S2A: Wasserstein GAN with Spatio-Spectral Laplacian Attention for Multi-Spectral Band Synthesis

CVPR-EarthVision 2020




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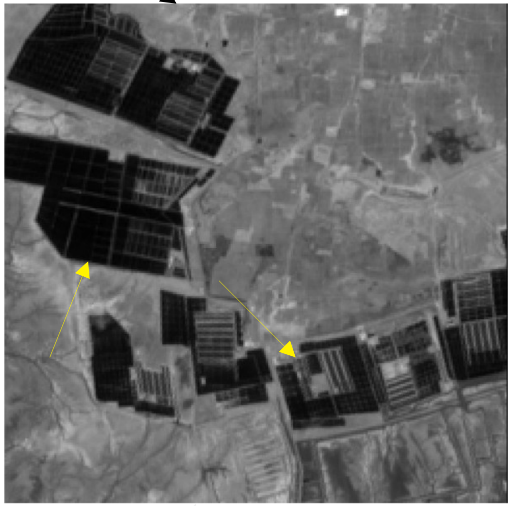
Space Applications Centre

Indian Space Research Organisation

Super-resolution as conditional band synthesis

LR-SWIR

HR-SWIR



- Direct super-resolution is intractable.
- Lack necessary geometric attributes.

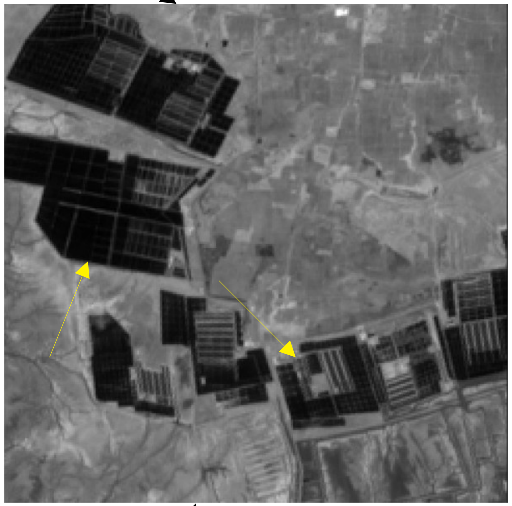
FCC: NIR (R), R (G), G(B)

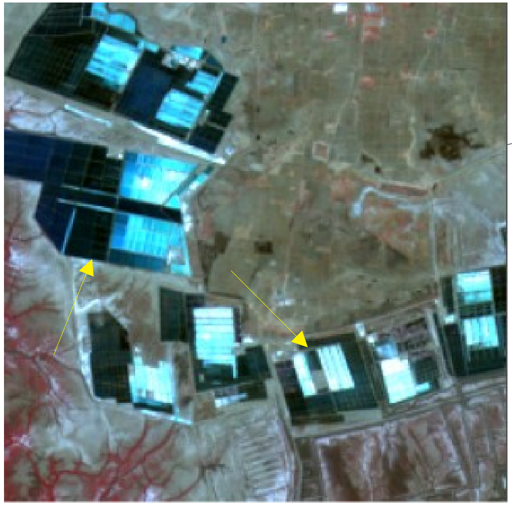
- Reformulate as conditional band synthesis.
- Geometry from existing high resolution bands: HR-NIR, R, G.
- Radiometry from corresponding low resolution band: LR-SWIR.

Super-resolution as conditional band synthesis

LR-SWIR

HR-SWIR





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Traditional Approach

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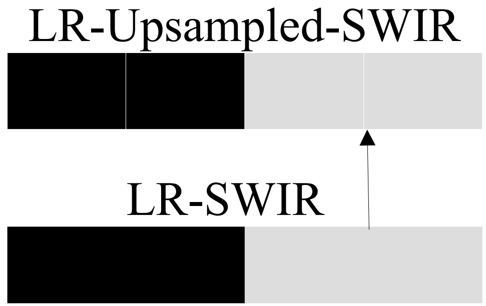

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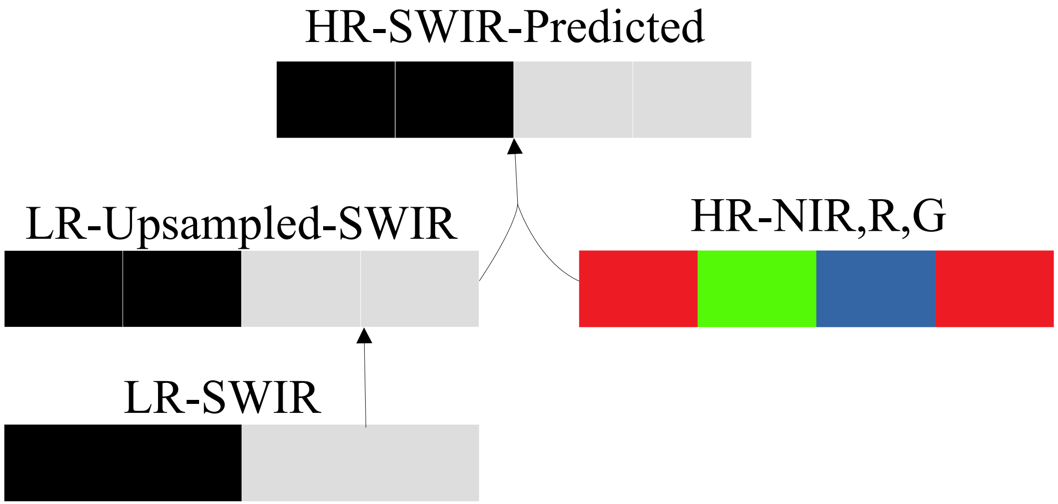

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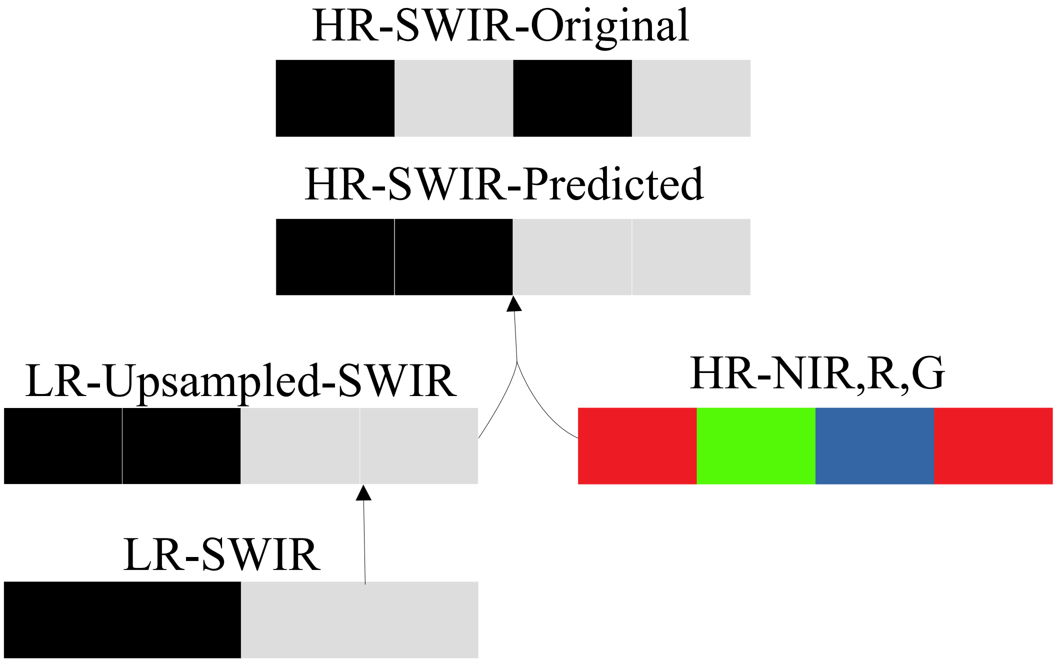

