Edge-based Blur Kernel Estimation Using Patch Priors Supplementary Material II Full Resolution Images and Results

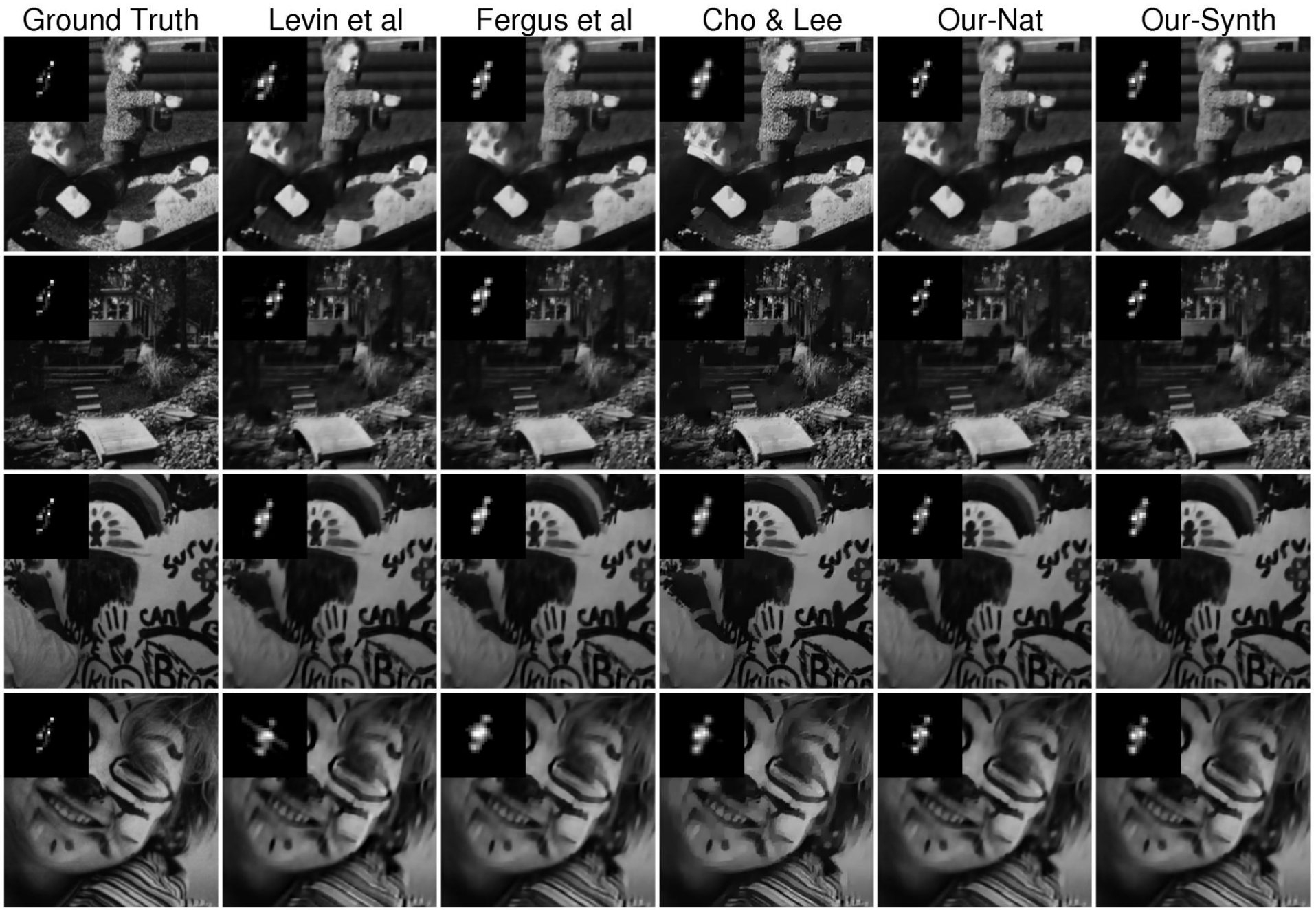
Libin Sun
Brown University

Sunghyun Cho
Adobe Research

Jue Wang
Adobe Research

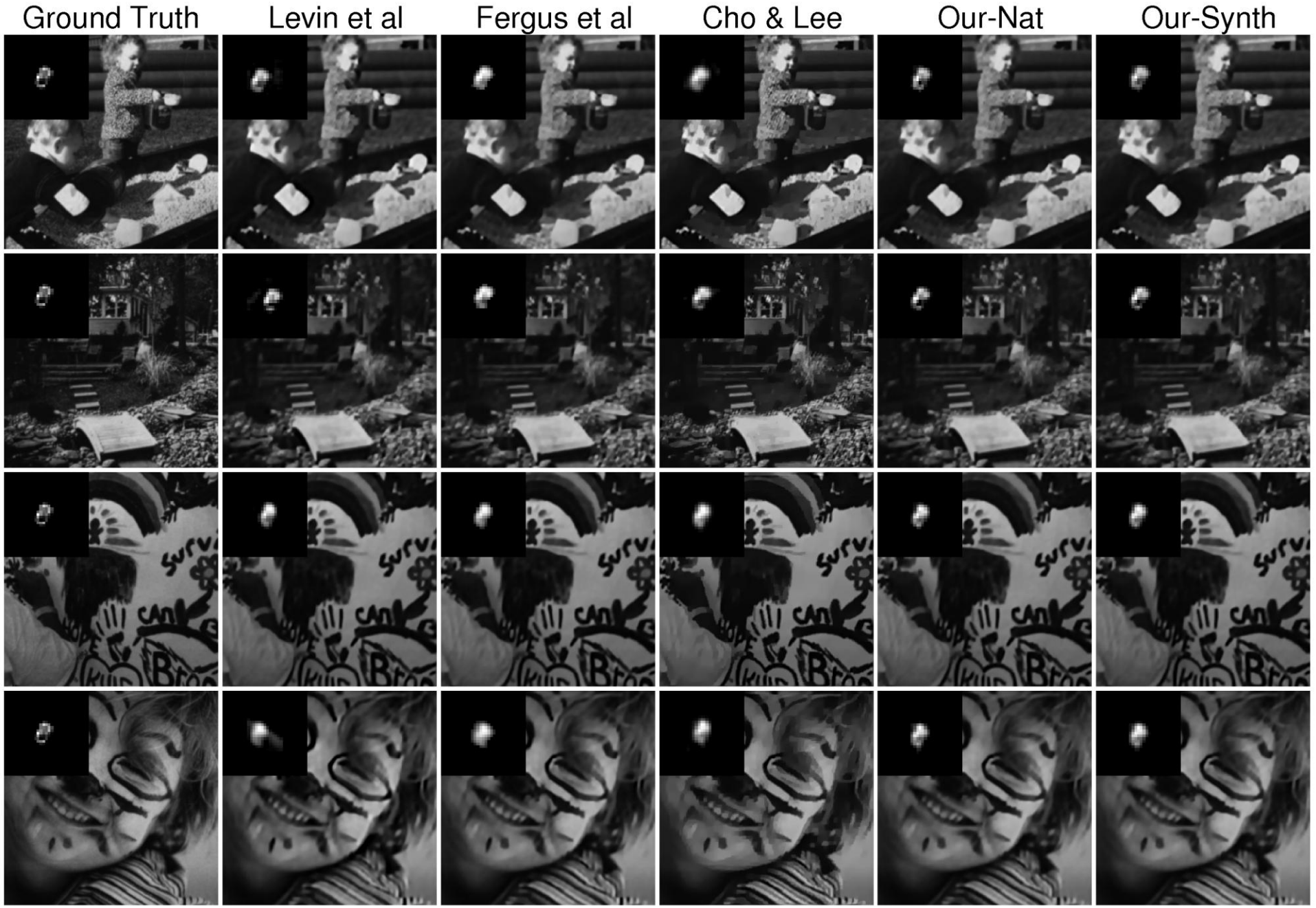
James Hays
