



武汉大学

WUHAN UNIVERSITY



Cloud Removal for Sentinel-2 By Progressively Spatio-Temporal Patch Group Learning

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IGARSS
2019

2019 IEEE
International Geoscience and
Remote Sensing Symposium
July 28 - August 2, 2019 Yokohama, JAPAN

Outline



1

Background

2

Methodology

3

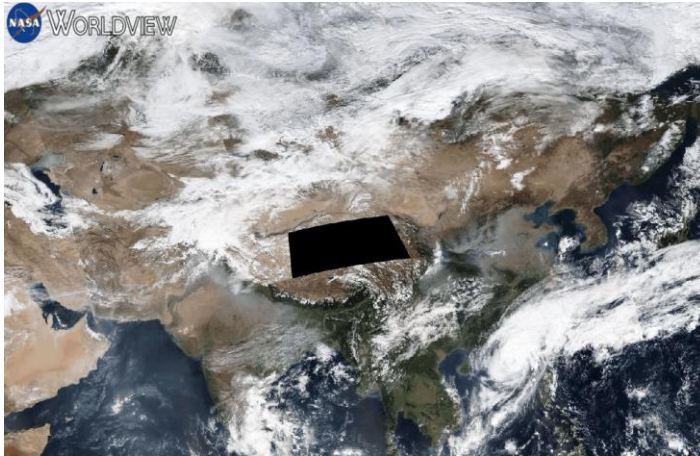
Experiments

4

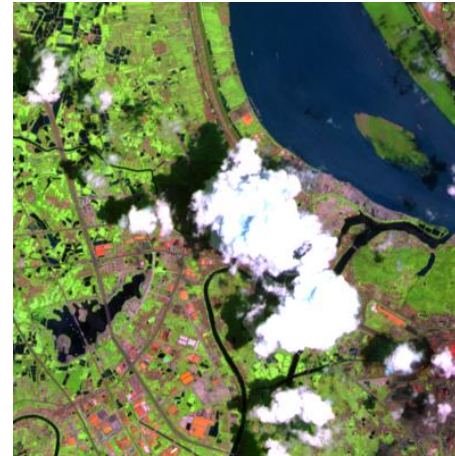
Summary

1

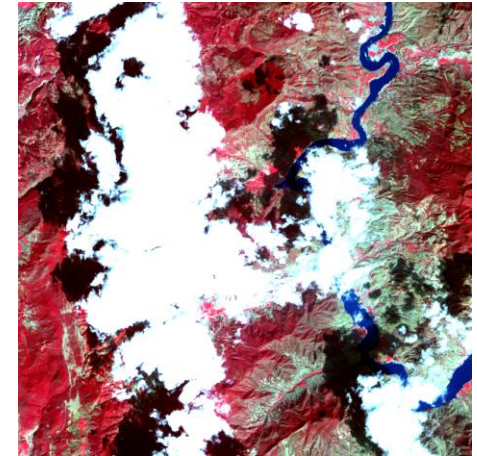
Background



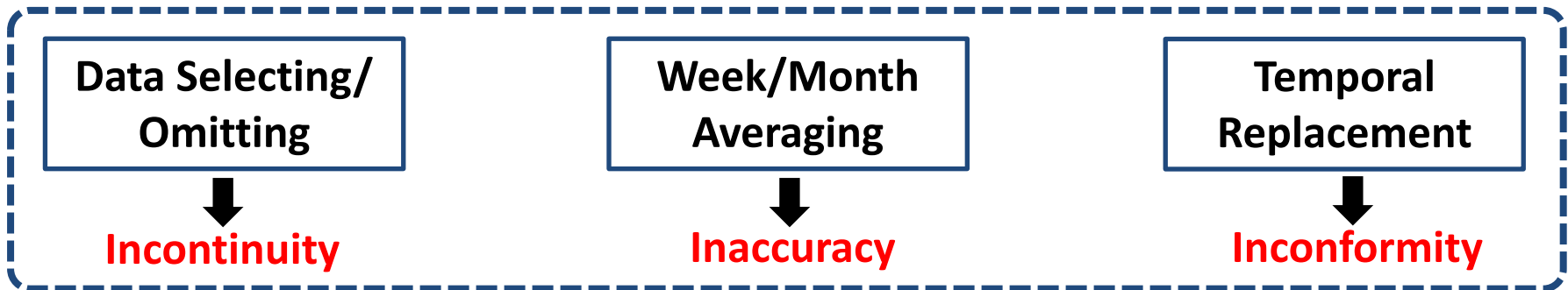
Large-scale Cloud Covering



Sentinel-2 MSI



Landsat-8 OLI

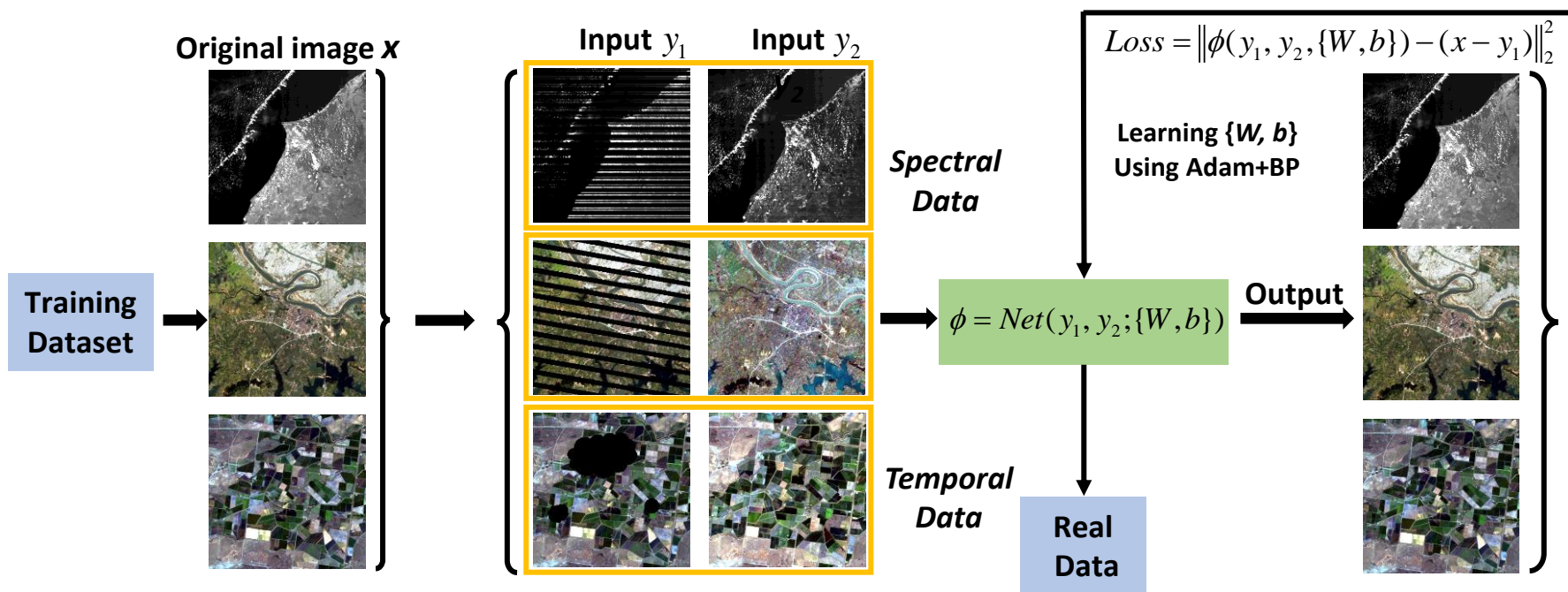


Cloud/shadow greatly
reduce the data usability!