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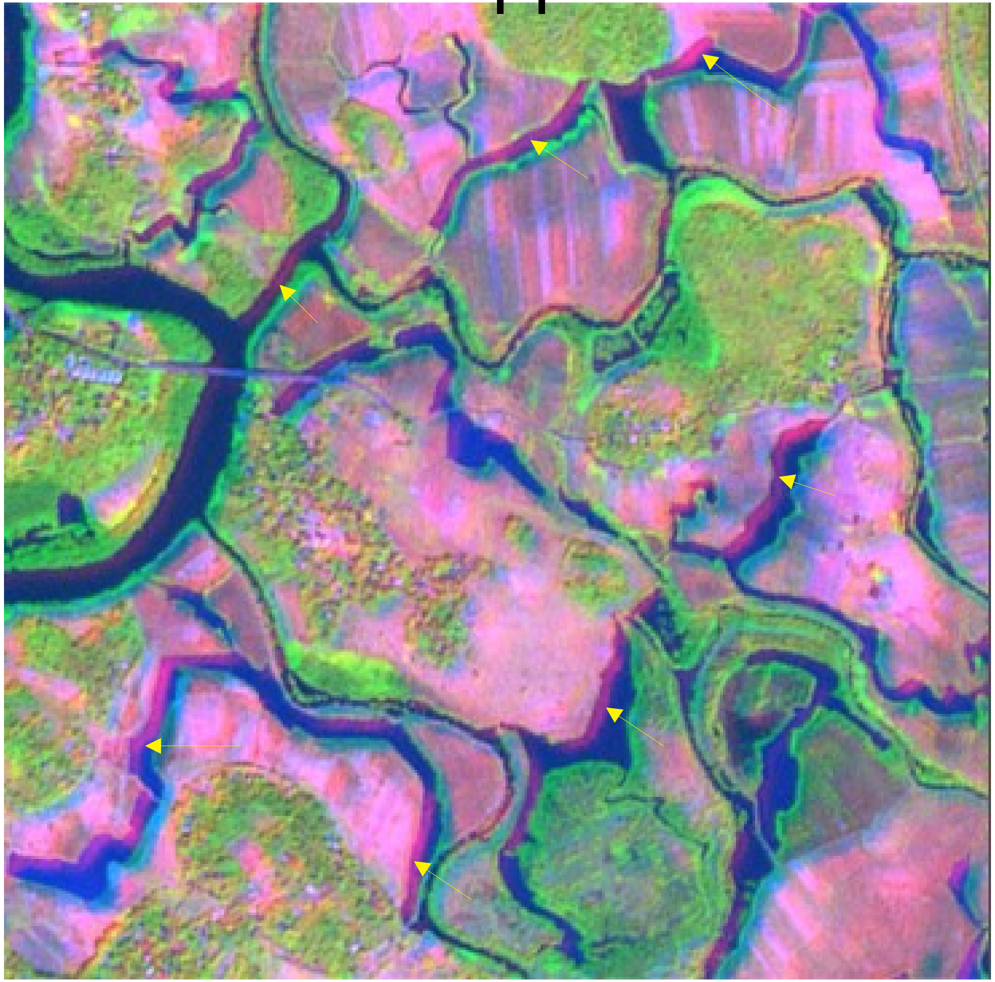
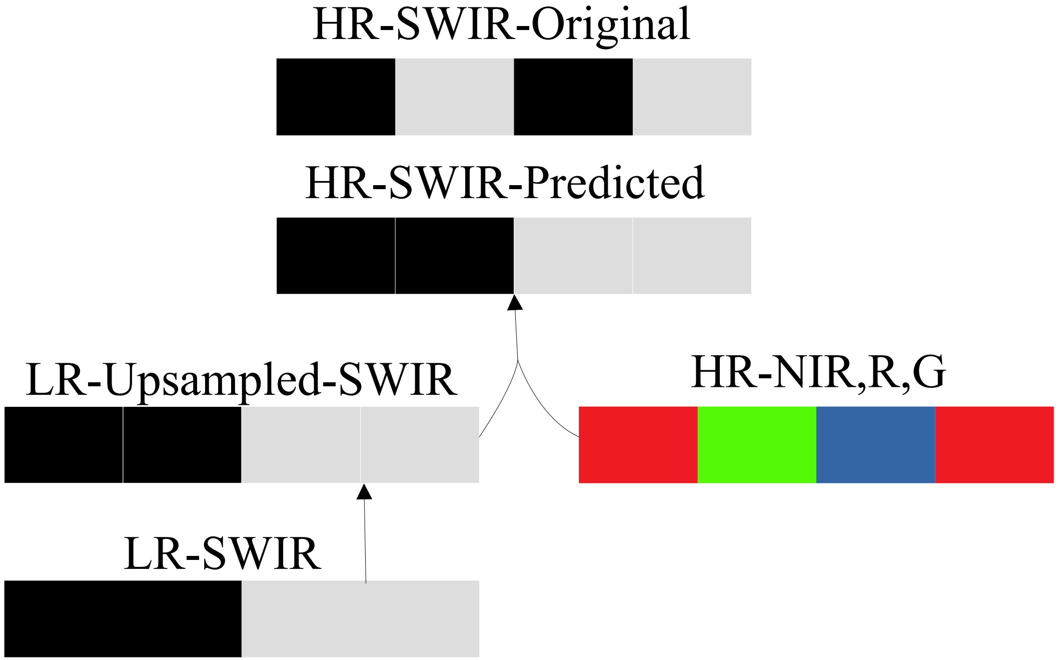


FCC: SWIR (R), NIR (G), Red (B)



Over dependence on upsampled coarse resolution band results in unpleasant artifacts.

- Geometric distortion
- Radiometric imbalance

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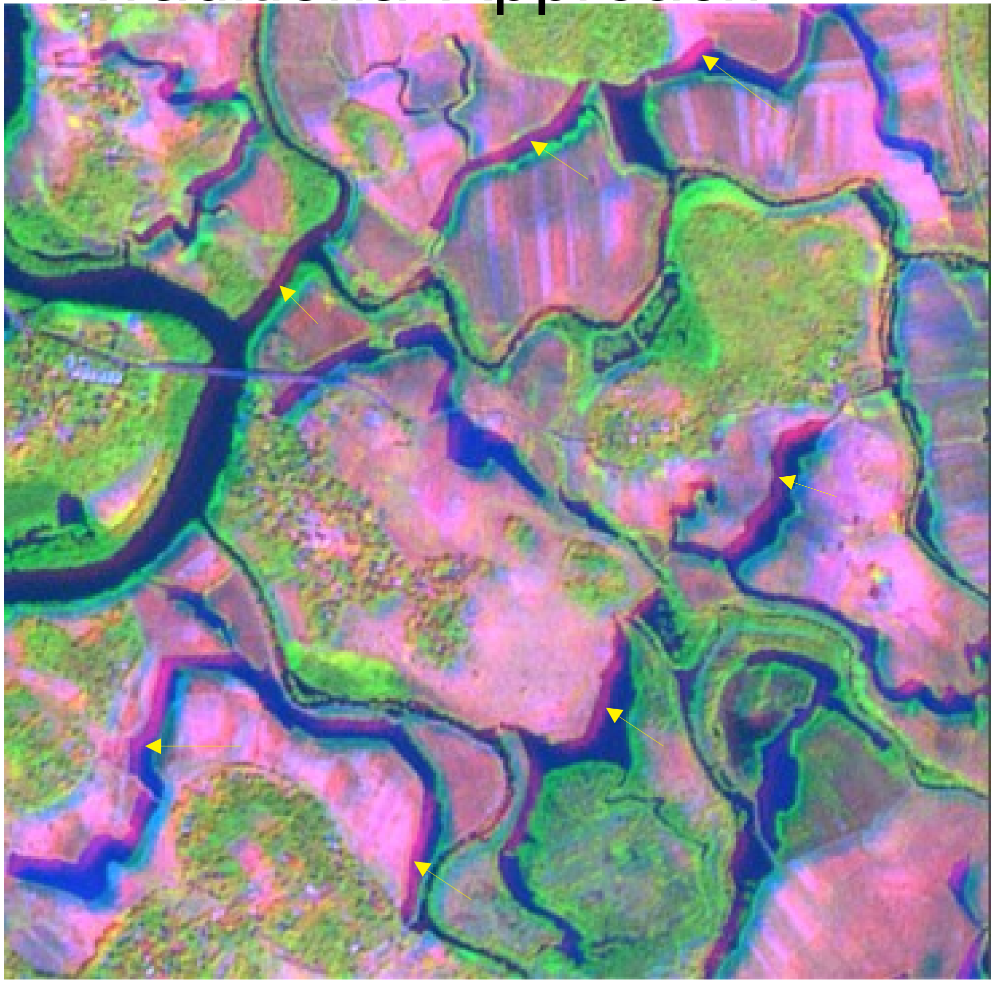

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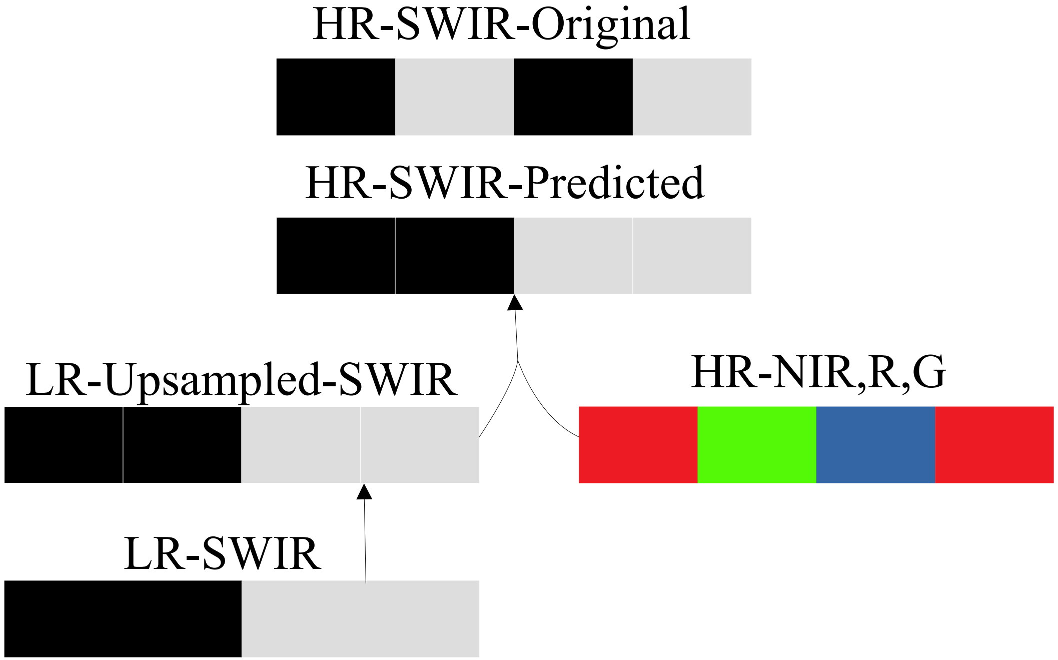