Brown University

Results: Levin *et al* dataset kernel #1

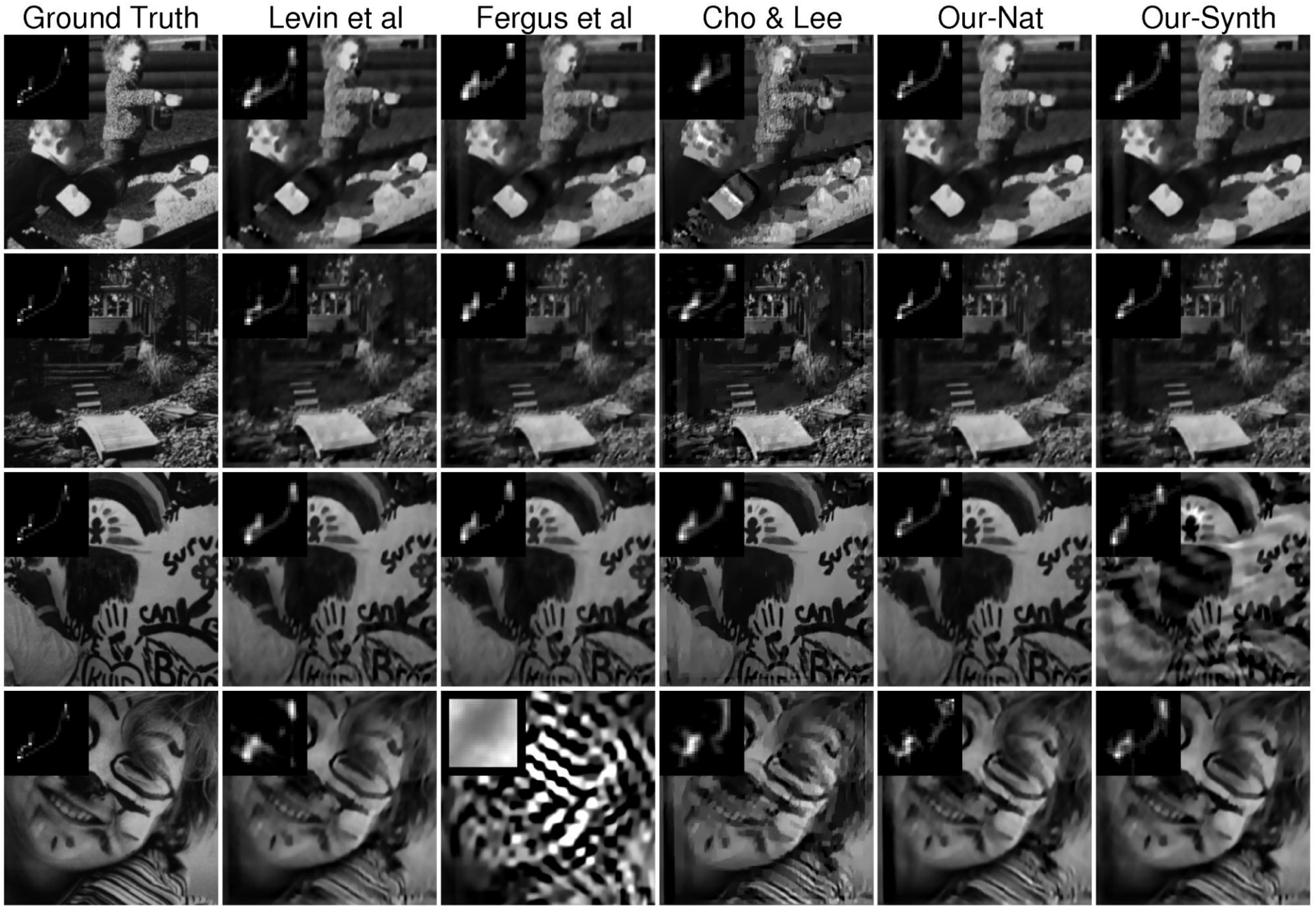


Results: Levin *et al* dataset kernel #2

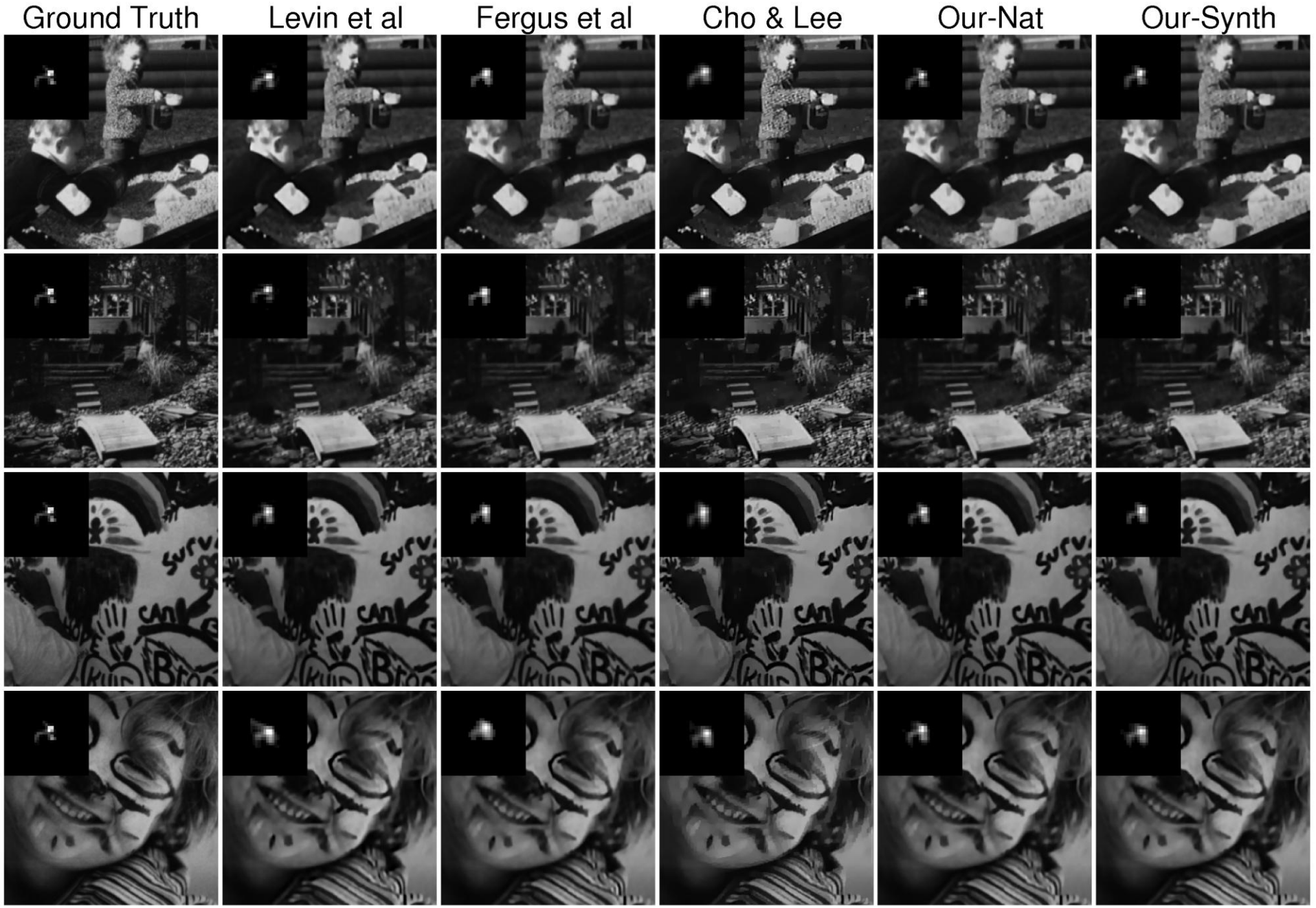
Results: Levin dataset kernel #3



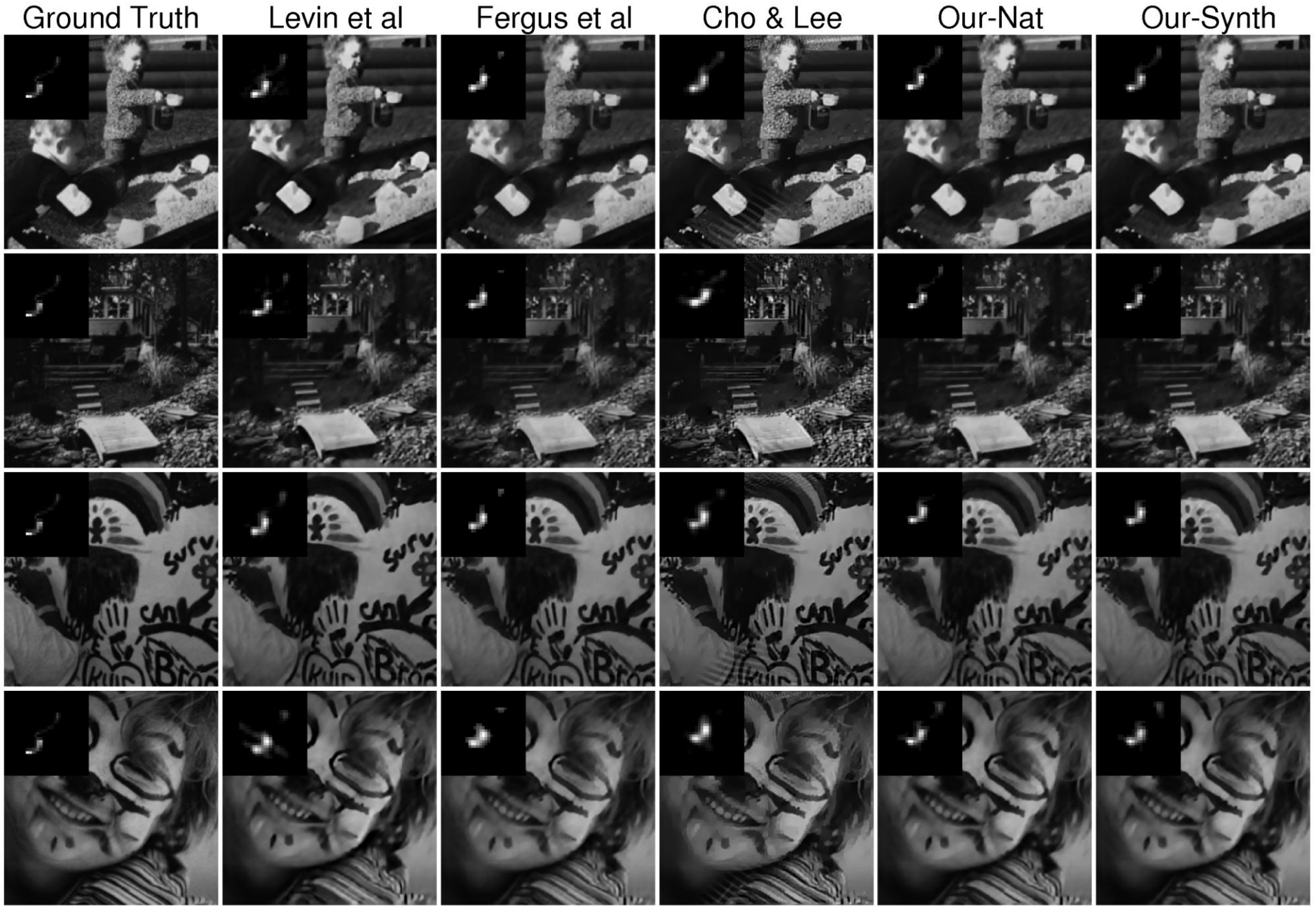
Results: Levin *et al* dataset kernel #4



Results: Levin *et al* dataset kernel #5



Results: Levin *et al* dataset kernel #6



Results: Levin *et al* dataset kernel #7

Results: Levin *et al* dataset kernel #8

Error Ratio

(image 1~4 x kernel 1~8)

An error ratio > 3 (in red) is deemed as failure according to Levin *et al* 2011.

