ESSI1.4 Deep Learning in Geosciences

EGU26 GENERAL ASSEMBLY

中国農業大學 China Agricultural University

FSG-Net: Exploring Frequency-Spatial Synergy for Remote Sensing Change Detection

Zhongxiang Xie[1], Shuangxi Miao[1], Yuhan Jiang[1], Zhewei Zhang[1], Jing Yao[2], Xuecao Li[1], Jianxi Huang[3], and Pedram Ghamisi[4]

1 China Agricultural University, Beijing

2 China Academy of Sciences, Beijing

3 Southwest Jiaotong University, Chengdu

4 Helmholtz-Zentrum Dresden-Rossendorf, Germany

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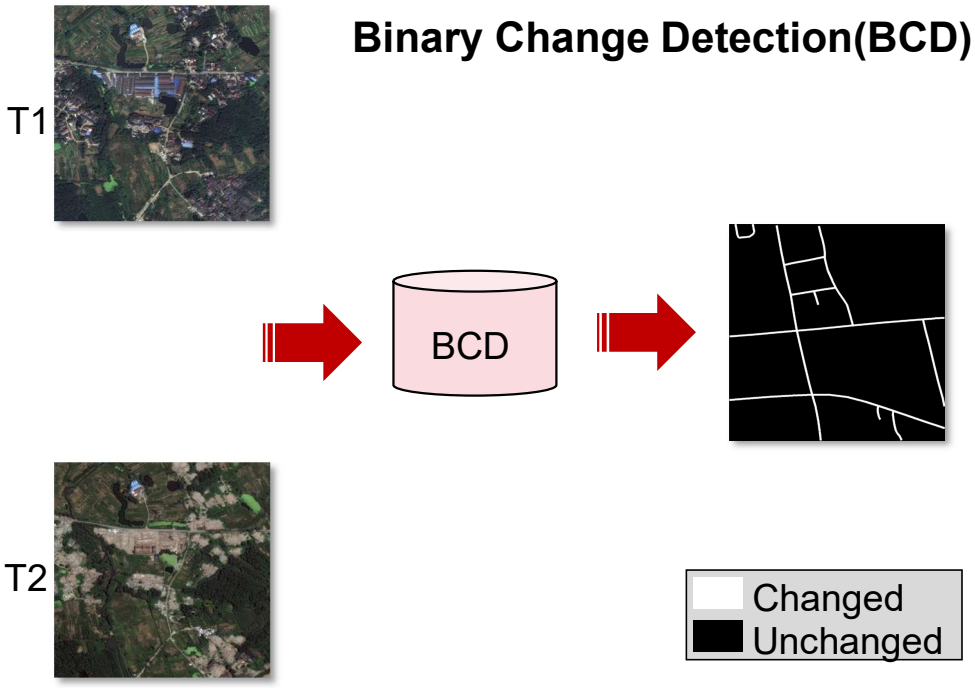
1.Background: What is Change Detection?

Change Detection in high-resolution remote sensing images is a vital technology for tracking geospatial changes at different times.




Urban Expansion


Resource Management


Disaster Assessment

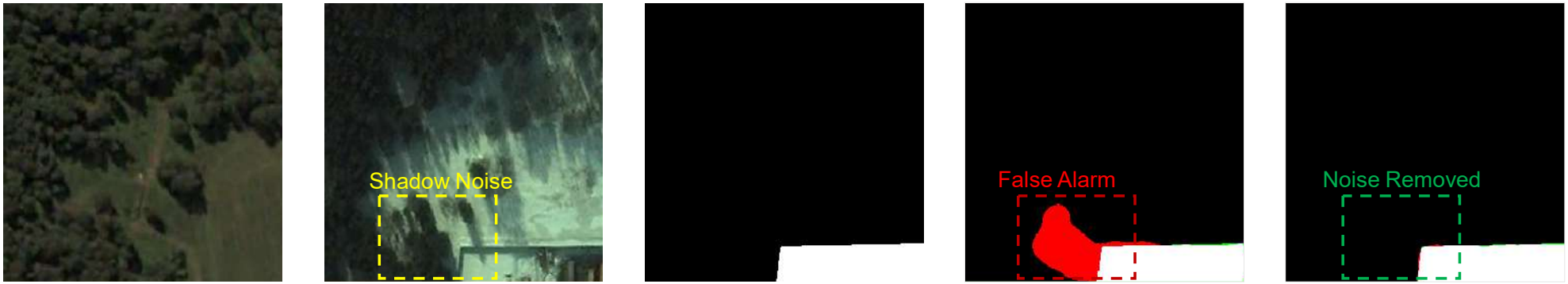

Environmental Monitoring

A fundamental task for understanding the Earth's surface dynamics

2. Motivation: Limitations of Existing Methods

True Negative True Positive False Negative False Positive

Challenge1: Pseudo-changes caused by discrepancies in imaging conditions



+ (DAWIM&STSAM)