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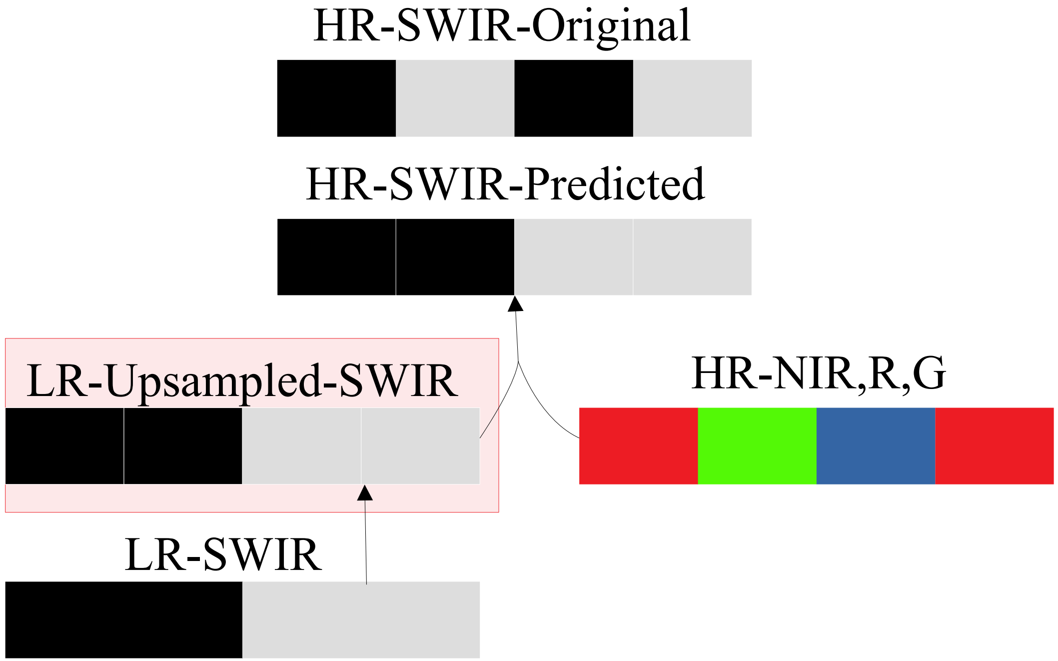

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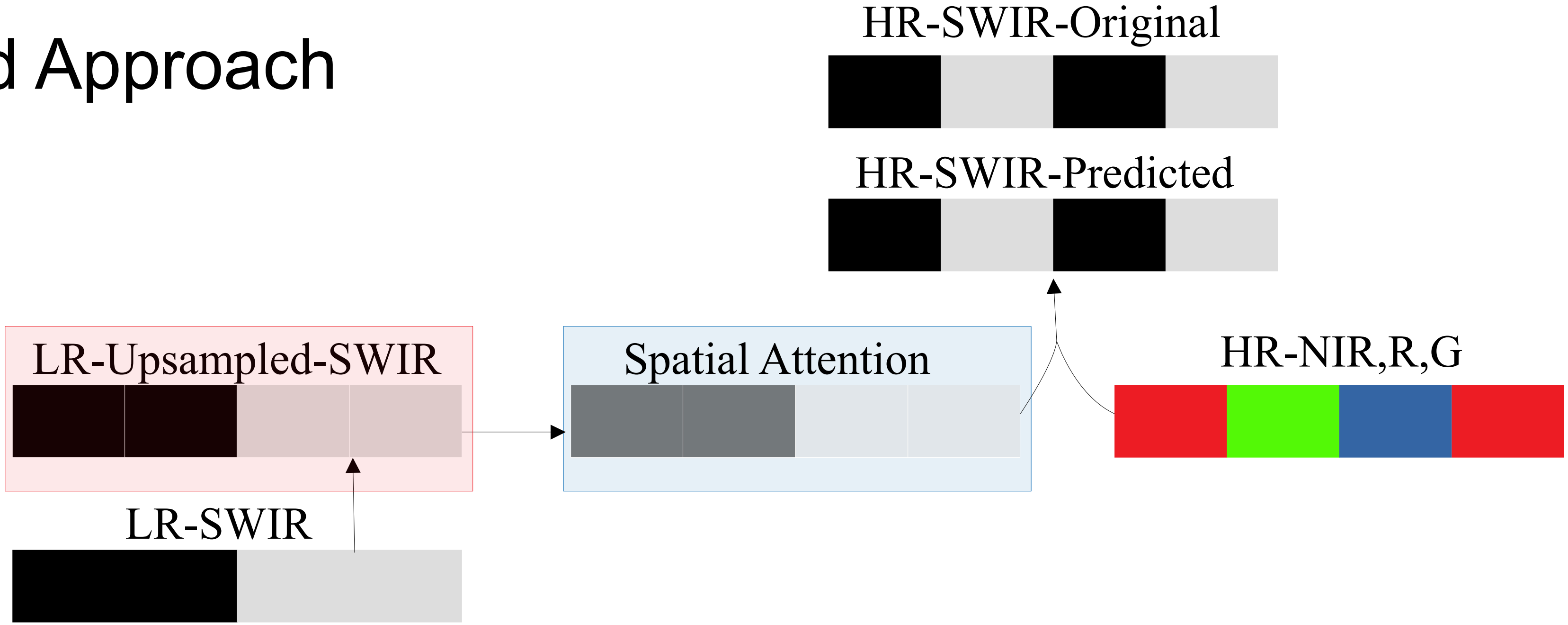
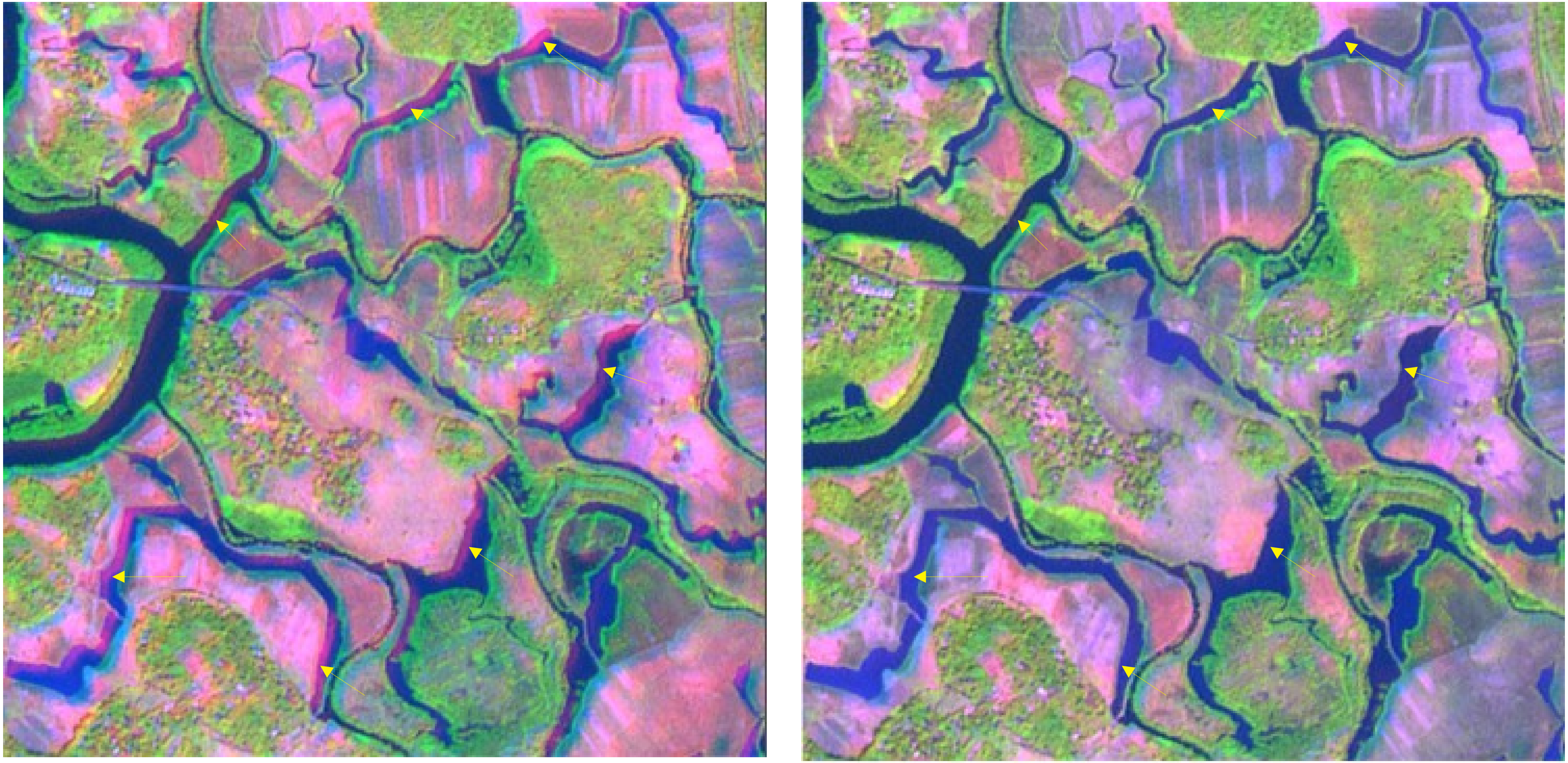
Proposed Approach



Over dependency on upsampled coarse resolution band can be suppressed by replacing it with spatial attention map.