Note: sparse deconvolution is used as the final non-blind deconvolution method to produce the latent image on our own estimated kernels, using the code provided by Levin *et al* 2011.

Levin et al (with sparse deconvolution from Levin et al)

1.3360	1.2909	1.3480	2.0090	1.2701	1.8128	2.2737	1.8636
1.3316	1.4425	1.5040	1.4540	1.2955	1.8147	1.6242	1.7489
1.2264	1.2897	1.0287	1.7434	1.1873	2.1079	2.0652	1.3467
2.6050	2.9217	3.2705	2.4617	2.2027	3.4851	6.6173	4.8858

- 4 failures

Fergus et al (with sparse deconvolution from Levin et al)

1.2049	1.0841	1.1571	2.6411	1.3097	2.8166	10.1775	1.9140
1.2407	1.2882	1.3040	1.5655	1.4220	4.1503	3.8586	2.1994
1.2484	1.1463	1.1591	2.0783	1.4682	3.3385	10.4548	2.2355
1.4769	2.1129	1.2860	293.8450	1.3353	2.6163	33.8606	33.8627

- Several extreme failures

Cho & Lee (with a different final non-blind deconvolution method)

1.0075	0.9329	1.1724	8.9746	1.2873	3.2630	4.9803	9.2060
1.4639	0.8459	0.7461	1.5363	1.0929	4.6685	2.4472	2.8248
0.7886	0.9137	0.9580	1.1411	1.8443	5.2996	4.0068	1.7796
1.2312	1.7011	1.2795	6.3879	1.4117	3.9204	2.8386	3.4510

- Several below 1, due to a different deconvolution method being used

- Quite a few failures

Our-Nat (with sparse deconvolution from Levin et al)

1.1184	1.0560	1.1187	1.5166	1.1882	1.1361	1.4330	1.2281
1.2009	1.2495	1.1471	1.3233	1.4099	1.4555	1.3096	1.4098
1.0583	1.1472	1.0701	1.2177	1.0832	7.0616	2.0717	1.2133
1.3978	1.2843	1.1109	2.8791	1.0211	1.4062	2.2374	1.7254

- 1 failure

Our-Synth (with sparse deconvolution from Levin et al)

1.1763	1.0524	1.0796	1.4858	1.1324	1.1466	1.4988	1.2052
1.2673	1.0798	1.2982	1.2703	1.4204	1.2503	1.2084	1.1197
1.1521	1.1262	1.2081	15.5952	1.2353	7.3139	1.8996	1.1331
1.5184	1.3915	1.0755	2.0433	1.0770	1.5269	2.1900	1.8142

- 2 failures

PSNR

(image 1~4 x kernel 1~8)

Known k (with sparse deconvolution from Levin et al)

32.9135	32.3482	33.9576	31.2881	34.9080	36.1414	34.9912	33.9605
31.2852	30.9984	31.8002	29.5068	33.6736	35.0428	32.1448	32.0036
33.1003	32.5021	35.4235	32.1685	36.4224	38.1147	36.9282	34.4356
33.3468	31.6807	36.2802	32.1296	36.2355	35.5925	36.4168	34.4896

Levin et al (with sparse deconvolution from Levin et al)

31.6553	31.2394	32.6609	28.2584	33.8695	33.5578	31.4239	31.2571
30.0414	29.4073	30.0279	27.8811	32.5494	32.4547	30.0384	29.5759
32.2140	31.3972	35.3008	29.7544	35.6767	34.8762	33.7785	33.1429
29.1887	27.0244	31.1340	28.2173	32.8059	30.1703	28.2100	27.6003

Fergus et al (with sparse deconvolution from Levin et al)

32.1039	31.9975	33.3238	27.0702	33.7362	31.6441	24.9148	31.1411
30.3487	29.8985	30.6474	27.5603	32.1447	28.8619	26.2806	28.5805
32.1367	31.9093	34.7822	28.9913	34.7545	32.8793	26.7350	30.9417
31.6532	28.4319	35.1878	7.4484	34.9796	31.4157	21.1199	19.1924

Cho & Lee (with a different final non-blind deconvolution method)

32.8809	32.6496	33.2669	21.7580	33.8114	31.0053	28.0187	24.3198
29.6301	31.7253	33.0723	27.6422	33.2879	28.3510	28.2581	27.4937
34.1318	32.8939	35.6099	31.5953	33.7641	30.8723	30.9002	31.9323
32.4436	29.3733	35.2099	24.0760	34.7382	29.6592	31.8858	29.1101

Our-Nat (with sparse deconvolution from Levin et al)

32.4226	32.1082	33.4679	29.5143	34.1554	35.5829	33.4276	33.0666
30.4865	30.0284	31.1959	28.3001	32.1799	33.4078	30.9715	30.5093
32.8474	31.9024	35.1274	31.3167	36.0650	29.6258	33.7649	33.5922
31.8923	30.5926	35.8234	27.5917	36.1481	34.1197	32.9279	32.1325

Our-Synth (with sparse deconvolution from Levin et al)

32.2043	32.1177	33.6176	29.6127	34.3660	35.5346	33.2284	33.1535
30.2522	30.6615	30.6654	28.4754	32.1486	34.0646	31.3178	31.5055
32.4837	31.9850	34.5988	20.9050	35.4942	29.4723	34.1397	33.8896
31.5287	30.2451	35.9622	29.0906	35.9183	33.7600	33.0268	31.9072

SSIM

(image 1~4 x kernel 1~8)

Known k (with sparse deconvolution from Levin et al)

0.9131	0.9119	0.9262	0.8916	0.9498	0.9478	0.9415	0.9310
0.8831	0.8847	0.8913	0.8390	0.9329	0.9380	0.9005	0.9030
0.9368	0.9364	0.9584	0.9244	0.9711	0.9682	0.9646	0.9508
0.9271	0.9136	0.9544	0.9101	0.9640	0.9522	0.9568	0.9418

Levin et al (with sparse deconvolution from Levin et al)

0.8979	0.8940	0.9123	0.8449	0.9410	0.9297	0.9089	0.9010
0.8586	0.8483	0.8587	0.7995	0.9196	0.9107	0.8759	0.8583
0.9275	0.9222	0.9567	0.8911	0.9667	0.9524	0.9448	0.9365
0.8671	0.8191	0.9030	0.8531	0.9370	0.9017	0.8766	0.8579

Fergus et al (with sparse deconvolution from Levin et al)