Challenge2: Imprecise boundary delineation resulting from the semantic gap between multilevel features

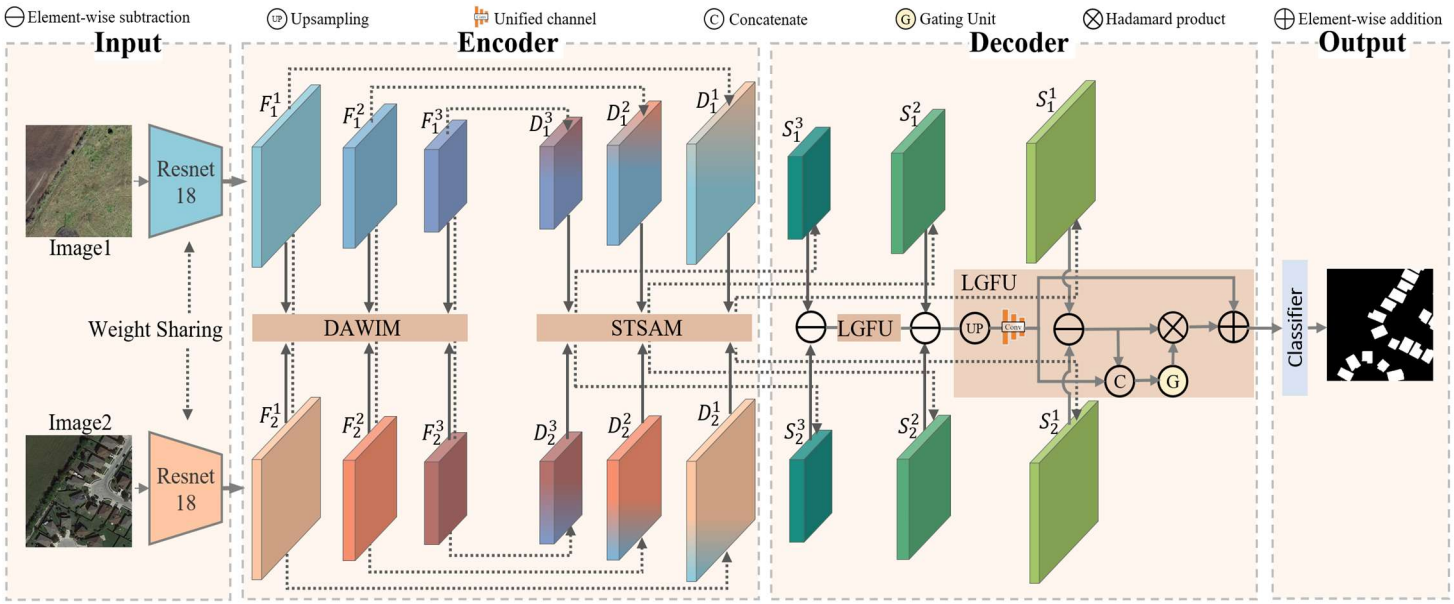
+ LGFU

T1 **T2** **Labels** **Others** **Ours**

3. Method: Overall Architecture

- **Frequency-Spatial synergistic Gated network for CD task (FSG-Net)**

Frequency Interaction → S-T Attention → Gating Fusion