Spatio-Temporal
Cloud/Shadow Removal

Our Pre-existing Work (**STS-CNN**) for Cloud Removal



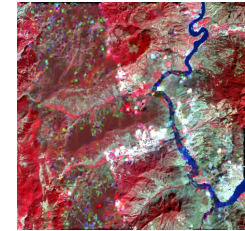
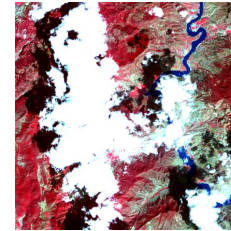
- Joint Spatial-Temporal-Spectral Information
- End-to-end Learning Model through DCNN
- Unified Framework for Inpainting Missing Data

Zhang *et al.*, *IEEE TGRS*, 2018.
Code has been released!
github.com/WHUQZhang

Deficiencies Analyzing of Pre-existing Works

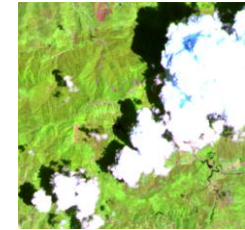
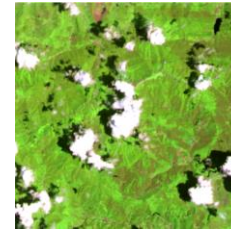
1) Large-scale Cloud/Shadow Covering

- Marginal Differences
- Vague Texture



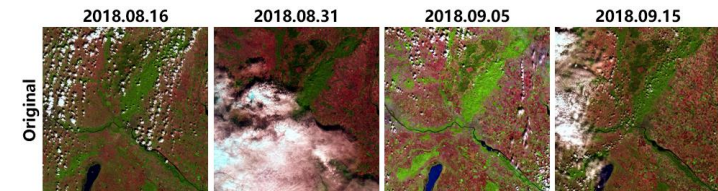
2) Need Ensure Integrity of Temporal Data

- Most Temporal Imageries are Fragmentary
- Limited in Actual Scenarios



3) Multiple Sequence Temporal data

- Redundancy Complementary Information
- Complicated/Changeable Scenarios



V1.0: STS

Upgrade a new framework!

For Cloud/Shadow Removal

V2.0: ?

Outline

1 Background



2 Methodology

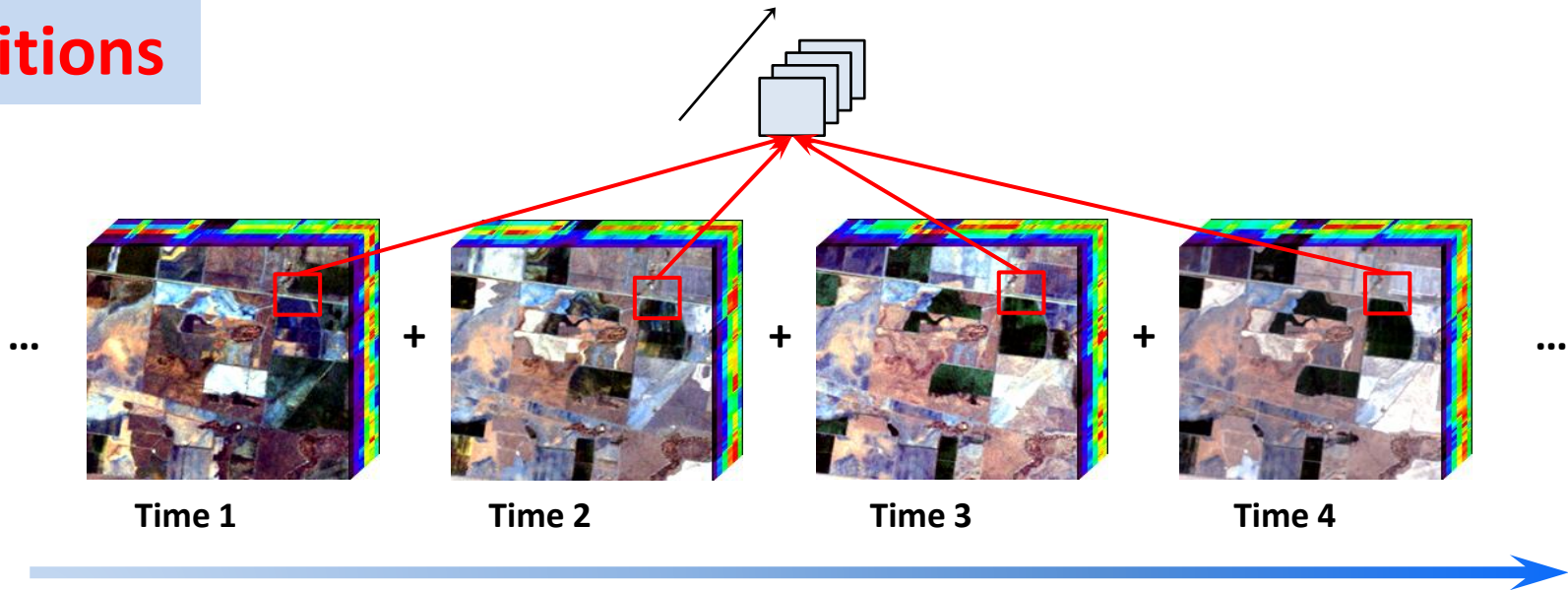
3 Experiments

4 Summary

2

Methodology

Intuitions



Targets:

Reconstructing

Multi-Temporal

Large Scenario

Strategy:

Patch Group

Data-Driven

Global-Local

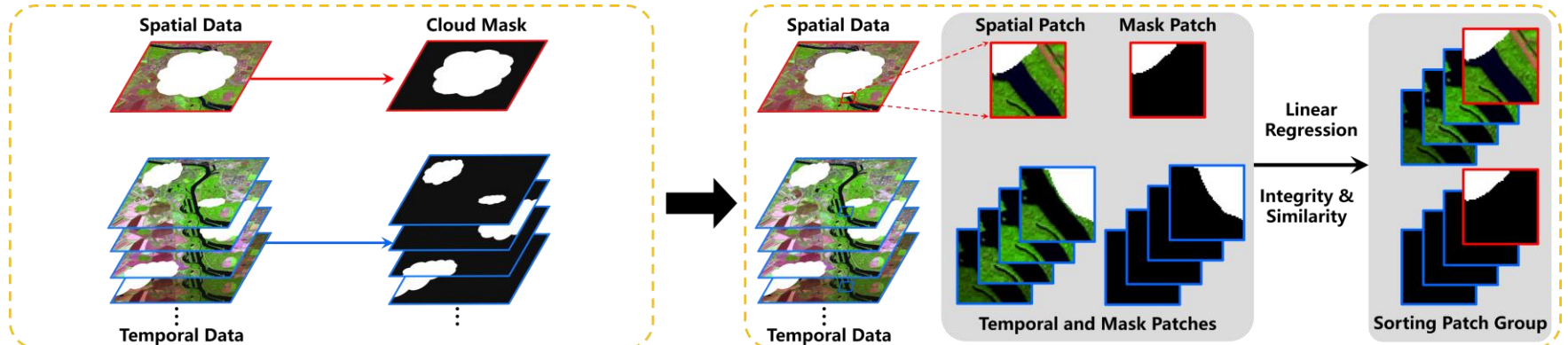
V1.0 (2018)

Upgrade!