0.9002	0.9037	0.9165	0.8314	0.9380	0.9172	0.8085	0.8965
0.8651	0.8606	0.8689	0.7933	0.9146	0.8669	0.8074	0.8428
0.9279	0.9290	0.9536	0.8775	0.9624	0.9403	0.8520	0.9015
0.9072	0.8547	0.9442	0.1159	0.9526	0.9215	0.5828	0.4890

Cho & Lee (with a different final non-blind deconvolution method)

0.9135	0.9122	0.9192	0.6900	0.9412	0.8874	0.8498	0.7381
0.8692	0.8989	0.9135	0.8117	0.9344	0.8601	0.8451	0.8406
0.9432	0.9394	0.9560	0.9148	0.9505	0.9003	0.9136	0.9313
0.9041	0.8689	0.9374	0.6805	0.9474	0.8769	0.9153	0.8725

Our-Nat (with sparse deconvolution from Levin et al)

0.9051	0.9065	0.9186	0.8632	0.9411	0.9404	0.9275	0.9192
0.8660	0.8621	0.8816	0.8091	0.9140	0.9230	0.8852	0.8773
0.9345	0.9290	0.9557	0.9148	0.9686	0.8927	0.9429	0.9424
0.9114	0.8983	0.9498	0.8098	0.9606	0.9400	0.9338	0.9220

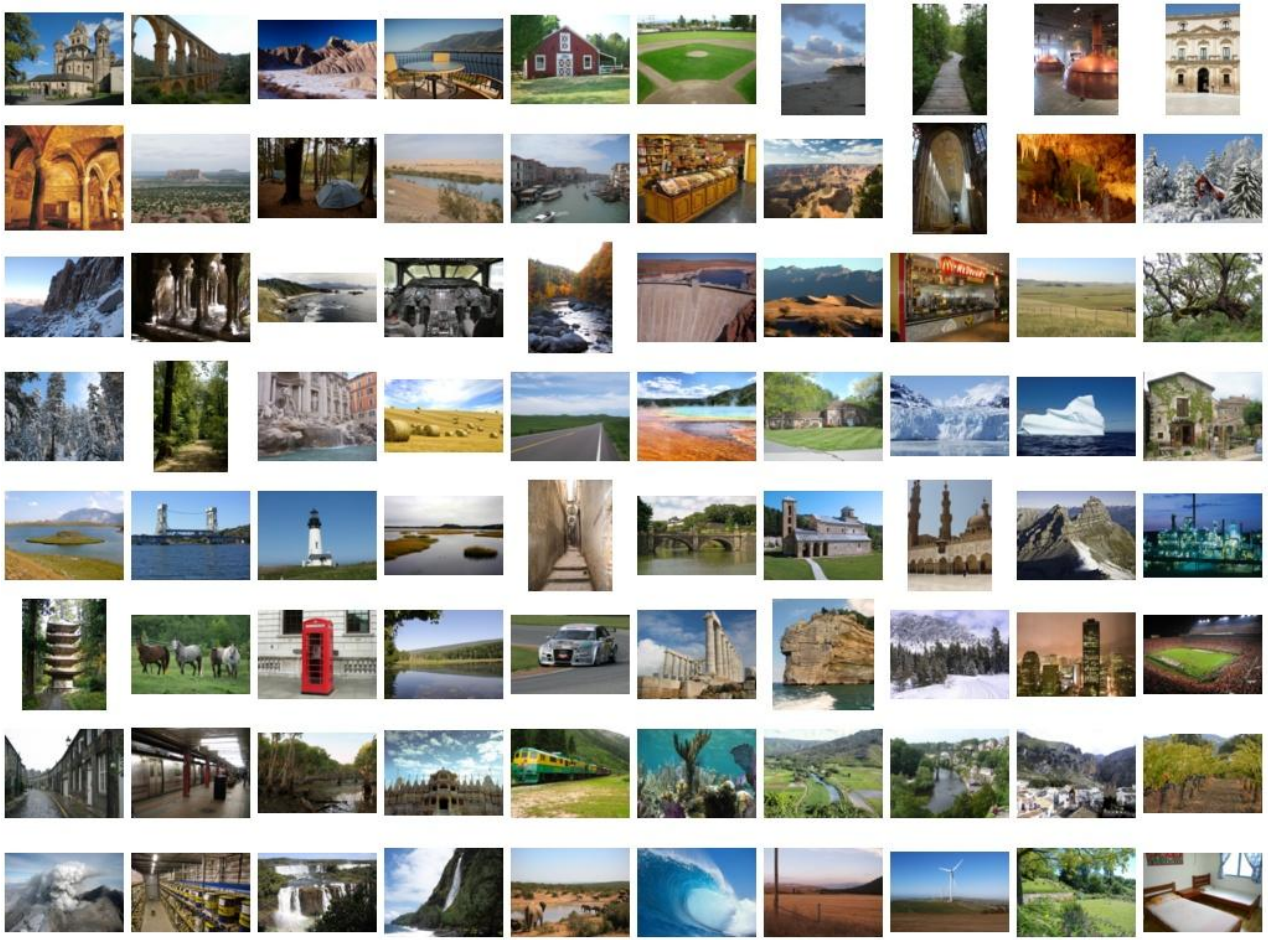
Our-Synth (with sparse deconvolution from Levin et al)

0.9009	0.9067	0.9198	0.8621	0.9416	0.9414	0.9273	0.9174
0.8630	0.8758	0.8739	0.8161	0.9130	0.9280	0.8908	0.8953
0.9310	0.9298	0.9524	0.6013	0.9660	0.8936	0.9458	0.9437
0.9068	0.8929	0.9506	0.8666	0.9593	0.9377	0.9354	0.9206

Results on Our Synthetic Dataset

- 80 images, 8 kernels
- All kernels are estimated assuming size 51x51 (but 29x29 is used here for Levin *et al* for better results)
- Zoran and Weiss (identical parameters) is used as the final non-blind deconvolution method
- Kernels are centered, cropped, and zoomed
- Output images are aligned with ground truth to minimize SSDE, maximize PSNR

Thumbnails of 80 diverse scenes (used in grayscale)