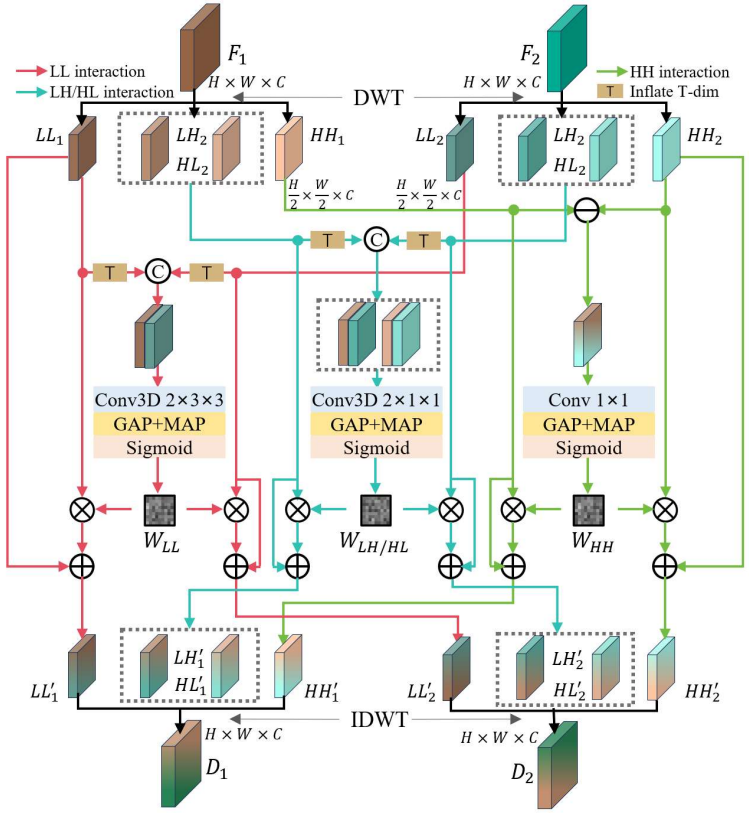
Overview of the proposed FSG-Net architecture

Key Ideas:

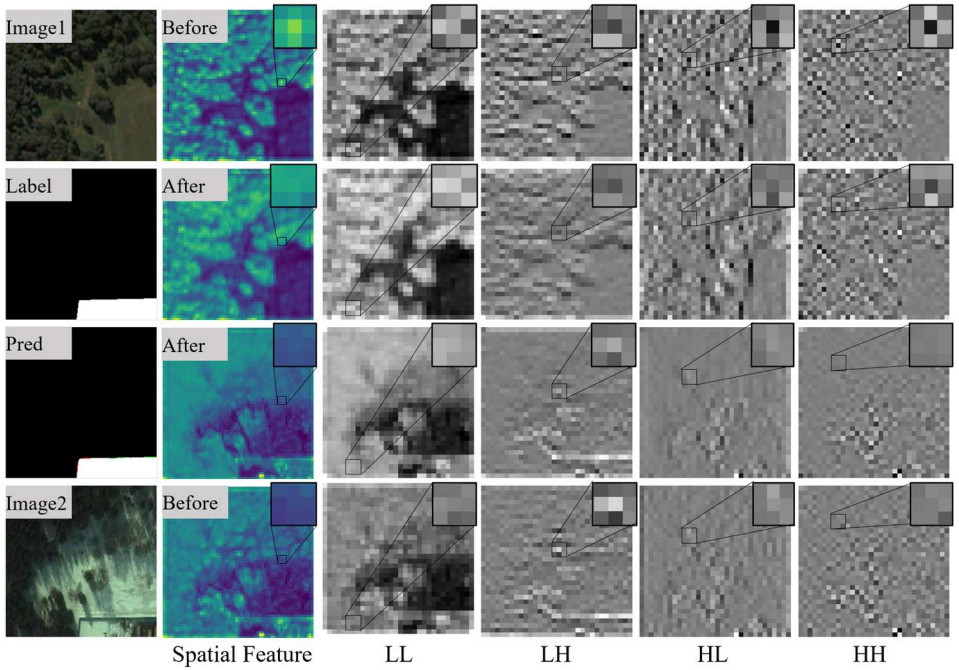
- **Suppress** pseudo-changes via frequency-domain feature interaction.
- **Enhance** real change perception using Spatio-Temporal Attention.
- **Align** deep semantics with shallow details through Gating Fusion.

