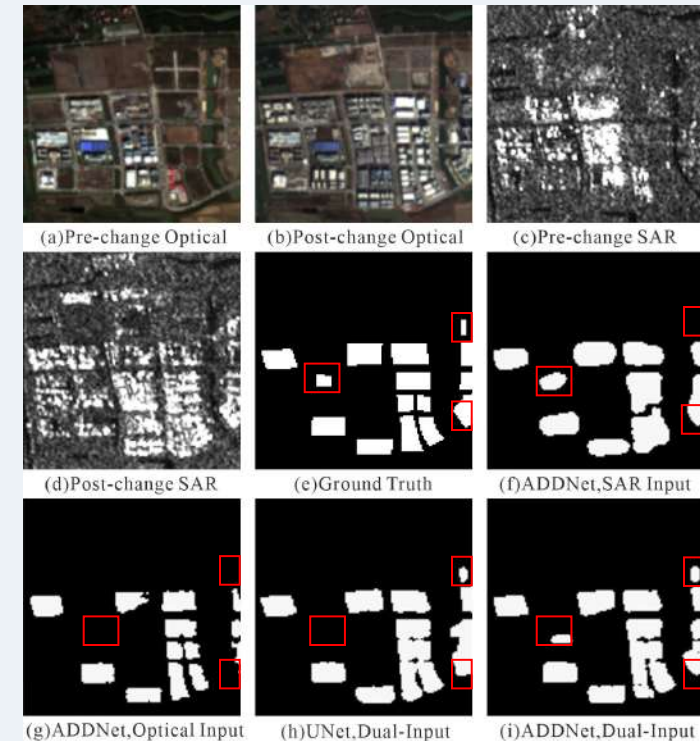
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ADDNet	Optical	0.9374	0.7296	0.8081	0.6941	0.9899
ADDNet	SAR	0.8287	0.7925	0.8034	0.6844	0.9894
ADDNet	Optical, SAR	0.8920	0.8843	0.8855	0.7985	0.9927

Comparisons of different methods. SAR and optical represent the different sources of input data

Visual results



- The ADDNet achieves the **most complete building detection coverage** when input SAR and optical data both.



The visual results of building change detection.

ADDNet can effectively fuse SAR and optical information.

Conclusion



Unlike conventional SAR-optical change detection approaches, we develop a **dual-stream** architecture to better extract and fuse the SAR and optical features.

In ADDNet, We designed feature fusion module and different convolutional modules for SAR and optical data, and introduced cross-attention and self-attention mechanisms as well as ASPP.

Experimental results demonstrate the method's superiority in urban building change detection, achieving F1-score at 88.55%, IoU at 79.85%, outperforming the other method and data input.



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