Input (blurred, 1% noise) and ground truth kernel

Error Ratio: 11.7162
PSNR: 20.4356
SSIM: 0.53689

Known k

Error Ratio: 1
PSNR: 31.1235
SSIM: 0.85078

Cho & Lee

Error Ratio: 20.0309
PSNR: 18.1065
SSIM: 0.58445

Cho *et al*

Error Ratio: 50.8794
PSNR: 14.0581
SSIM: 0.26029

Krishnan *et al*

Error Ratio: 6.8496
PSNR: 22.7669
SSIM: 0.76174

Levin *et al*

Error Ratio: 4.5147
PSNR: 24.5772
SSIM:0.77439

Xu & Jia

Error Ratio: 2.9845
PSNR: 26.3747
SSIM: 0.8133

Our-Nat

Error Ratio: 1.7535
PSNR: 28.6845
SSIM: 0.82754

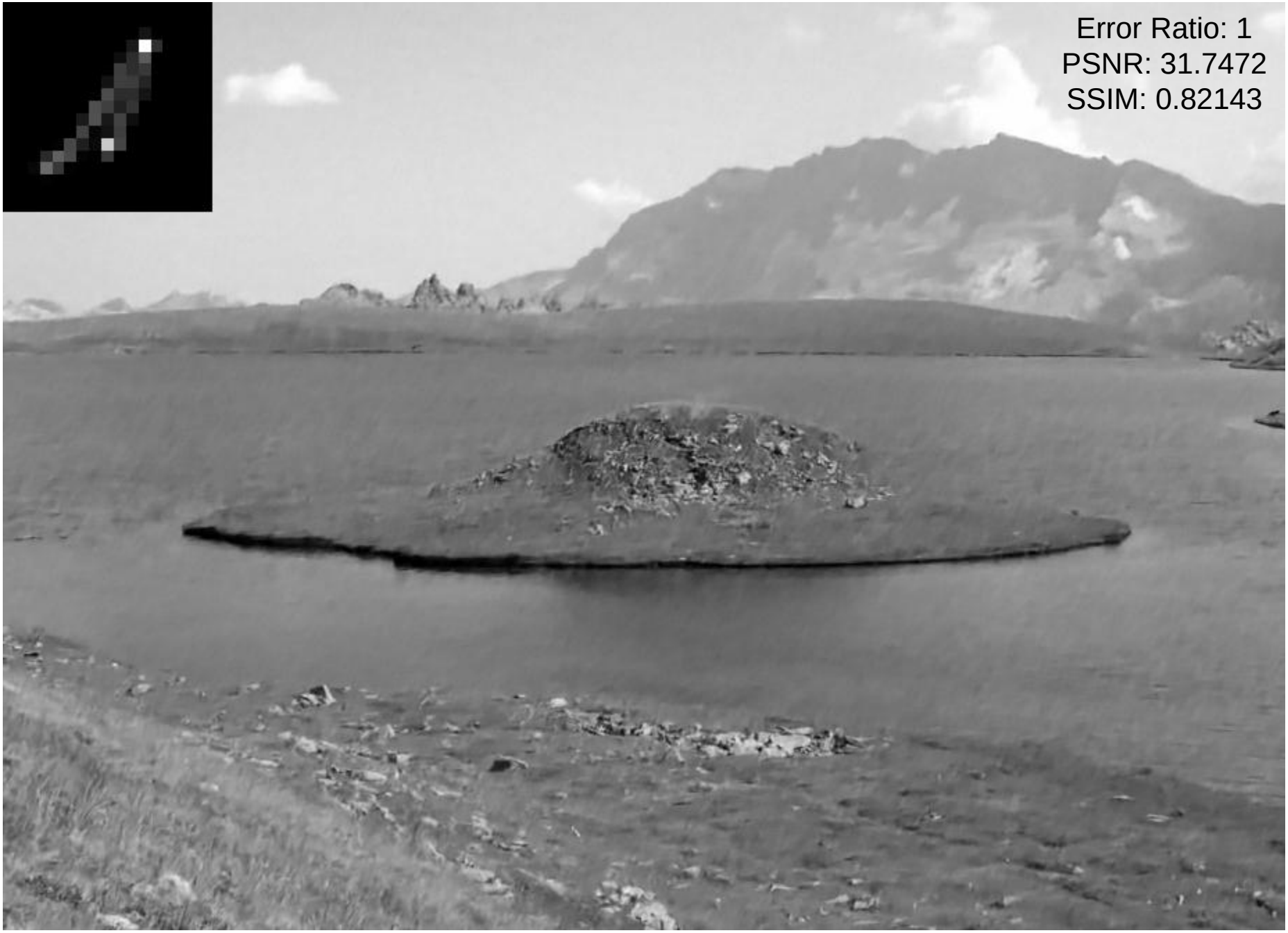
Our-Synth

Error Ratio: 1.8565
PSNR: 28.4366
SSIM: 0.82823

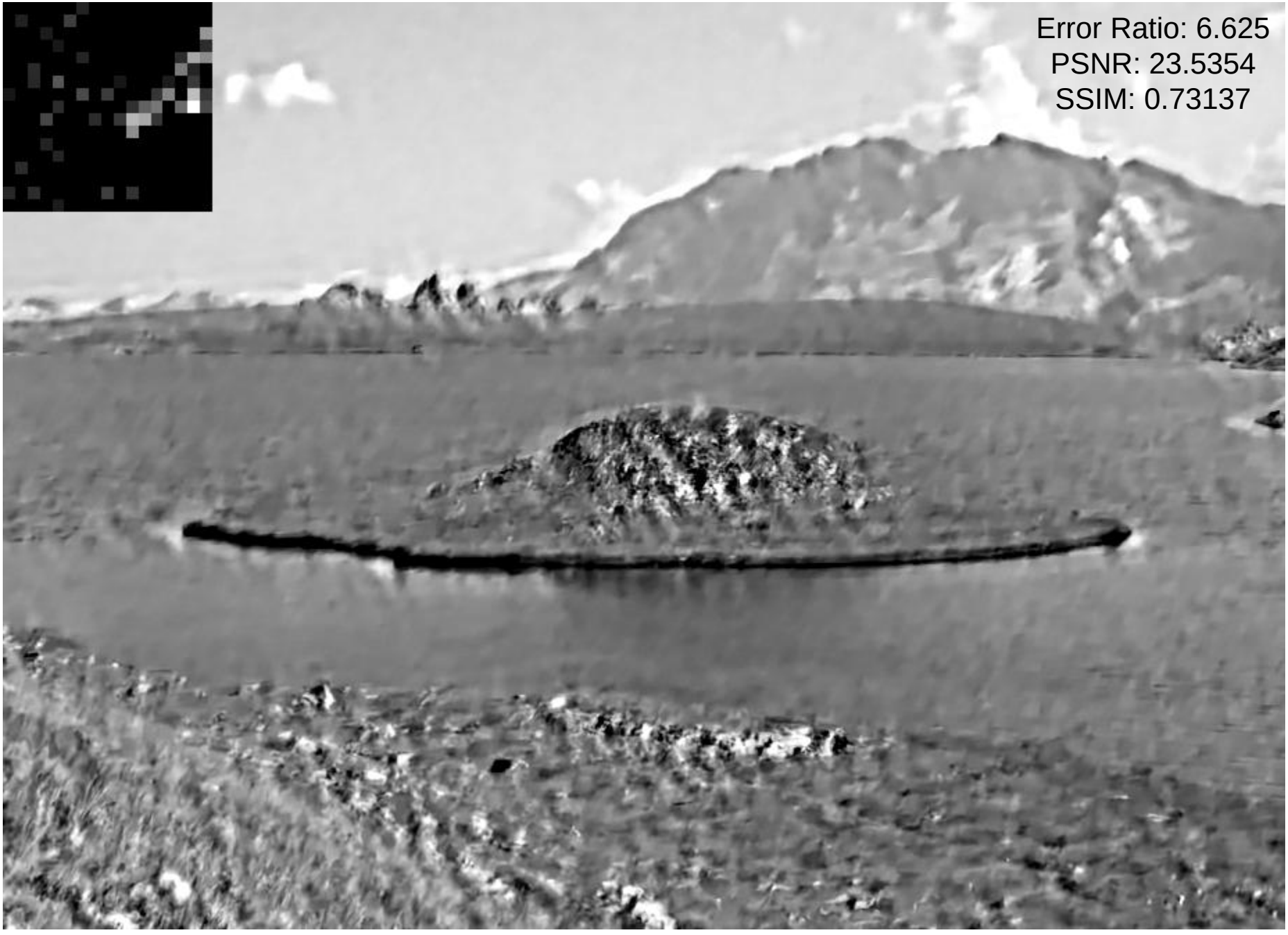
Ground truth image and kernel

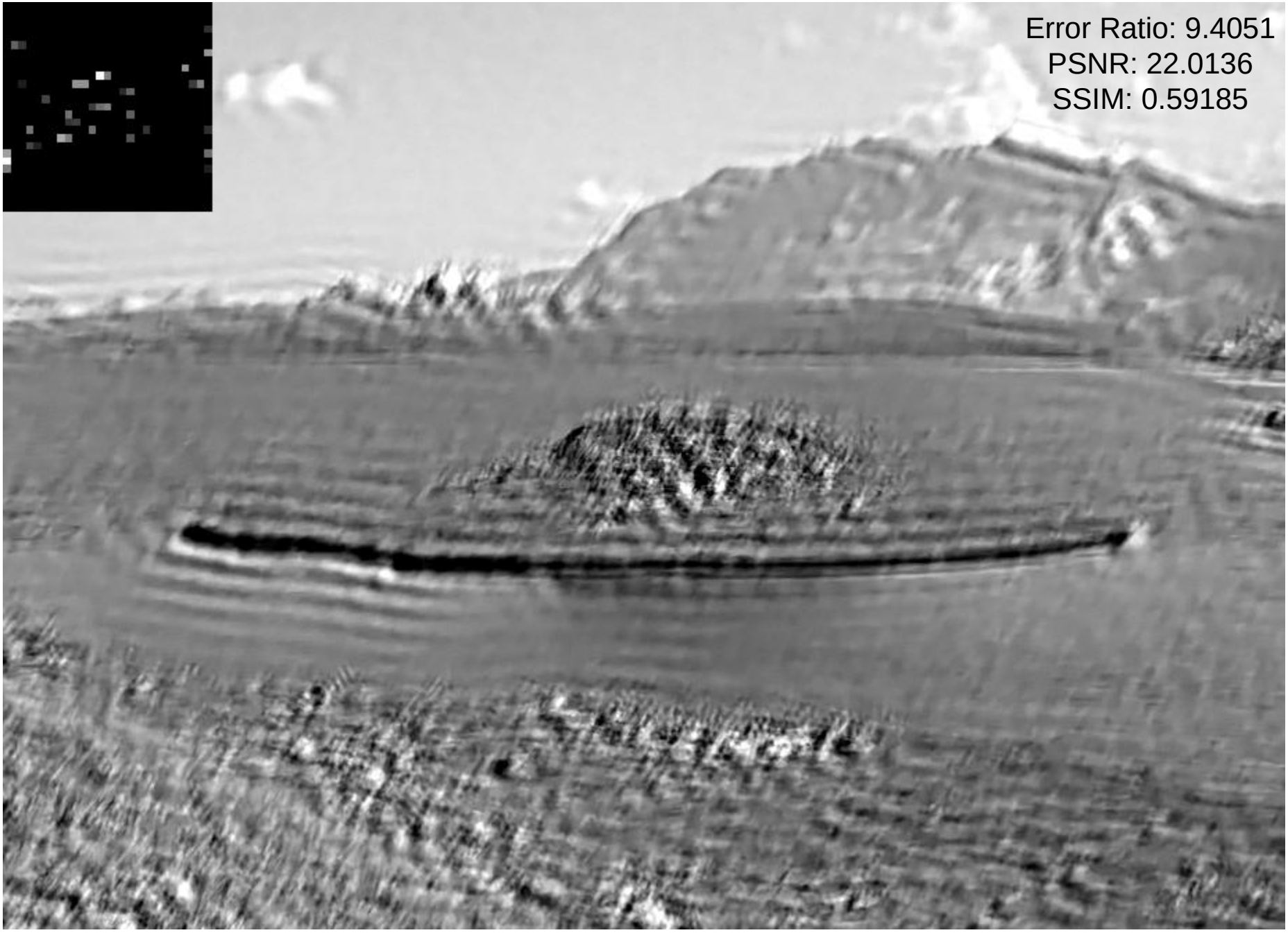
Input (blurred, 1% noise) and ground truth kernel