3. Method: Frequency Branch

- **Discrepancy-Aware Wavelet Interaction Module (DAWIM)**



Operational workflow of the DAWIM



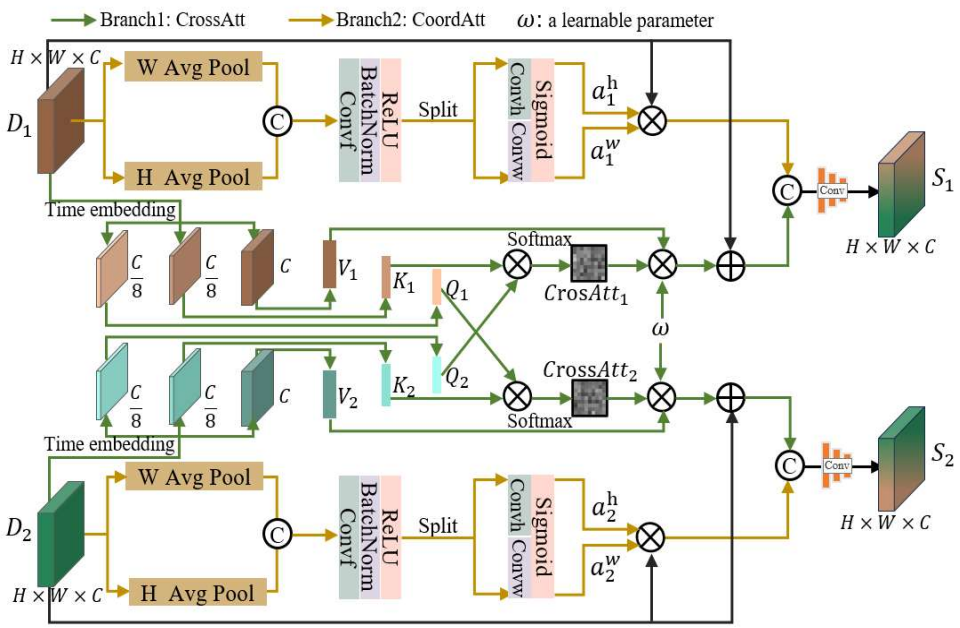
LL: Low-frequency (Main content); LH/HL/HH: High-frequency (Details/Noise)

Feature modulation process of DAWIM

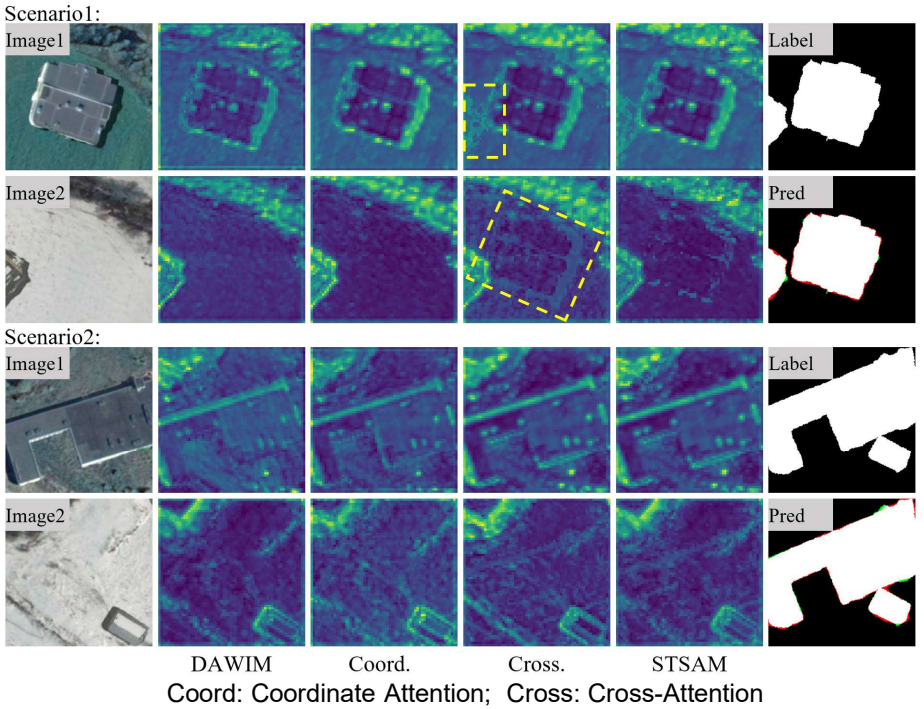
Effectively suppress pseudo-changes while preserving structural details