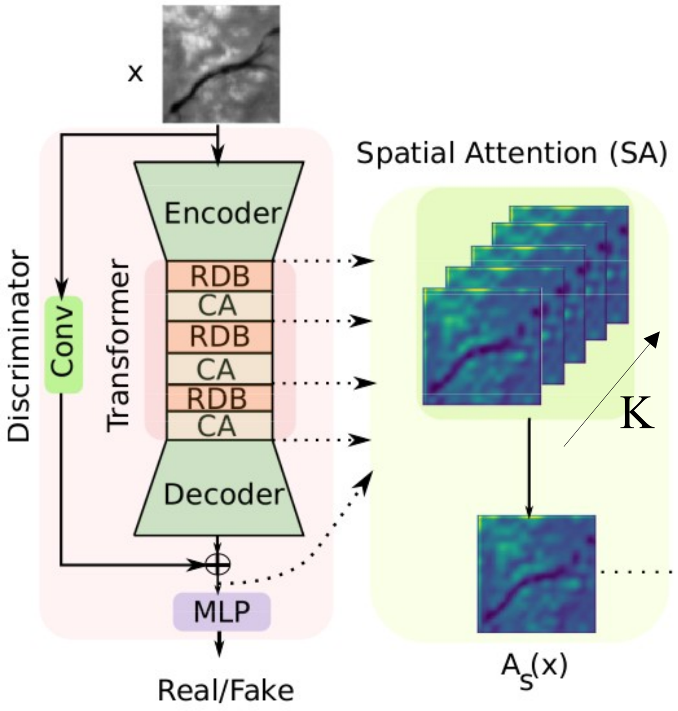
Traditional Approach

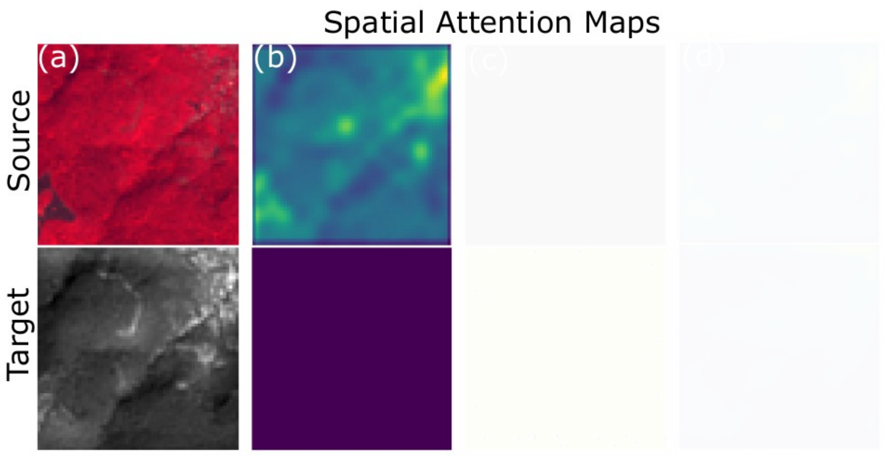
Proposed Approach



FCC: SWIR (R), NIR (G), Red (B)

Spatial Attention from Discriminator





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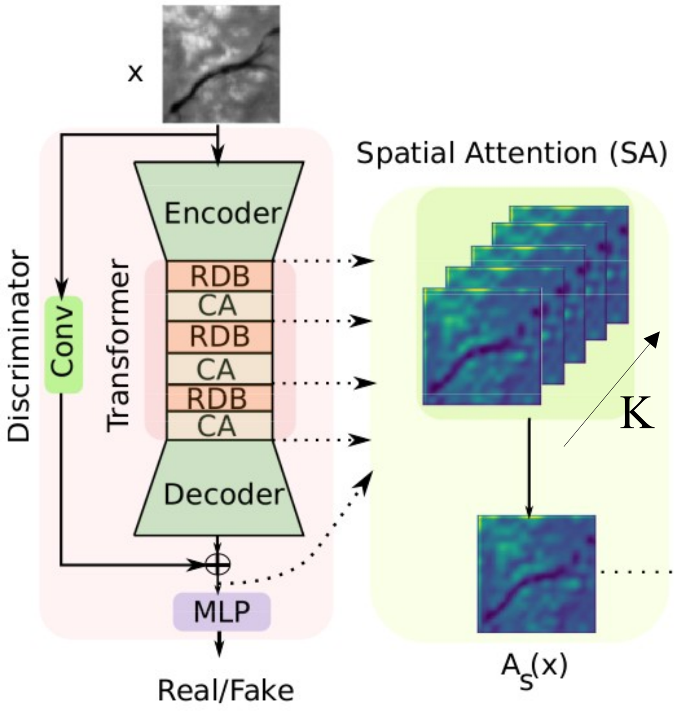

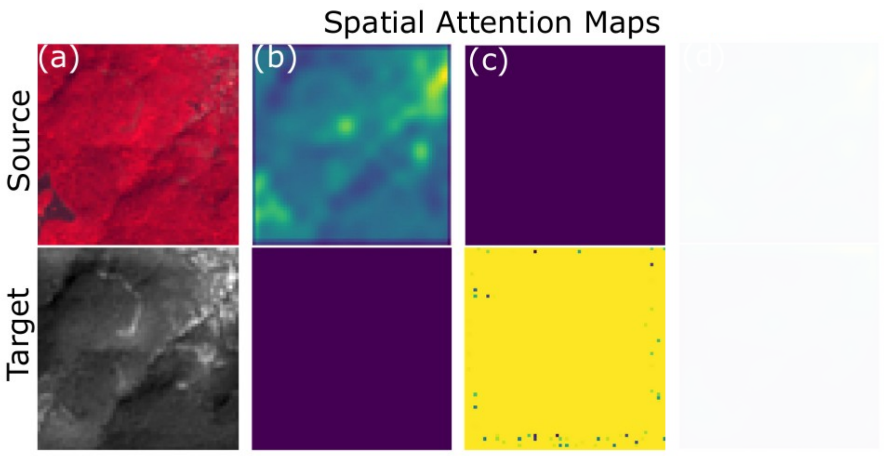

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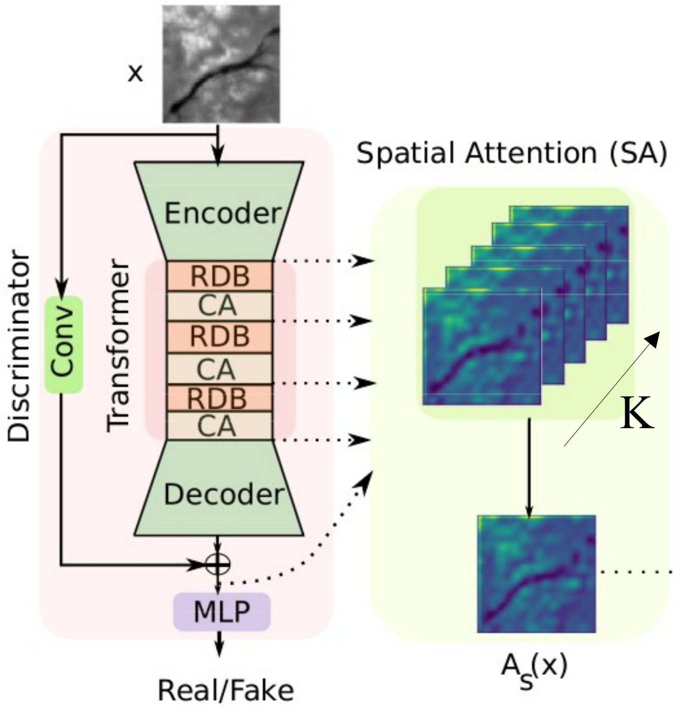
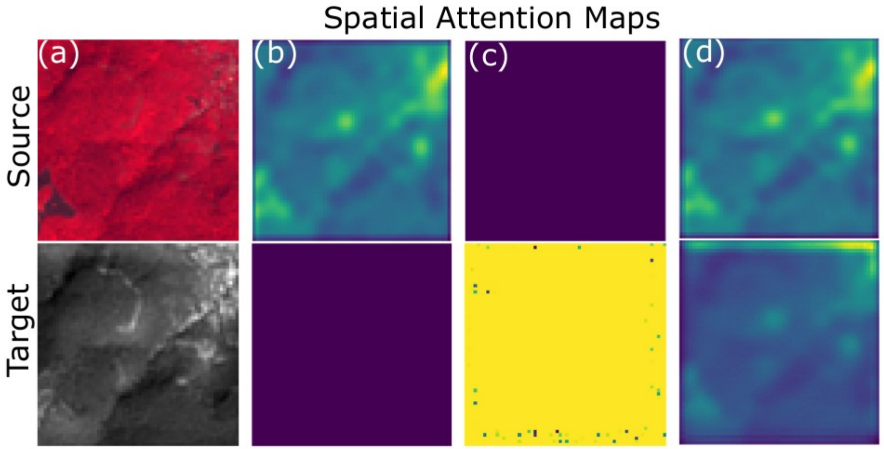




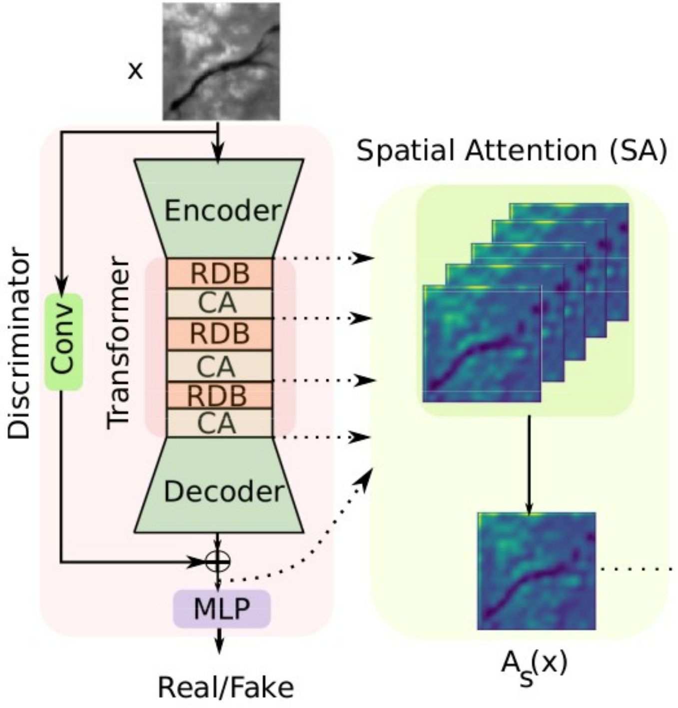
$$A_s(x) = \mathcal{N}\left(D_s(x)\right),$$

$$D_s(x) = \sum_{i=1}^{K} \mathcal{N}\left(\sum_{j=1}^{C} |A_{ij}(x)|\right)$$

Spatial Attention from Discriminator

Spatial Attention Loss

$$\mathscr{L}_{sa} = \mathbb{E}_{\hat{x}\sim\mathbb{P}_{\hat{x}},\, y\sim\mathbb{P}_y}\left[\|A_s(\hat{x}) - A_s(y)\|_2^2\right]$$