For Cloud/Shadow Removal

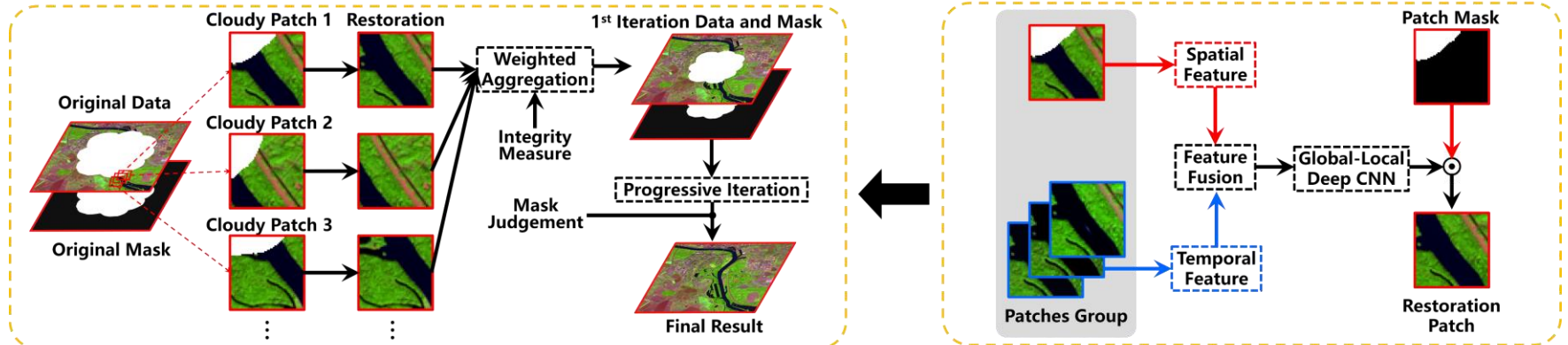
V2.0 (2019)

Flowchart of the Proposed Method



(1) Cloud and Shadow Detection

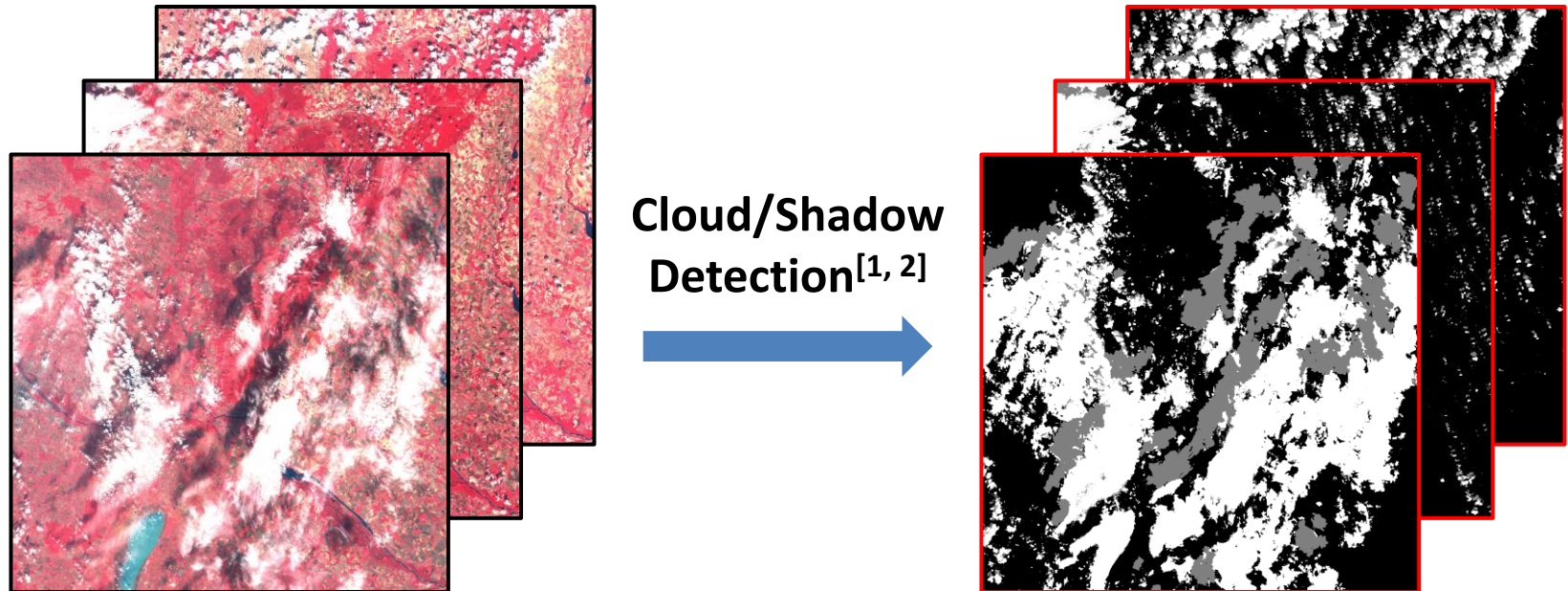
(2) Multi-Temporal Patch Group Stacking



(4) Weighted Aggregation & Progressive Iteration

(3) Spatio-Temporal Recovering Model

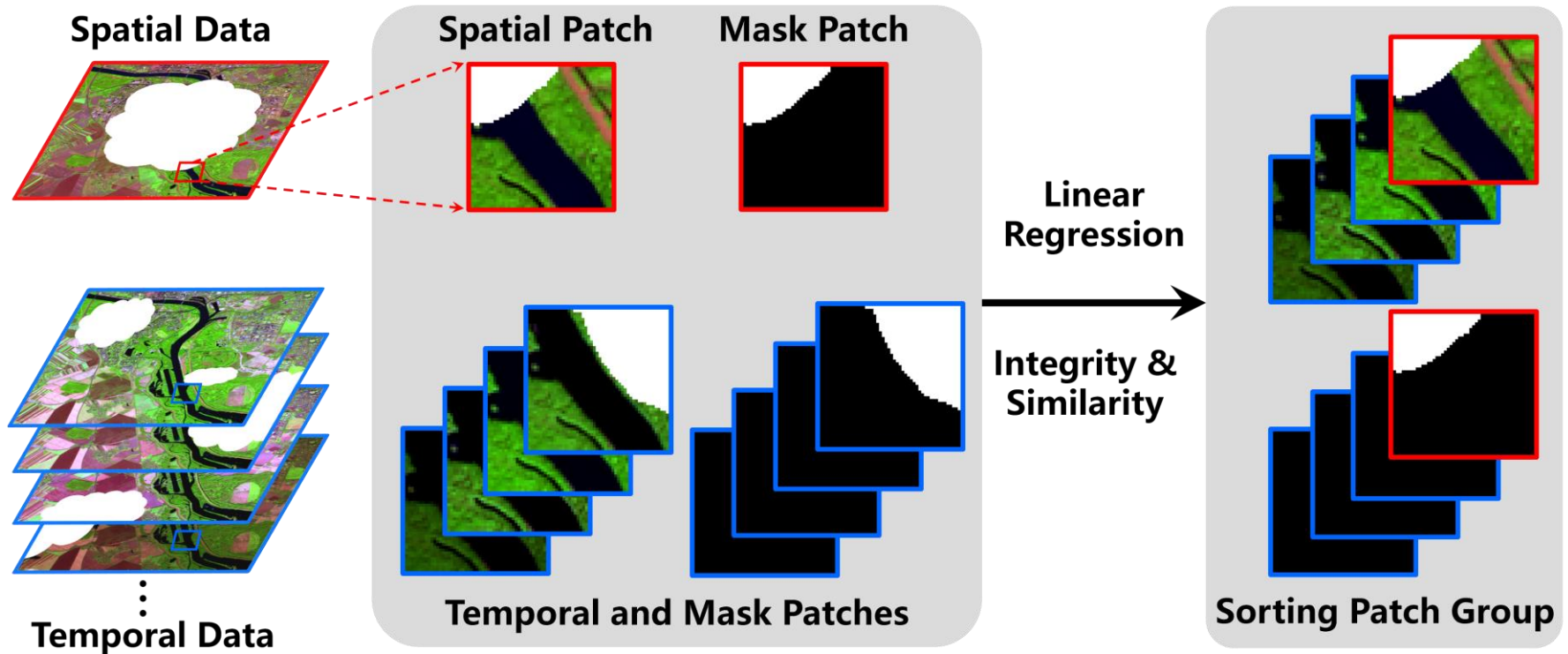
(1) Multi-Temporal Imagery **Cloud/Shadow Detection**