3. Method: Spatial Branch

- **Synergistic Temporal–Spatial Attention Module (STSAM)**



Internal mechanism of the STSAM



Coord: Coordinate Attention; Cross: Cross-Attention

Progressive feature refinements of STSAM

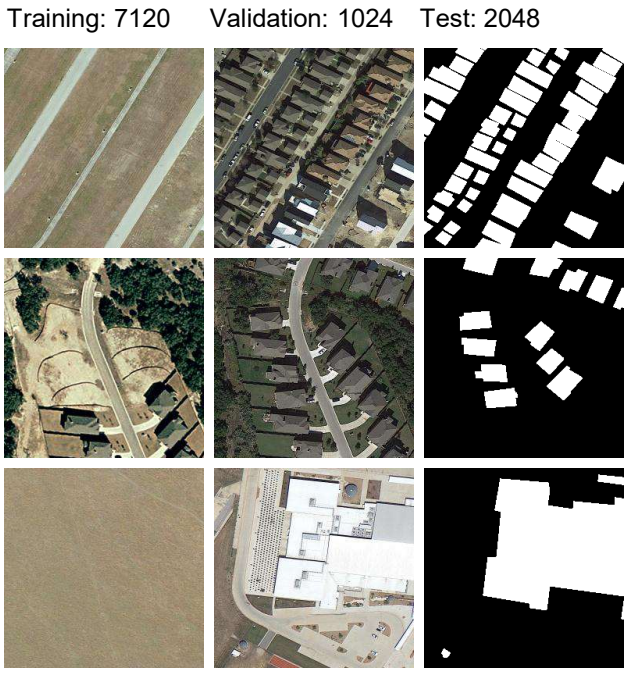
Precisely enhance change region perception and detail refinement

4. Experiments: Datasets

- **Evaluated on Three Challenging Datasets**

CDD (Seasonal)
16000 images
Resolution: 0.03-1m

GZ-CD (Urban)
1073 images
Resolution: 0.5m



LEVIR-CD (Building)
10214 images
Resolution: 0.5m

Providing a rigorous test in handling spectral noise and spatial complexity

4. Experiments: Quantitative Results

Comprehensive Performance Benchmarking

TABLE I

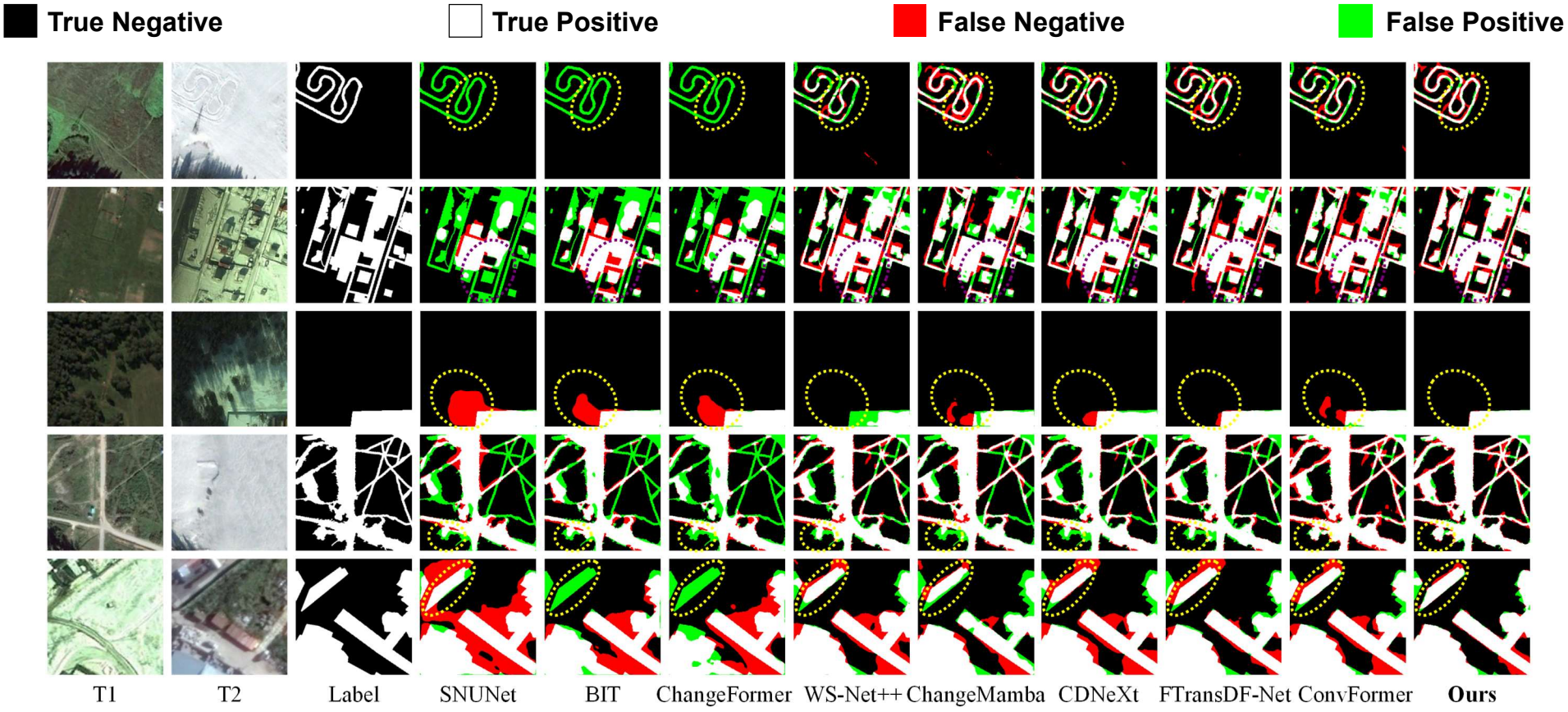
COMPARISON RESULTS ON THE THREE CD DATASETS. THE BEST SCORE IS HIGHLIGHTED IN BOLD. ALL RESULTS ARE DESCRIBED AS PERCENTAGES (%)