Domain Adaptation Loss

$$\mathscr{L}_{da} = \mathbb{E}_{\tilde{y}\sim\mathbb{P}_{\tilde{y}},\, y\sim\mathbb{P}_y}\left[\|A_s(\tilde{y}) - A_s(y)\|_2^2\right]$$

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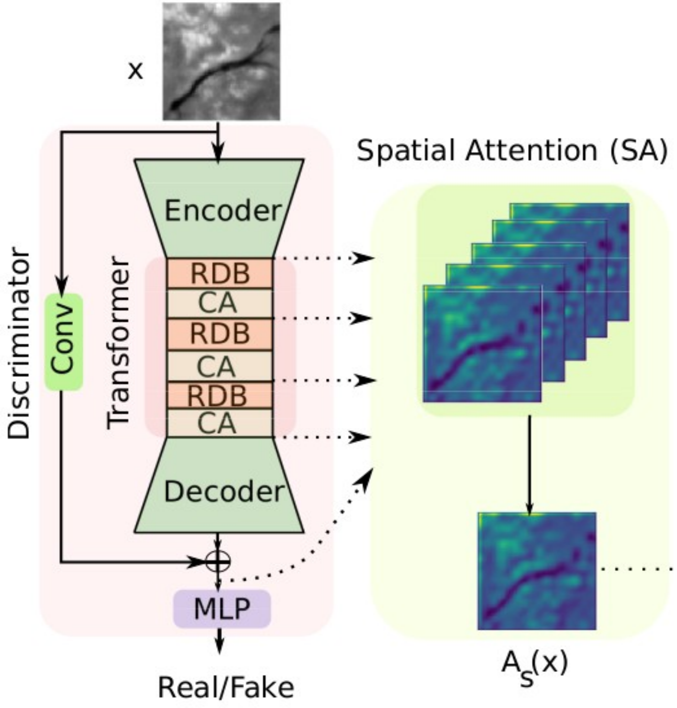

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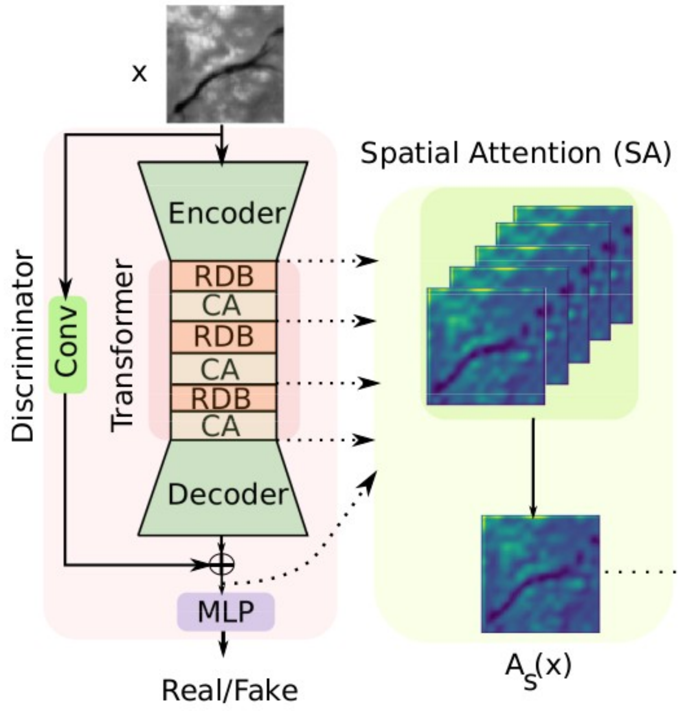
Discriminator Objective

$$\min_D \mathbb{E}_{\hat{x}\sim\mathbb{P}_{\hat{x}}}[D(\hat{x})] - \mathbb{E}_{x\sim\mathbb{P}_x}[D(x)]$$
$$+ \lambda_{gp}\mathbb{E}_{\tilde{x}\sim\mathbb{P}_{\tilde{x}}}\left[(\|\nabla_{\tilde{x}} D(\tilde{x})\|_2 - 1)^2\right]$$
$$+ \lambda_{sa}\mathcal{L}_{sa} + \lambda_{da}\mathcal{L}_{da},$$

Spatial Attention from Discriminator



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$$\mathscr{L}_{sa} = \mathbb{E}_{\hat{x}\sim\mathbb{P}_{\hat{x}}, y\sim\mathbb{P}_y}\left[\|A_s(\hat{x}) - A_s(y)\|_2^2\right]$$

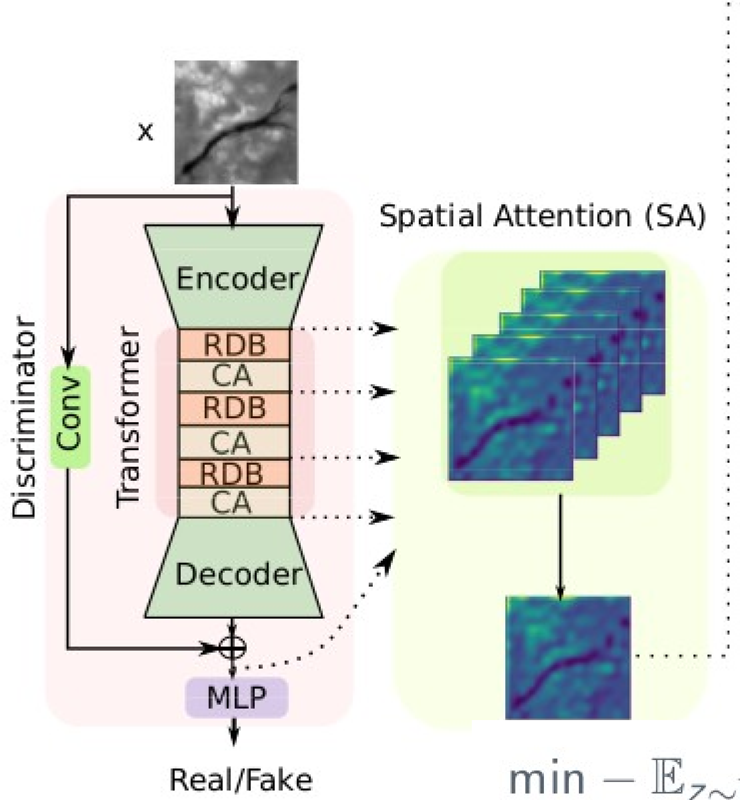
Domain Adaptation Loss

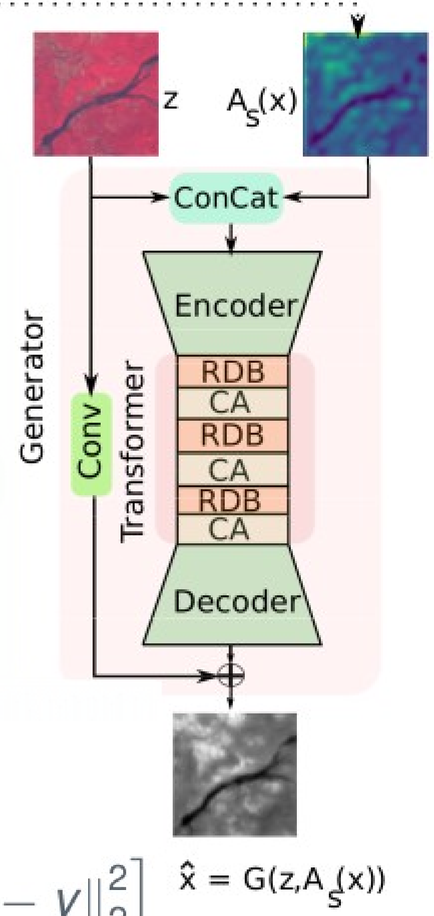
$$\mathscr{L}_{da} = \mathbb{E}_{\tilde{y}\sim\mathbb{P}_{\tilde{y}}, y\sim\mathbb{P}_y}\left[\|A_s(\tilde{y}) - A_s(y)\|_2^2\right]$$

Discriminator Objective

$$\min_D \mathbb{E}_{\hat{x}\sim\mathbb{P}_{\hat{x}}}[D(\hat{x})] - \mathbb{E}_{x\sim\mathbb{P}_x}[D(x)] + \lambda_{gp}\mathbb{E}_{\tilde{x}\sim\mathbb{P}_{\tilde{x}}}\left[(\|\nabla_{\tilde{x}} D(\tilde{x})\|_2 - 1)^2\right] + \lambda_{sa}\mathscr{L}_{sa} + \lambda_{da}\mathscr{L}_{da},$$