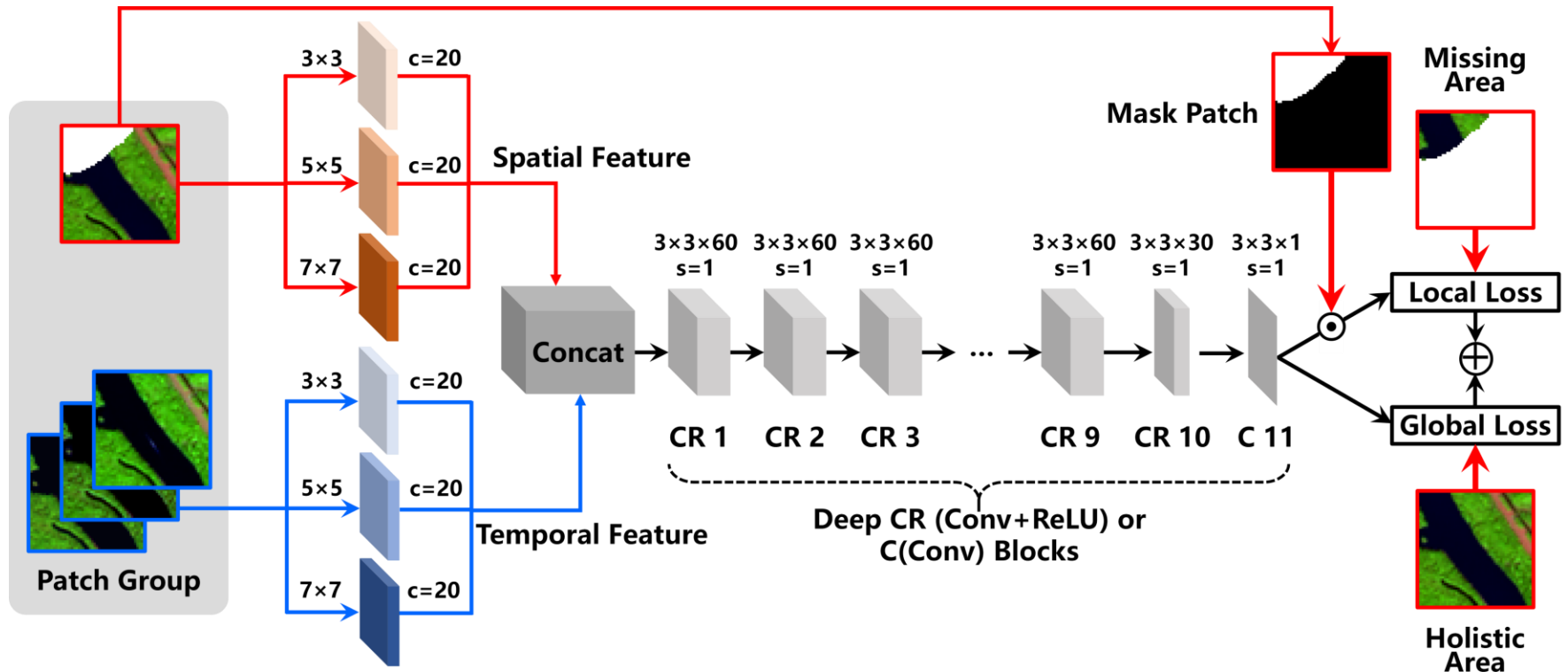
Obtaining Accurate **Location** of Cloud/Shadow for Reconstructing

[1] **Fmask 4.0**: S. Qiu *et al.*, RSE, 2019.

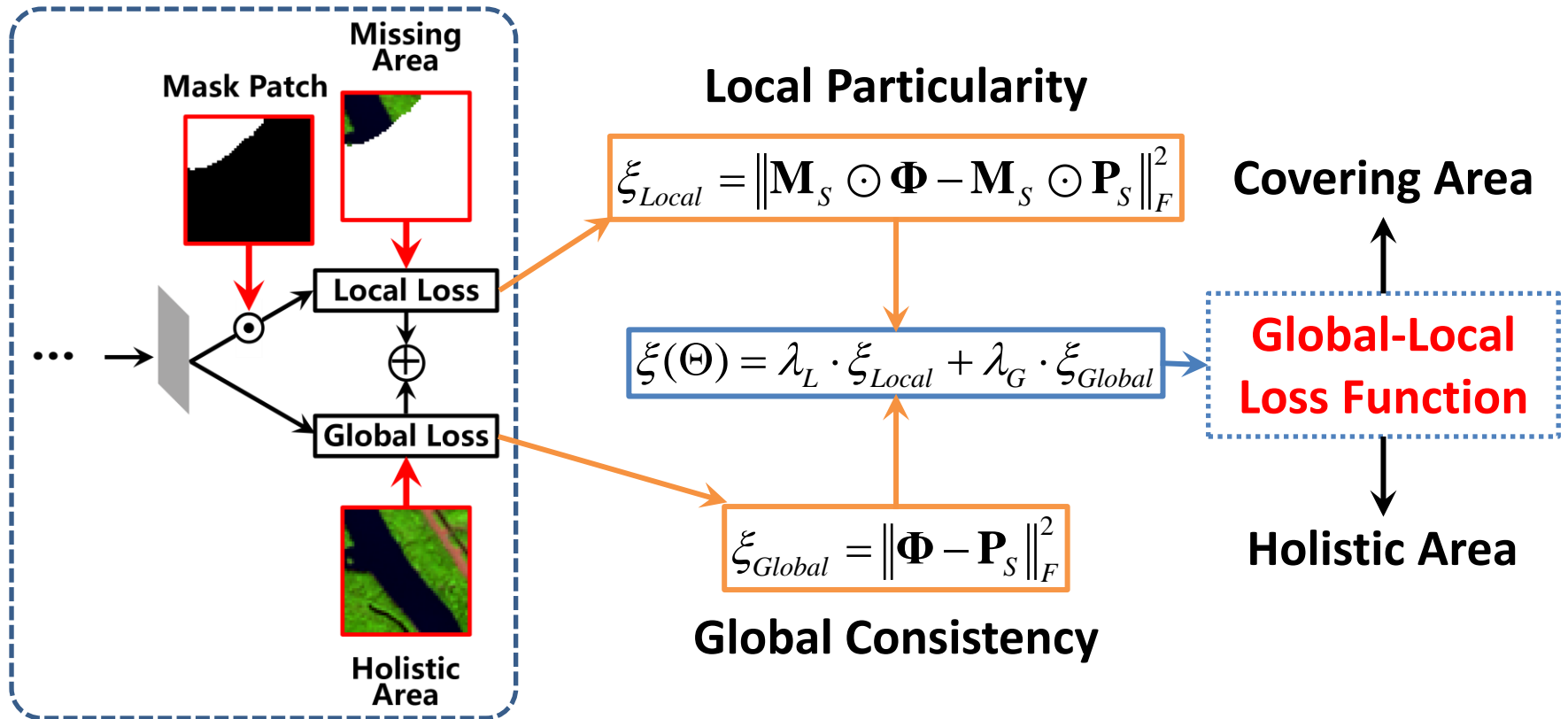
[2] **MSCFF**: Z. Li *et al.*, ISPRS, 2019.