Methods	Ref.	CDD					GZ-CD					LEVIR-CD				
		Pre.	Rec.	F1	IOU	OA	Pre.	Rec.	F1	IOU	OA	Pre.	Rec.	F1	IOU	OA
SNUNet [39]	GRSL21	90.54	86.61	88.53	79.42	97.26	82.76	80.55	81.64	68.98	90.56	89.31	89.56	89.43	80.88	98.89
BIT [45]	TGRS21	90.67	86.44	88.50	79.37	97.26	82.90	80.68	81.77	69.16	90.63	89.24	89.37	89.30	80.67	98.88
ChangeFormer [43]	IGARSS22	91.54	89.31	90.41	82.50	97.68	84.59	84.28	84.43	73.06	91.90	91.97	89.03	90.48	82.62	99.02
DMINet [18]	TGRS23	92.45	90.72	91.58	84.47	97.96	89.04	86.52	87.76	78.19	93.71	92.27	88.94	90.57	82.77	99.03
AMTNet [10]	ISPRS23	92.32	92.91	92.61	86.24	98.19	88.51	85.27	86.86	76.77	93.28	91.34	89.76	90.54	82.72	99.02
WS-Net++ [20]	TGRS24	92.95	93.21	93.08	87.06	98.31	88.32	85.76	87.02	77.02	93.33	92.11	**90.05**	91.07	83.60	99.08
ChangeMamba [61]	TGRS24	92.84	93.41	93.12	87.13	98.31	89.32	87.17	88.23	78.94	93.94	91.76	89.54	90.64	82.88	99.03
CDNeXt [47]	JAG24	92.76	93.87	93.31	87.46	98.35	89.21	86.34	87.75	78.17	93.72	92.15	89.69	90.91	83.33	99.06
FTransDF-Net [26]	JAG25	93.10	94.03	93.56	87.90	98.42	89.13	87.45	88.28	79.02	93.95	92.19	89.73	90.94	83.39	99.07
ConvFormer [46]	TGRS25	**93.35**	93.19	93.28	87.41	98.36	89.11	87.58	88.33	79.11	93.97	92.14	89.69	90.90	83.32	99.06
FSG-Net	Ours	93.33	**95.01**	**94.16**	**88.96**	**98.56**	**90.85**	**88.20**	**89.51**	**81.01**	**94.61**	**92.53**	90.04	**91.27**	**83.94**	**99.10**