Spatial Attention from Discriminator

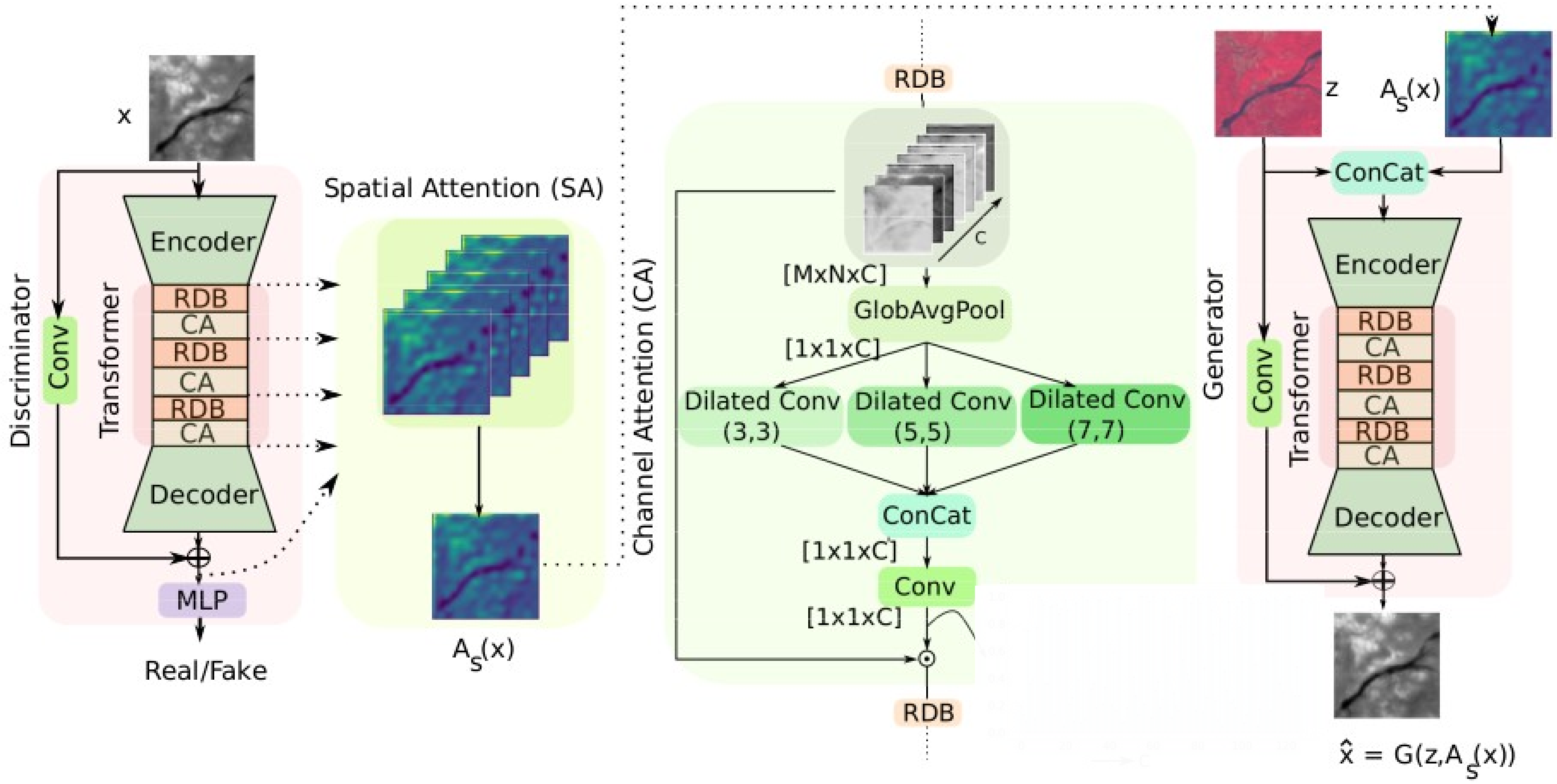




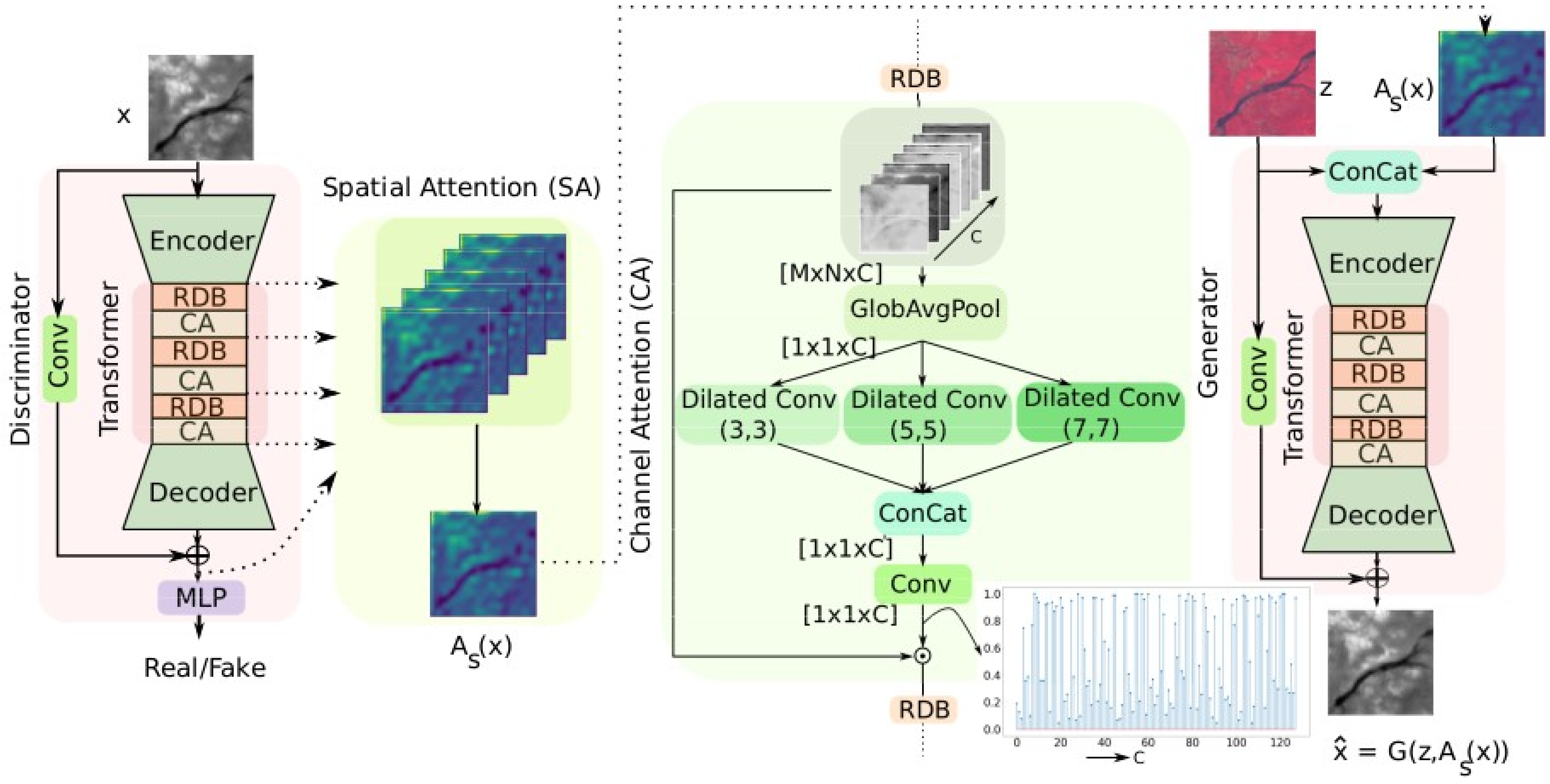
Generator Objective

$$\min_{G} -\mathbb{E}_{z\sim\mathbb{P}_s,\tilde{y}\sim\mathbb{P}_{\tilde{y}}}\left[D(G(z,A_s(\tilde{y})))\right]$$
$$+\lambda_p\mathbb{E}_{z\sim\mathbb{P}_s,\tilde{y}\sim\mathbb{P}_{\tilde{y}},y\sim\mathbb{P}_y}\left[\|G(z,A_s(\tilde{y}))-y\|_2^2\right]$$