(2) Multi-Temporal **Patch Group** Stacking and Sorting

Building **Spatio-Temporal Patch Group** With High Correlation

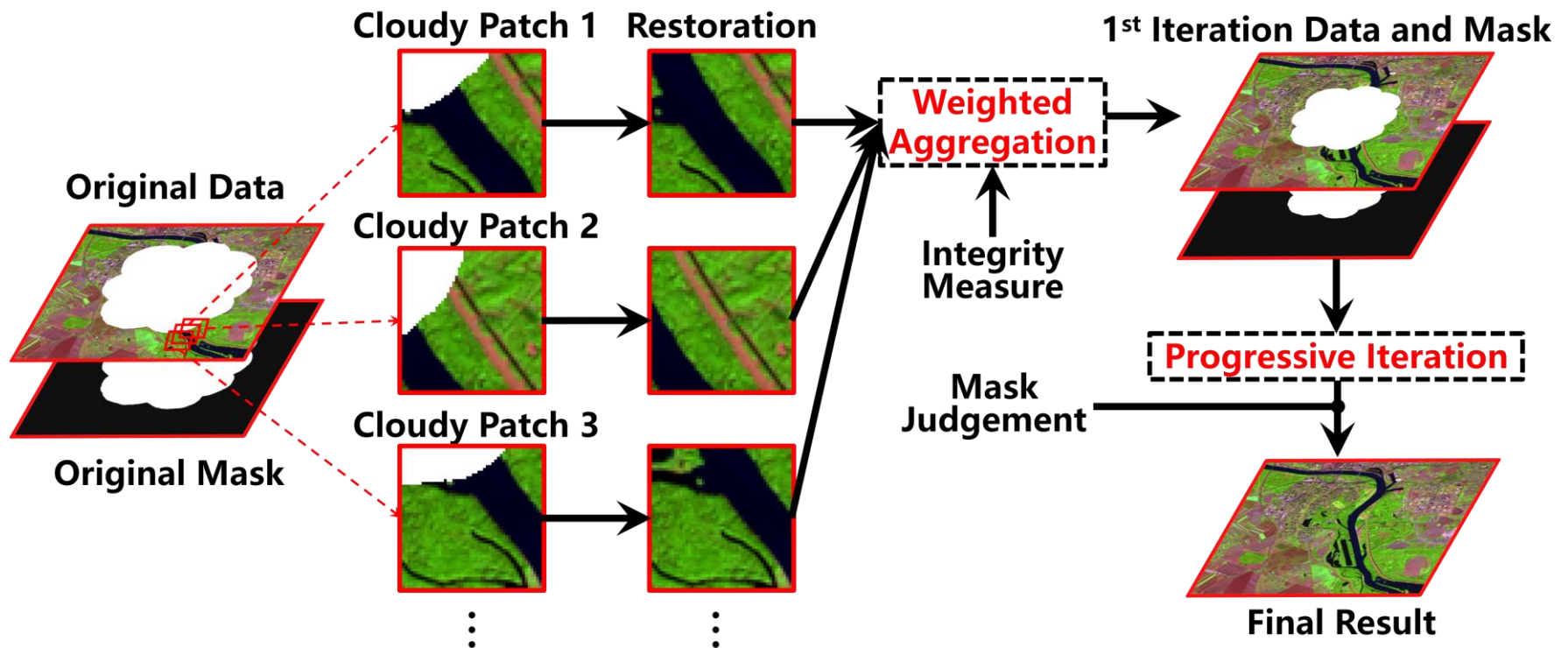
(3) Spatio-Temporal Patch Group **Recovering Model**

Reconstructing Spatial Patch Covered by Cloud/Shadow

(3) Spatio-Temporal Patch Group **Recovering Model**

Considering **Global-Local Constraint** for Recovering Spatial Patch

(4) Weighted Aggregation and Progressive Iteration



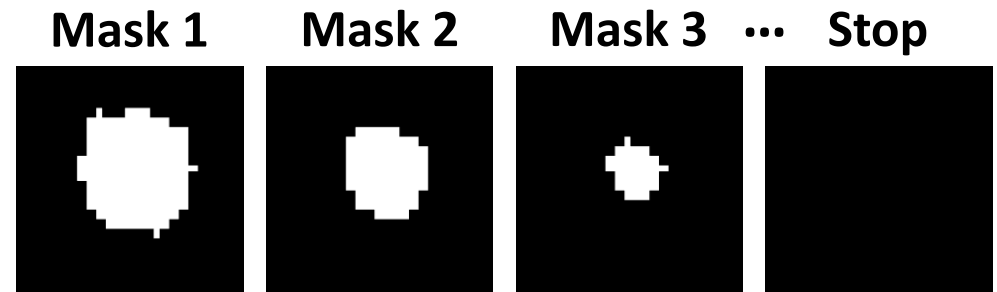
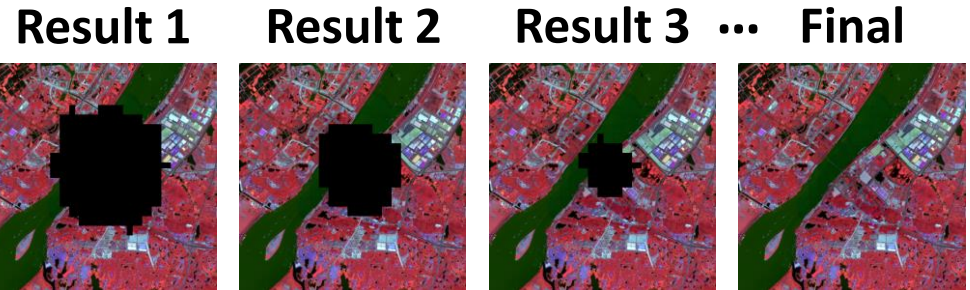
Reconstructing **Final Integral** Result Through **Multiple Restored Patches**

(4) **Weighted Aggregation** and **Progressive Iteration**

$$\mathbf{A}_S^1 = \frac{\sum_{i=1}^N \frac{1}{1 - I_S^i} \cdot \mathbf{R}_S}{\sum_{i=1}^N \frac{1}{1 - I_S^i}}$$

Regenerating **Integral Result**

$$\mathbf{A}_{M_S}^1 = \mathbf{A}_{M_S}^0 \cup \mathbf{M}_S^1 \cdots \cup \mathbf{M}_S^\eta$$

Regenerating **Integral Mask****Weighted Aggregation****Progressive Iteration**

Larger Integrity I_S → More Believable Spatial information

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1 Background

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3 Experiments

4 Summary

Simulated Experiments: Case 1 (Sentinel-2, Single Temporal)