FSG-Net achieves SOTA performance across all three datasets

4. Experiments: Qualitative Results

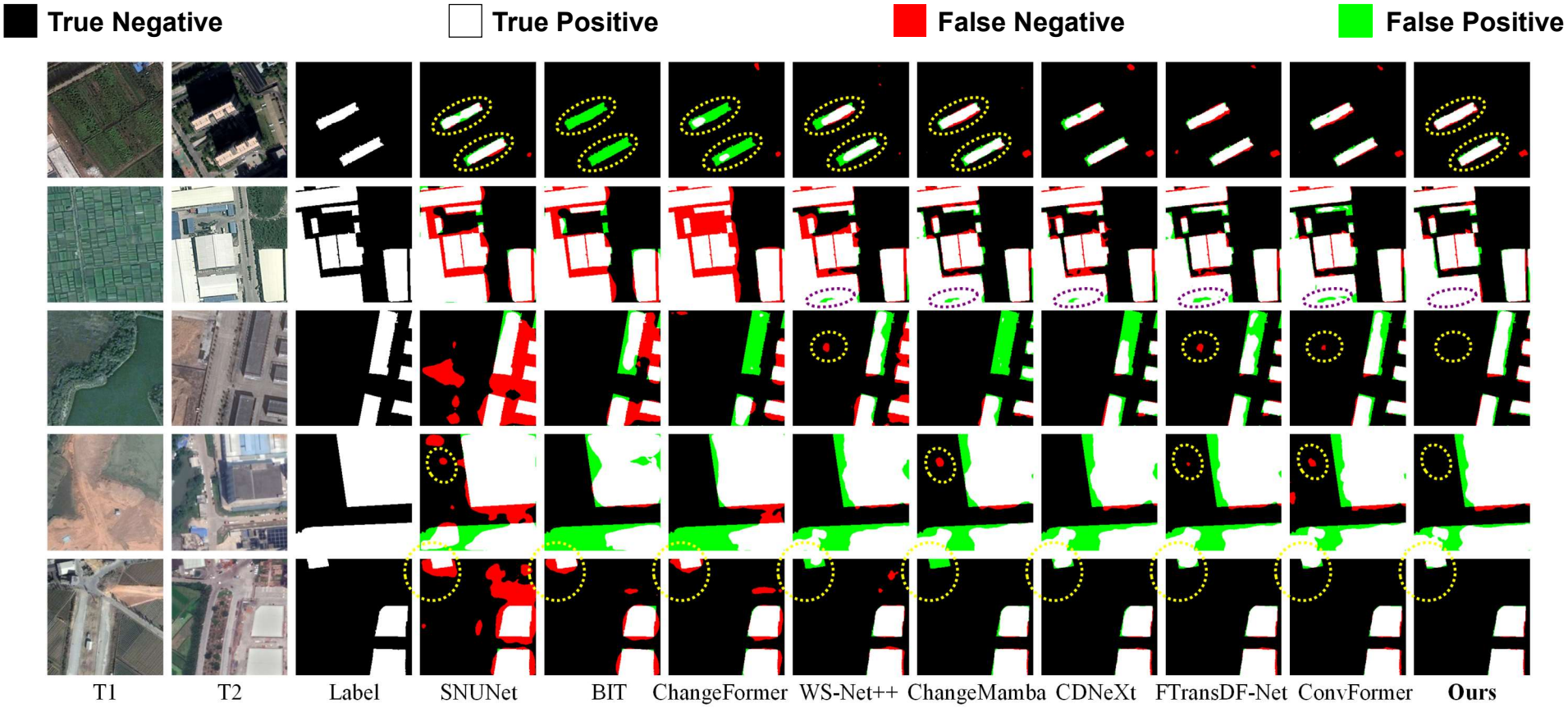
- **Visualization of results on CDD Datasets**