Spatio-Spectral Laplacian Attention

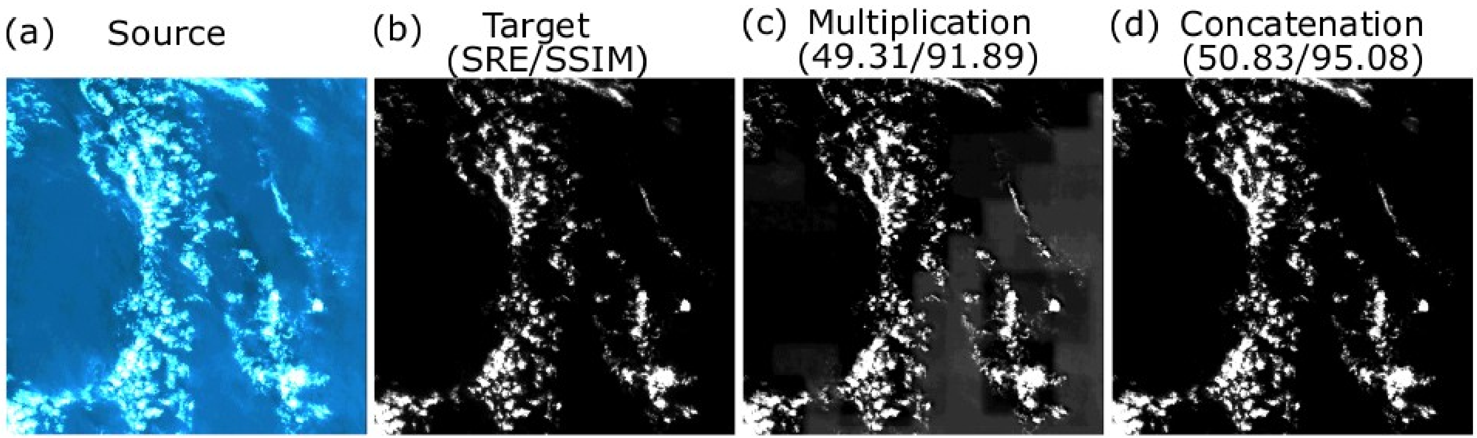


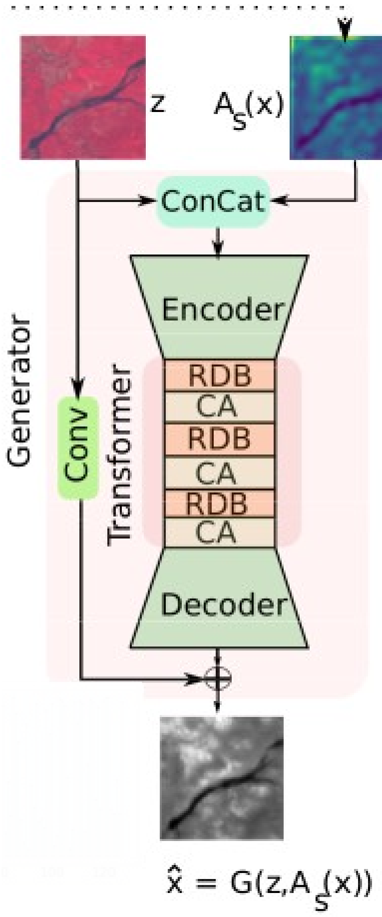
Spatio-Spectral Laplacian Attention



Spectral attention coefficients

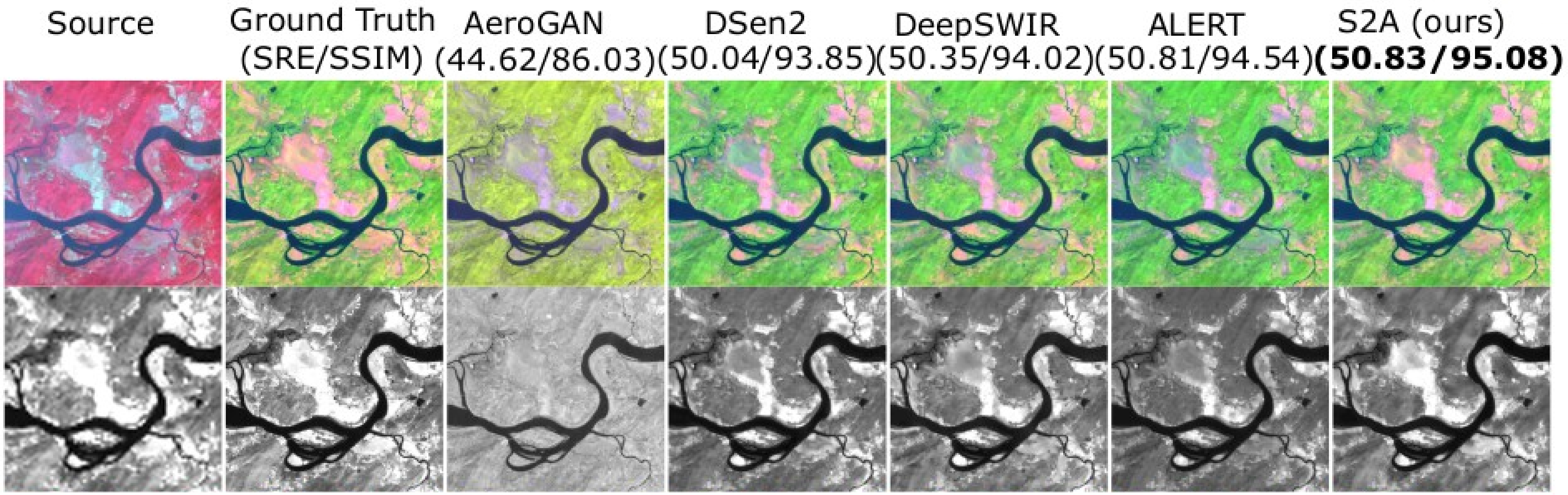
Combining Spatial Attention with Source Bands



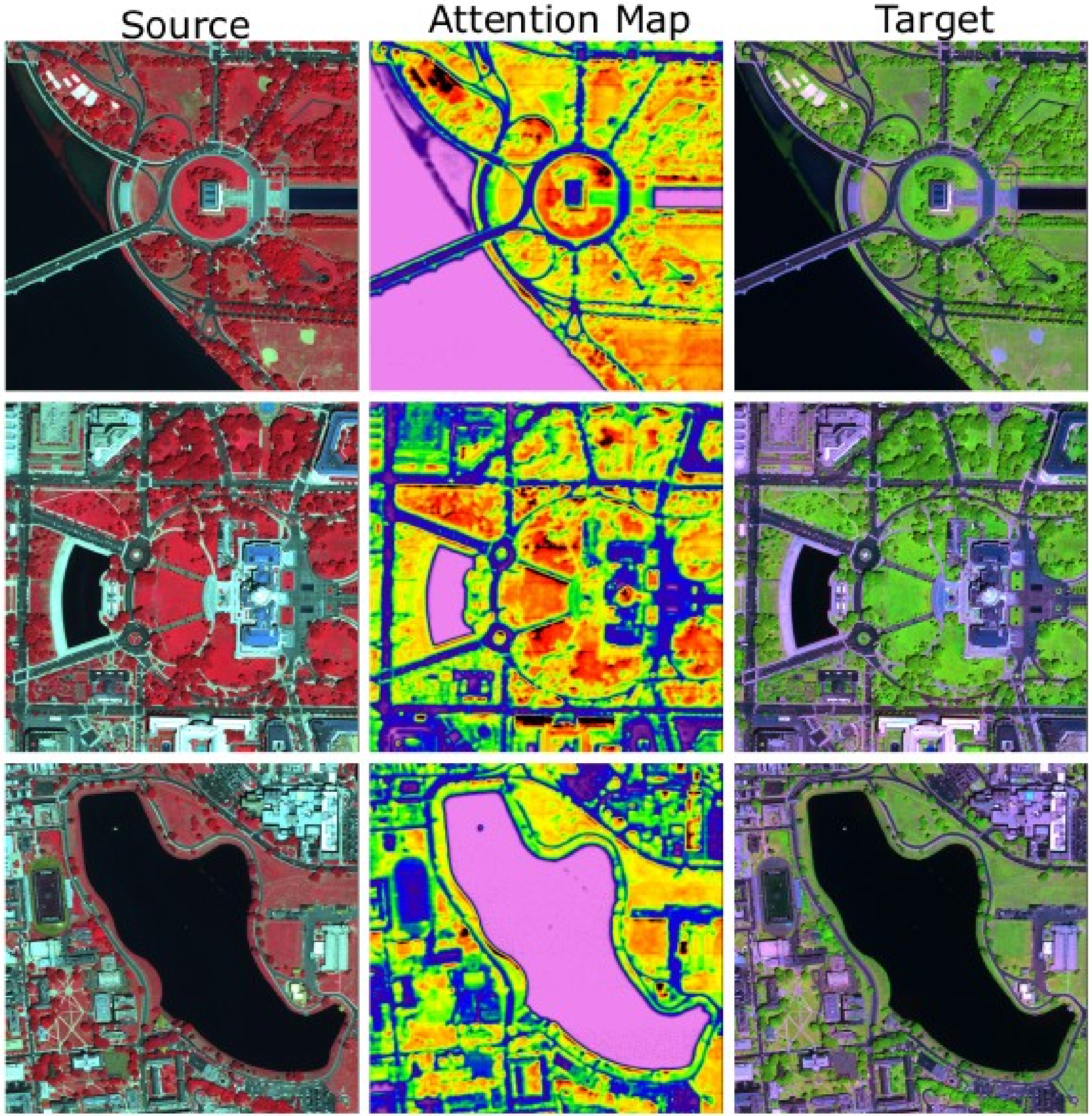


Multiplication:

- Attention module latches on to bright targets.
- Synthesized band contains blocky artifacts.

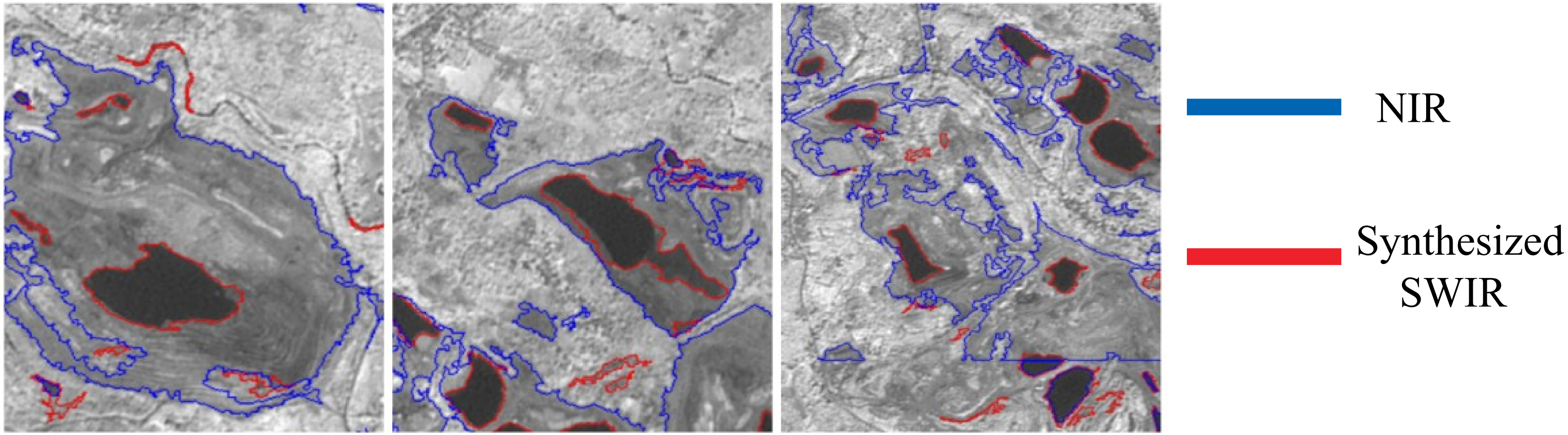


Method	RMSE	SSIM(%)	SRE(dB)	PSNR(dB)	SAM(deg)
AeroGAN [31]	21.62	86.03	44.62	36.50	12.15
DSen2 [21]	14.14	93.85	50.04	41.94	7.88
DeepSWIR [33]	13.75	94.02	50.35	42.27	7.66
ALERT [32]	12.97	94.54	50.81	42.80	7.48
S2A (ours)	11.74	95.08	50.83	42.76	6.87