(a) B05, B8A, B12



(b) Simulated Cloudy



(c) Temporal data



(d) STS

By Zhang et al., TGRS, 2018



(e) WLR

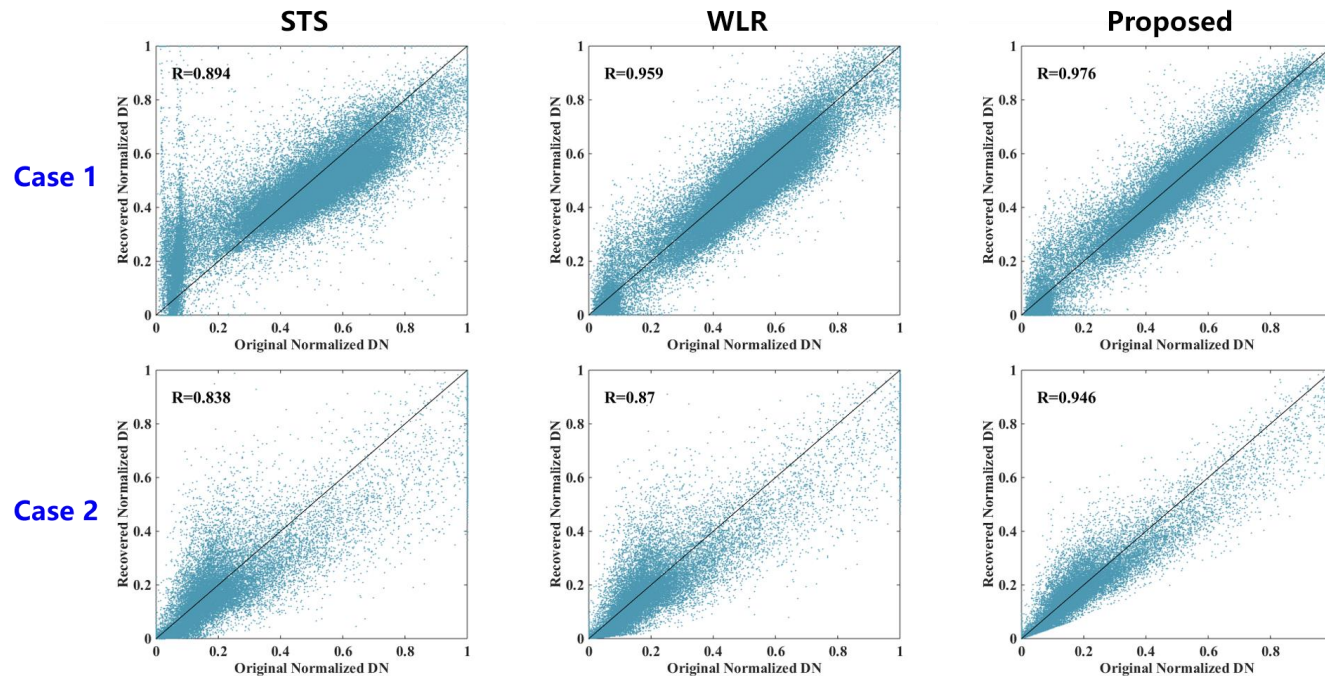
By Zeng et al., RSE, 2013



(f) Proposed

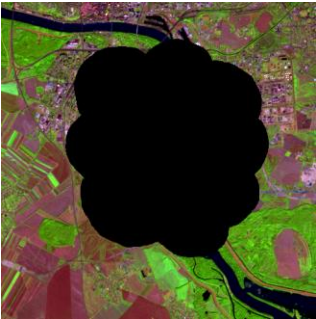
Simulated Experiments: **Index Evaluation**

Index	Ideal	Case 1				Case 2			
		Linear	WLR	STS	Proposed	Linear	WLR	STS	Proposed
CC	1	0.9270	0.9617	0.9395	0.9881	0.9689	0.9859	0.9772	0.9937
SSIM	1	0.7834	0.9083	0.8498	0.9414	0.9262	0.9623	0.9486	0.9814
RMSE	0	0.0843	0.0510	0.0722	0.0298	0.0486	0.0317	0.0403	0.0213



Simulated Experiments: Case 3 (Sentinel-2, Multi-Temporal)

2018.09.05



2018.09.15



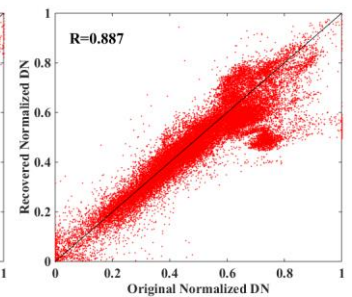
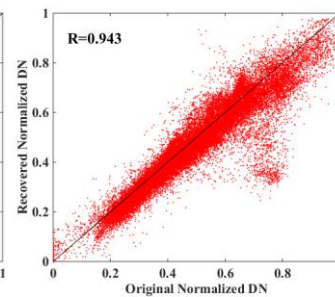
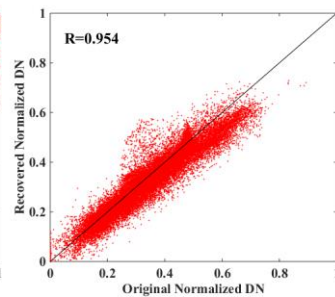
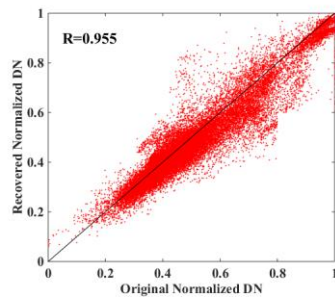
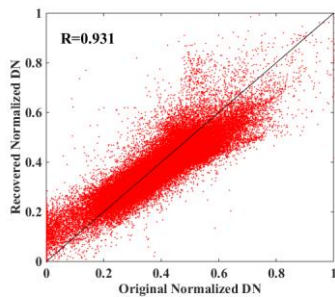
2018.09.20



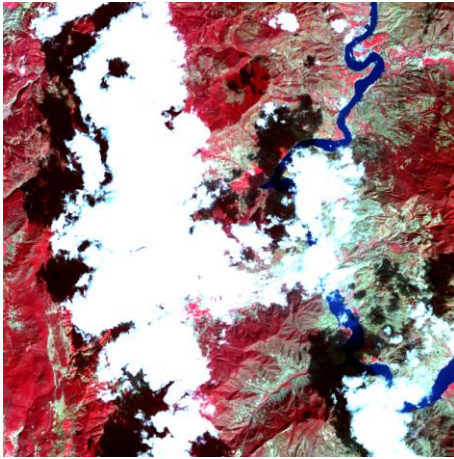
2018.10.05



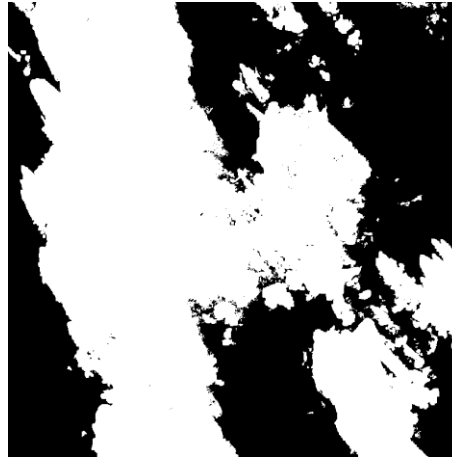
2018.10.15



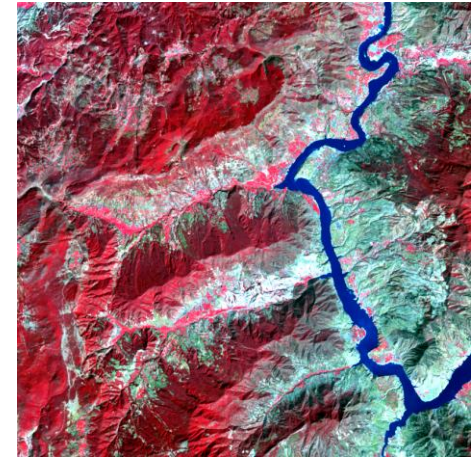
Real Experiments: (Sentinel-2 MSI, Single Temporal Data)