Significant suppression of seasonal and shadow pseudo-changes

4. Experiments: Qualitative Results

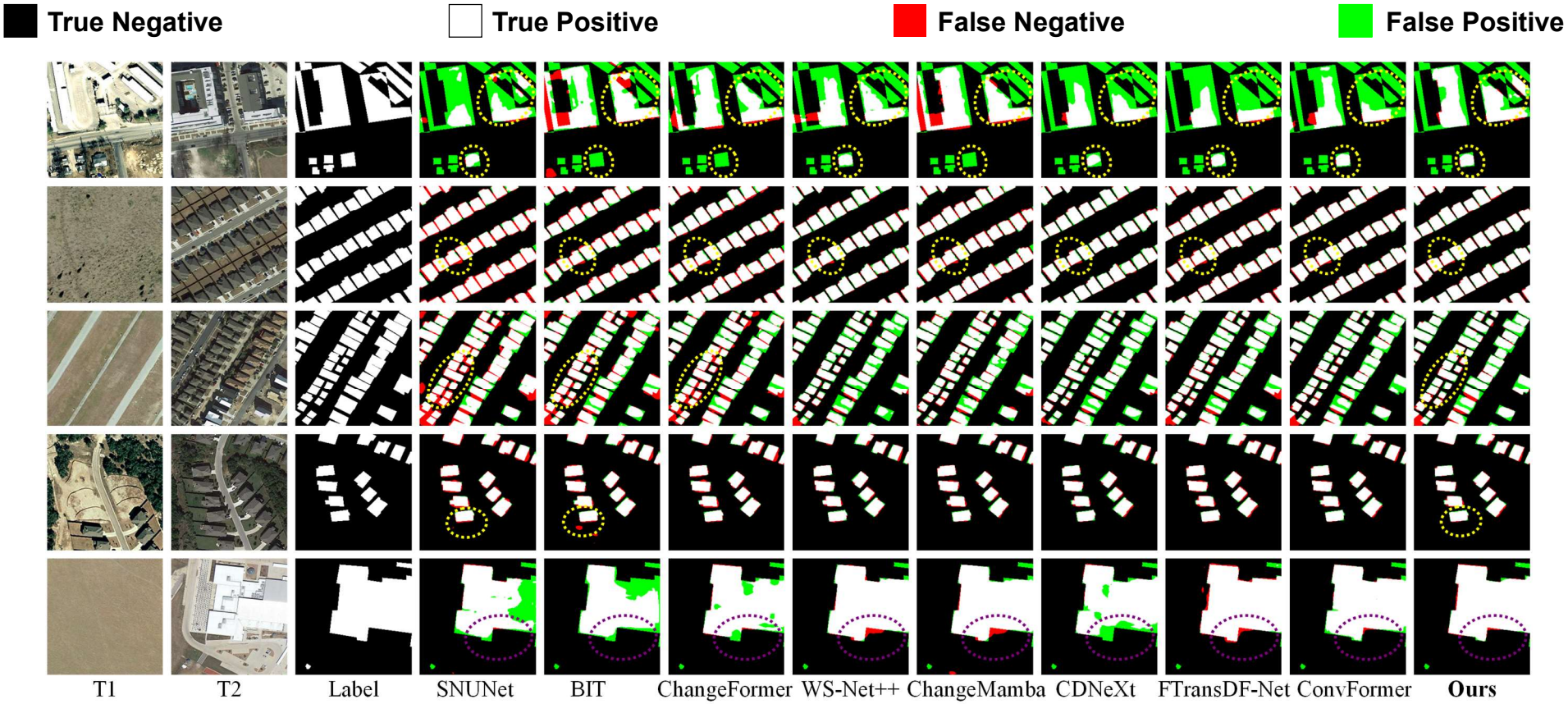
- **Visualization of results on GZ-CD Datasets**



Superior robustness to complex urban textures and multi-scale variations

4. Experiments: Qualitative Results

- **Visualization of results on LEVIR-CD Datasets**



Sharp and precise building boundary delineation

5. Conclusion and Outlook

What we achieved: FSG-Net

A synergistic Framework

Proposed a frequency-spatial synergy pipeline to systematically disentangle semantic changes from nuisance variations.

A "Push-Pull" Mechanism

Designed a reciprocal interaction strategy where DAWIM suppresses noise and STSAM enhances saliency.

A New SOTA

Validated superiority across CDD, GZ-CD, and LEVIR-CD benchmarks, achieving highest F1-scores.

What is next: Trust-CC (will be online on arXiv soon)

Efficiency

Focusing on lightweight network architectures and efficient feature extraction for edge device deployment.

Multi-modality

Integrating multi-modal data (SAR, Hyperspectral) to enhance robustness in extreme imaging conditions.

Foundation Models

Constructing knowledge graphs and rule-based constraints for semantics-aware alignment in foundation models.

Reference: Z. Xie et al., "FSG-Net: Frequency-Spatial Synergistic Gated Network for High-Resolution Remote Sensing Change Detection," in IEEE Transactions on Geoscience and Remote Sensing, vol. 64, Art no. 4702115, 2026, doi: 10.1109/TGRS.2026.3666124.

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中国農業大学 China Agricultural University

Thank you for your attention!

Any Questions?

GitHub github.com/zxXie-Air/FSG-Net

contact: zx_xie@cau.edu.cn

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