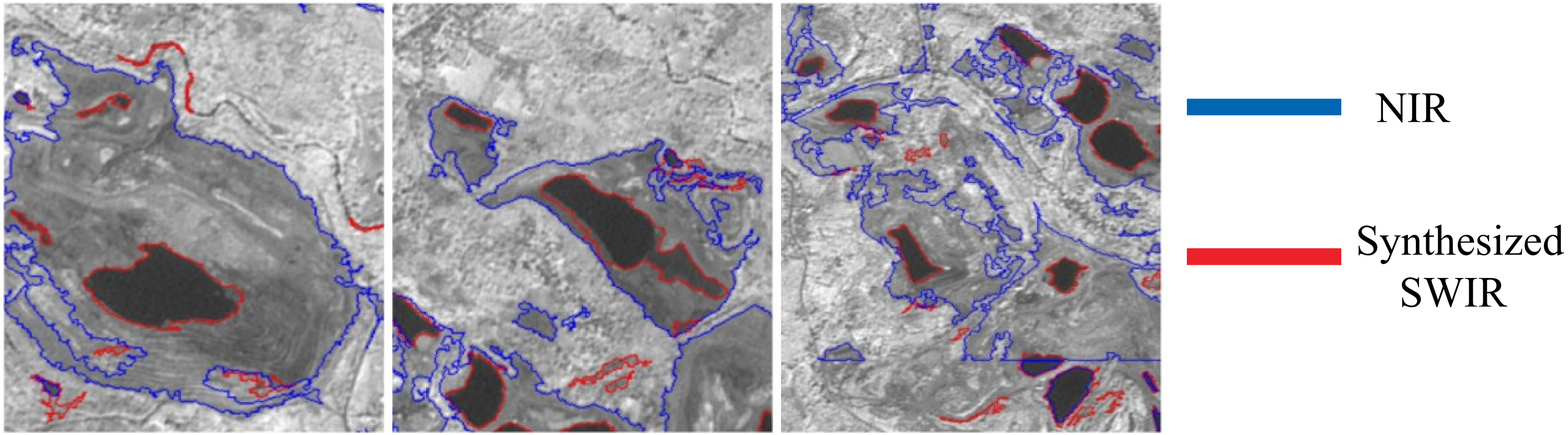
- Learns to attend to relevant parts of source imagery.
- Homogeneous and heterogeneous targets are discernible.
- Similar features have similar attention coefficients

Wetland Delineation



Water Segmentation

Wetland Delineation



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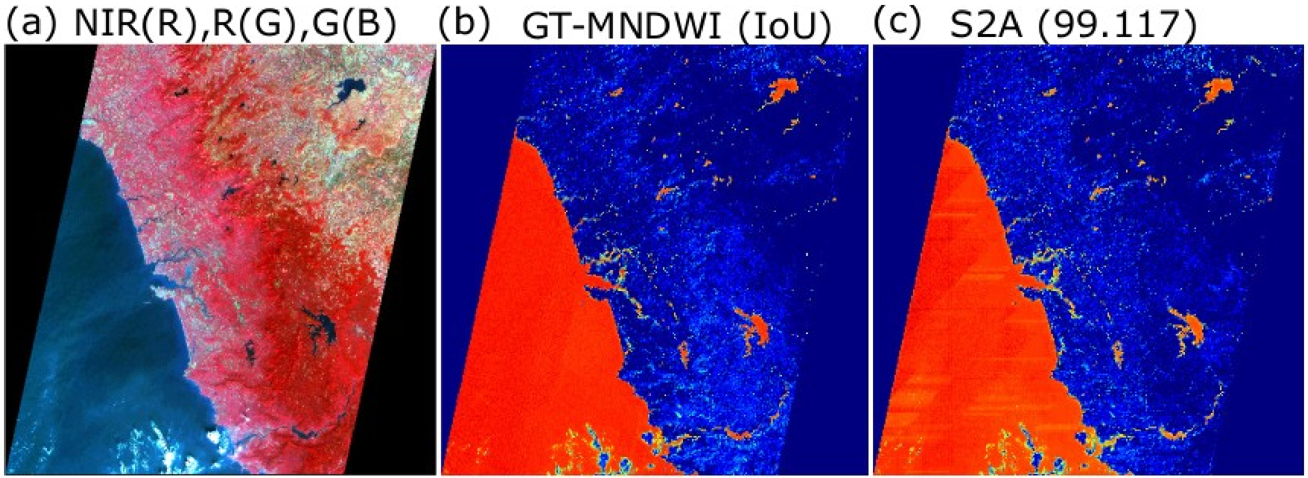
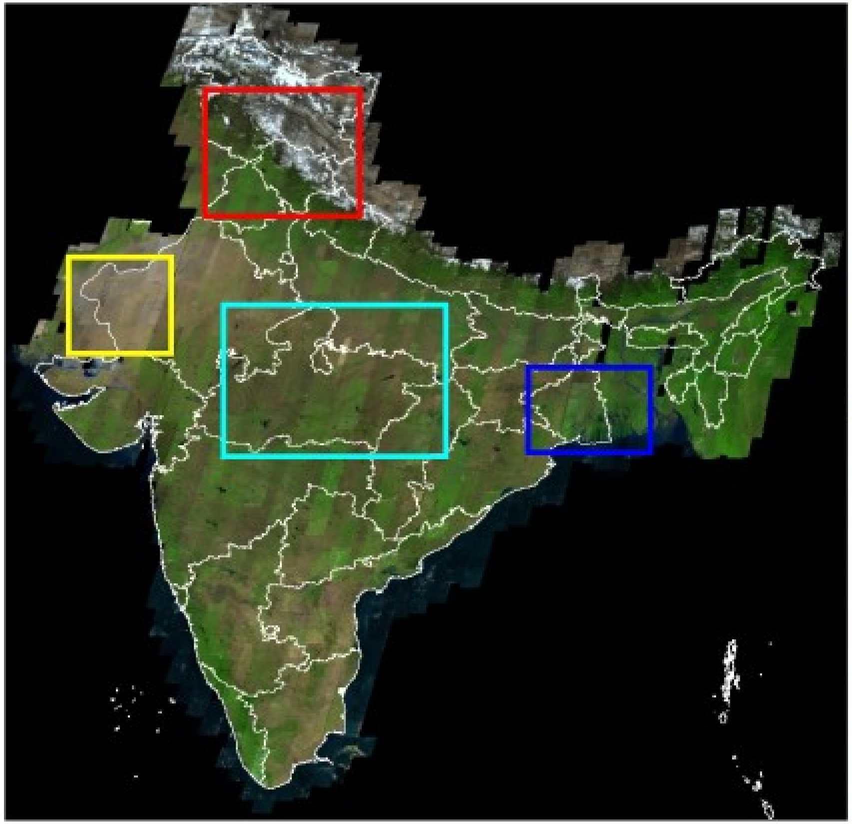
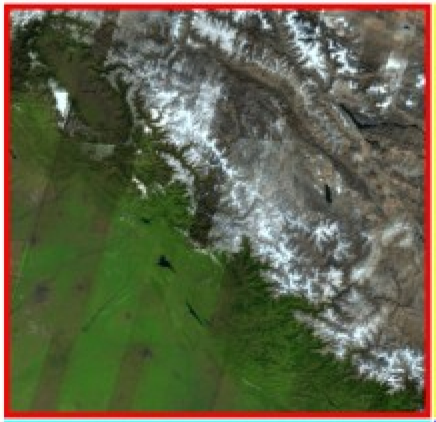


Additional Value Product Generation

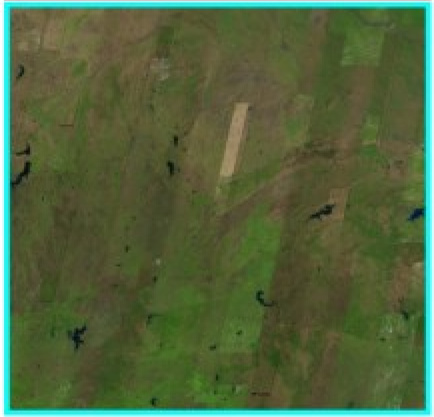


India

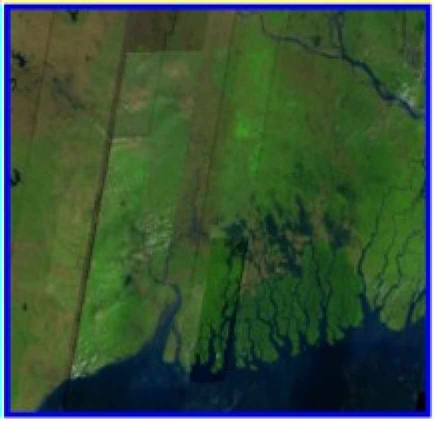
Hilly Terrain



Desert



Main land



Coastal

Summary

- Formulated super resolution as conditional band synthesis
- Regulated band synthesis through spatial and Laplacian spectral channel attention
- Introduced two new cost functions for the discriminator:
    - Spatial attention loss
    - Domain adaptation loss
- Experimented on multiple datasets:
    - LISS-3
    - LISS-4
    - WorldView-2
- Demonstrated real world applications of synthesized band:
    - Wetland delineation
    - Index based water segmentation
    - Additional value product generation/ Large area mosaic