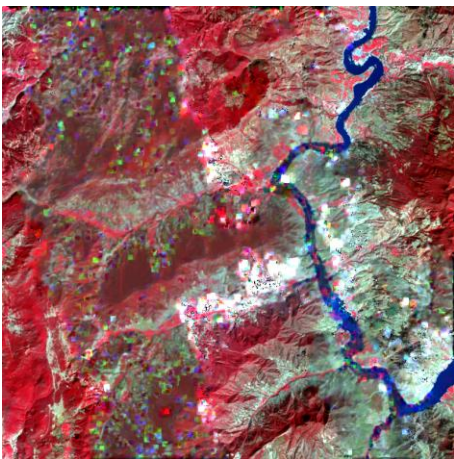
(a) B05, B8A, B12



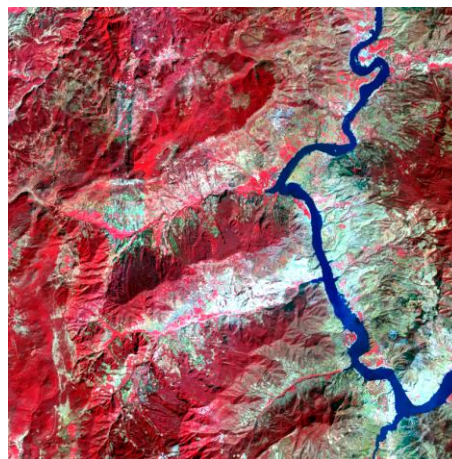
(b) Cloud Mask



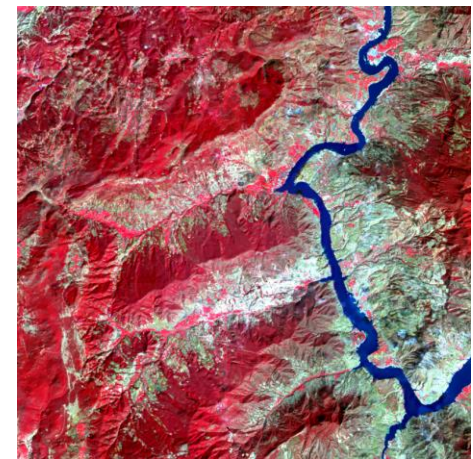
(c) Temporal



(d) STS

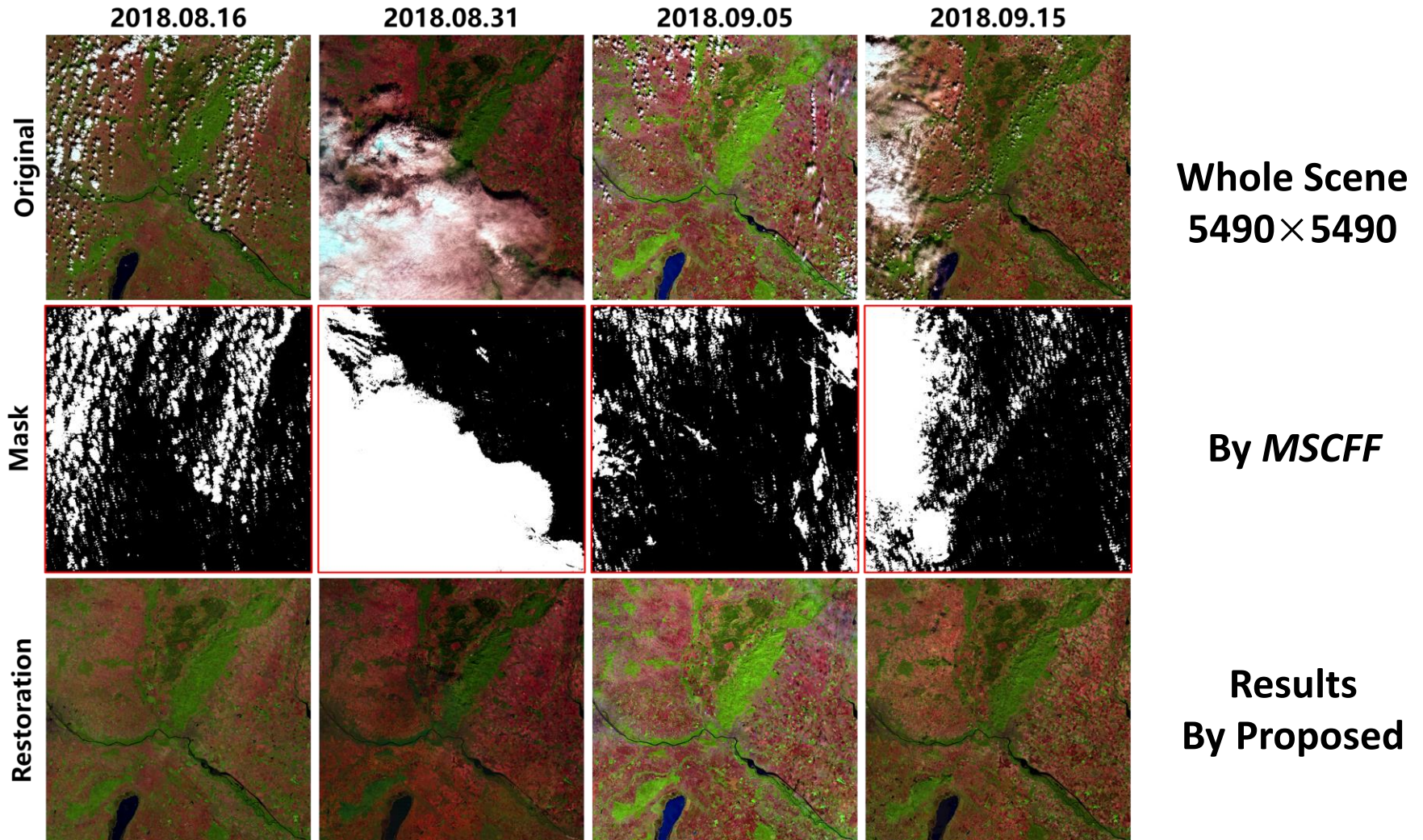


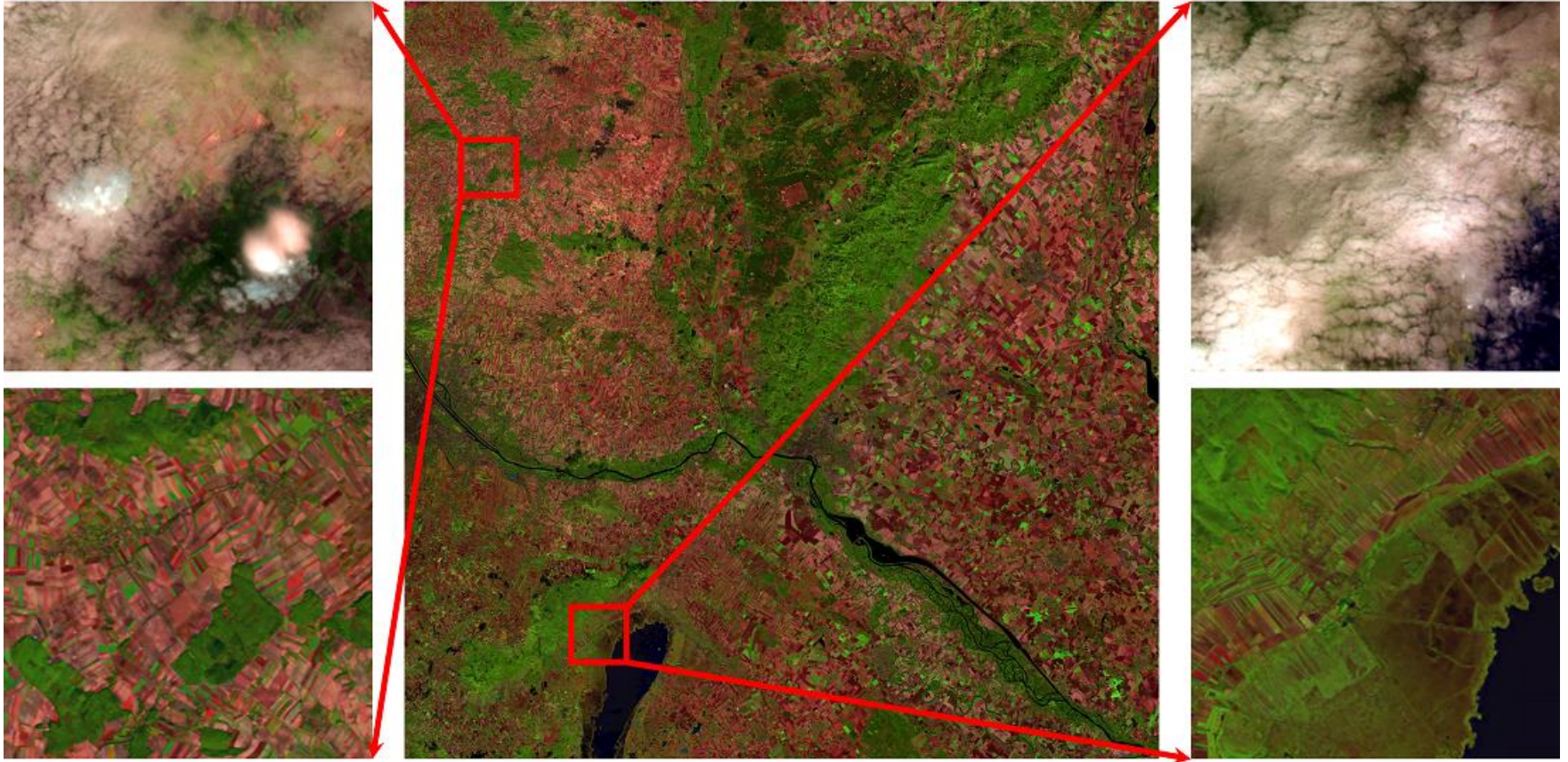
(e) WLR



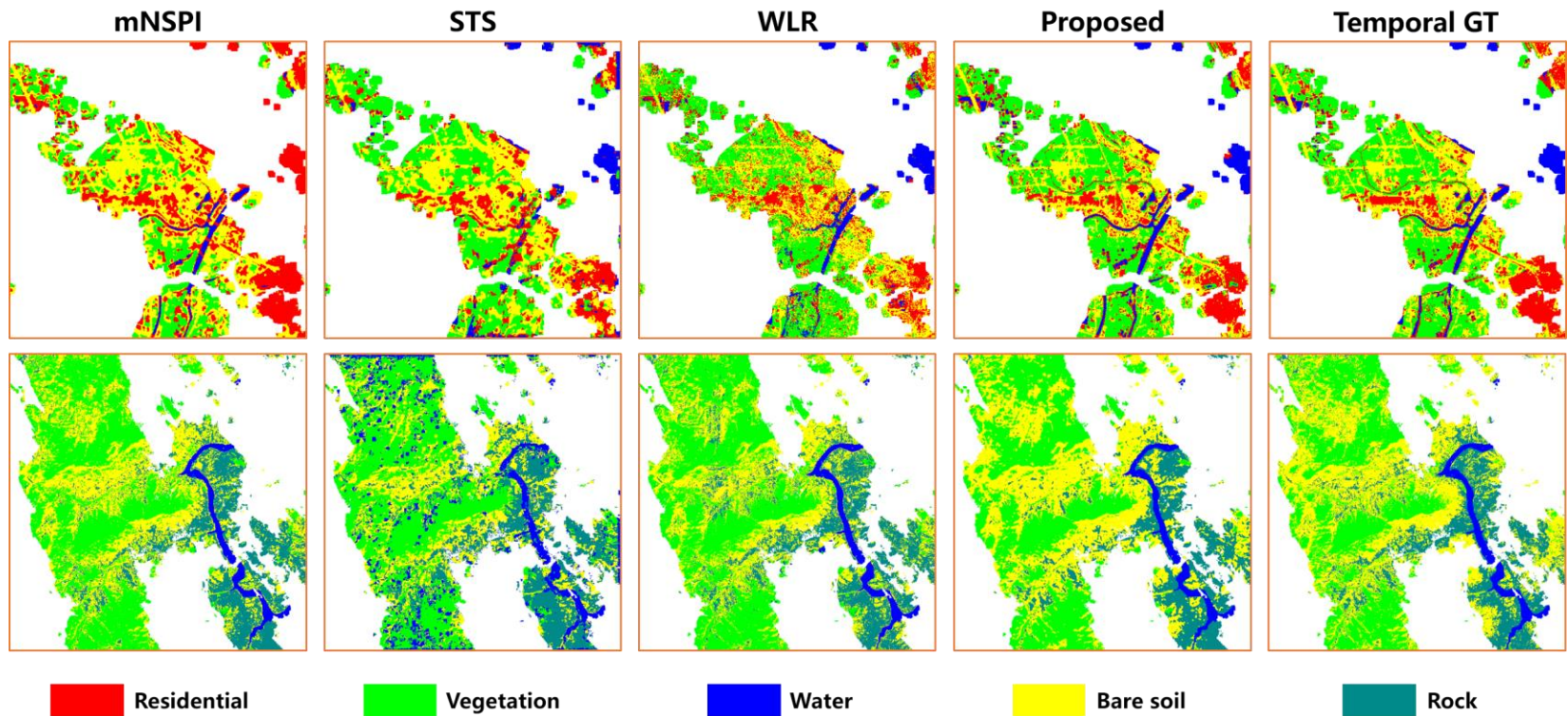
(f) Proposed

Real Experiments: (Sentinel-2 MSI, Multi-Temporal Data)



Real Experiments: (Multi-temporal, Large-Scale Scenarios)

Global and Two Local Amplification Results In 2018.09.15

Discussion: **Validation** of the Restoring Results

	Linear	STS	WLR	Proposed
Data 1	74.4%/0.628	69.5%/0.587	76.8%/0.646	81.3%/0.695
Data 2	76.8%/0.647	64.5%/0.549	77.3%/0.652	79.4%/0.683

Supervised Land Cover Evaluation Index (OA/Kappa)

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1 Background

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4 Summary

Conclusions

Spatio-Temporal Patch Group Cloud Removal Framework

- Cloud and Shadow Detection
- Multi-Temporal Patch Group Stacking
- Spatio-Temporal Recovering Model
- Weighted Aggregation and Progressive Iteration

Deficiencies and Future Works

- Mask Type (Thick Cloud, Thin Cloud, and Shadow)
- Patch Group (Patch Size, Aggregating Weights, Global-Local...)
- Spatial Self-Reconstructing under no Temporal Information
- For Other Satellite Products Recovering (AOD, LST, NDVI...)



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Released Codes

Thanks!

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www.escience.cn/people/qz/index.html