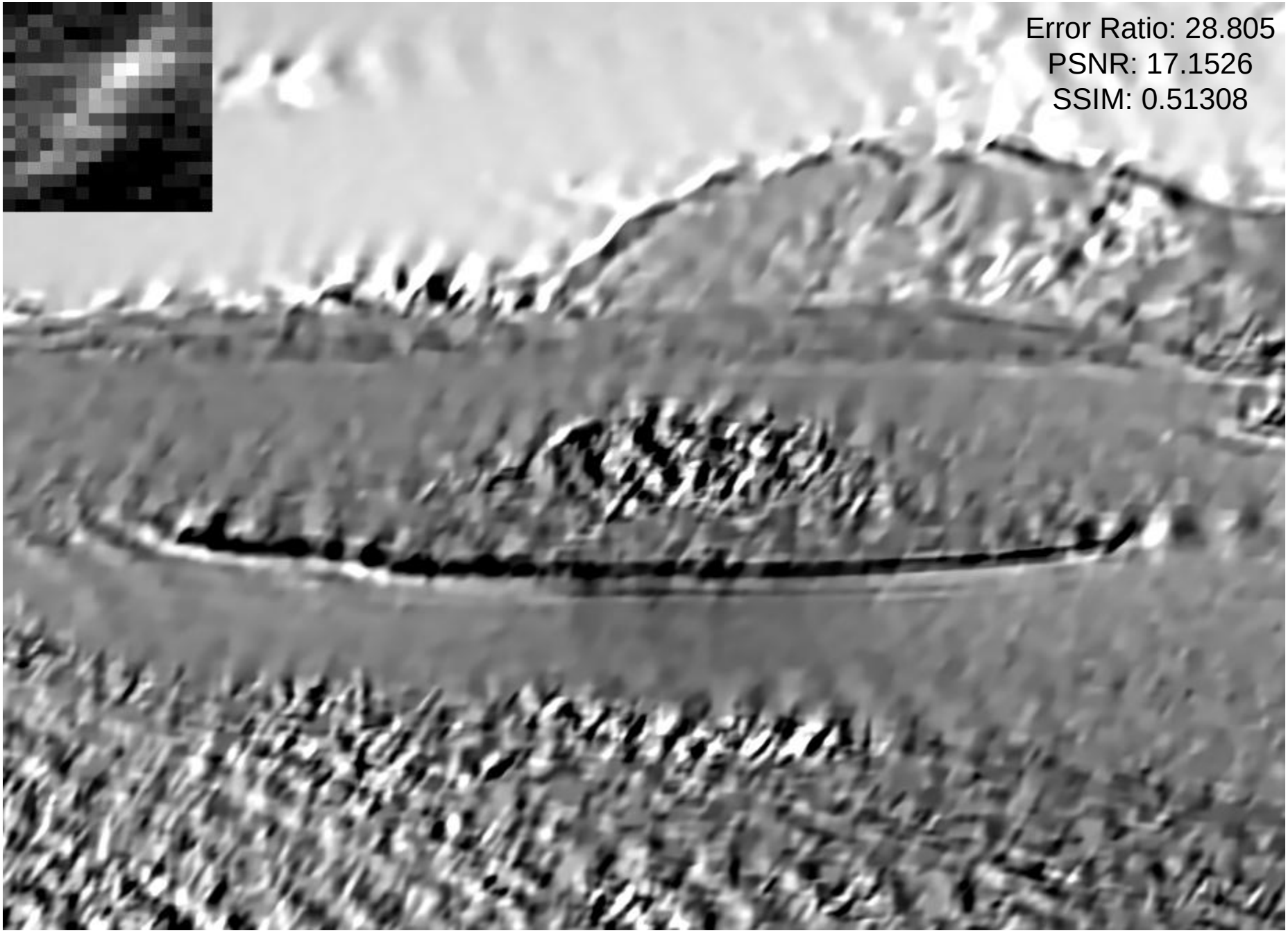
Known k



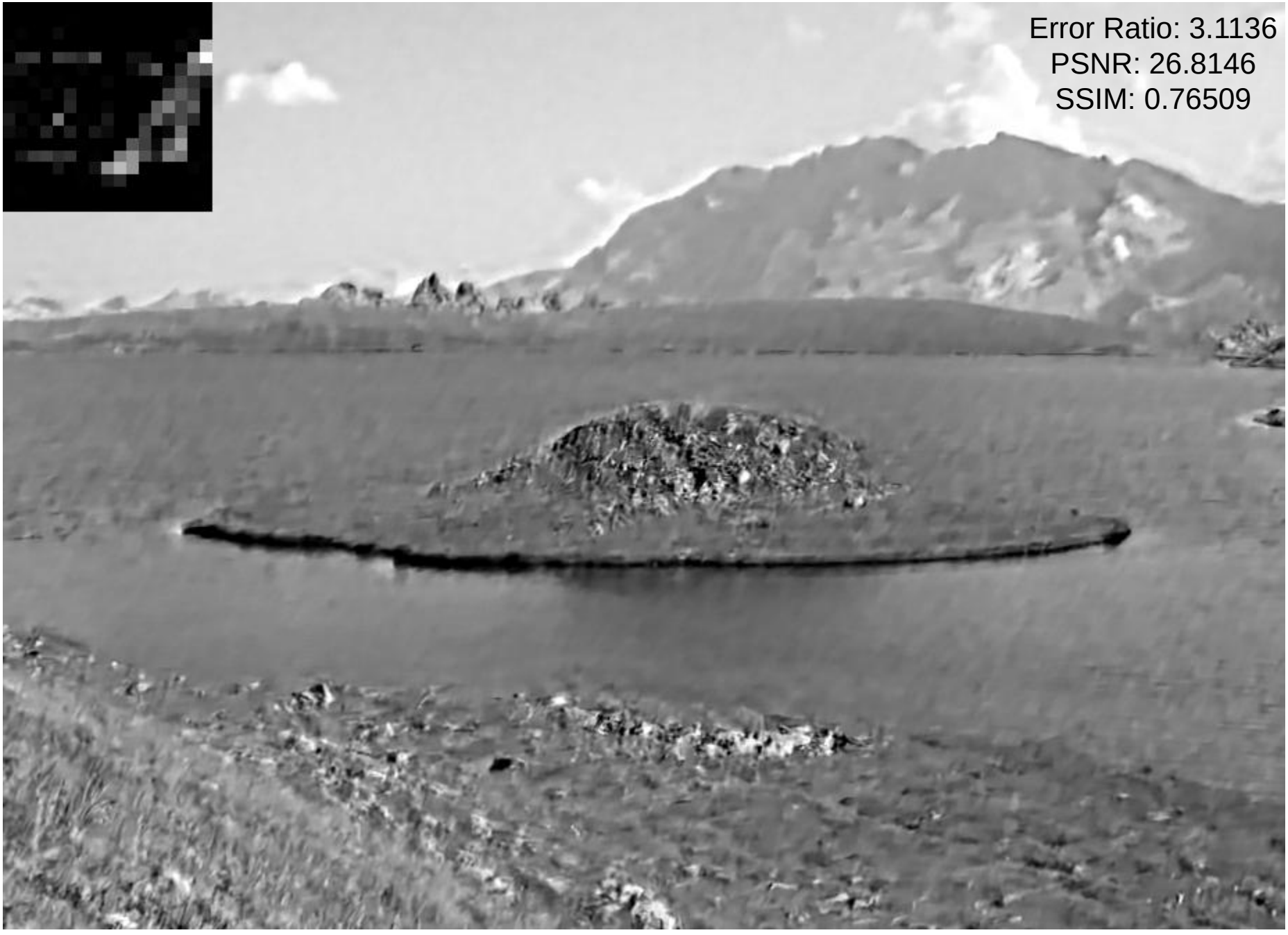
Cho & Lee



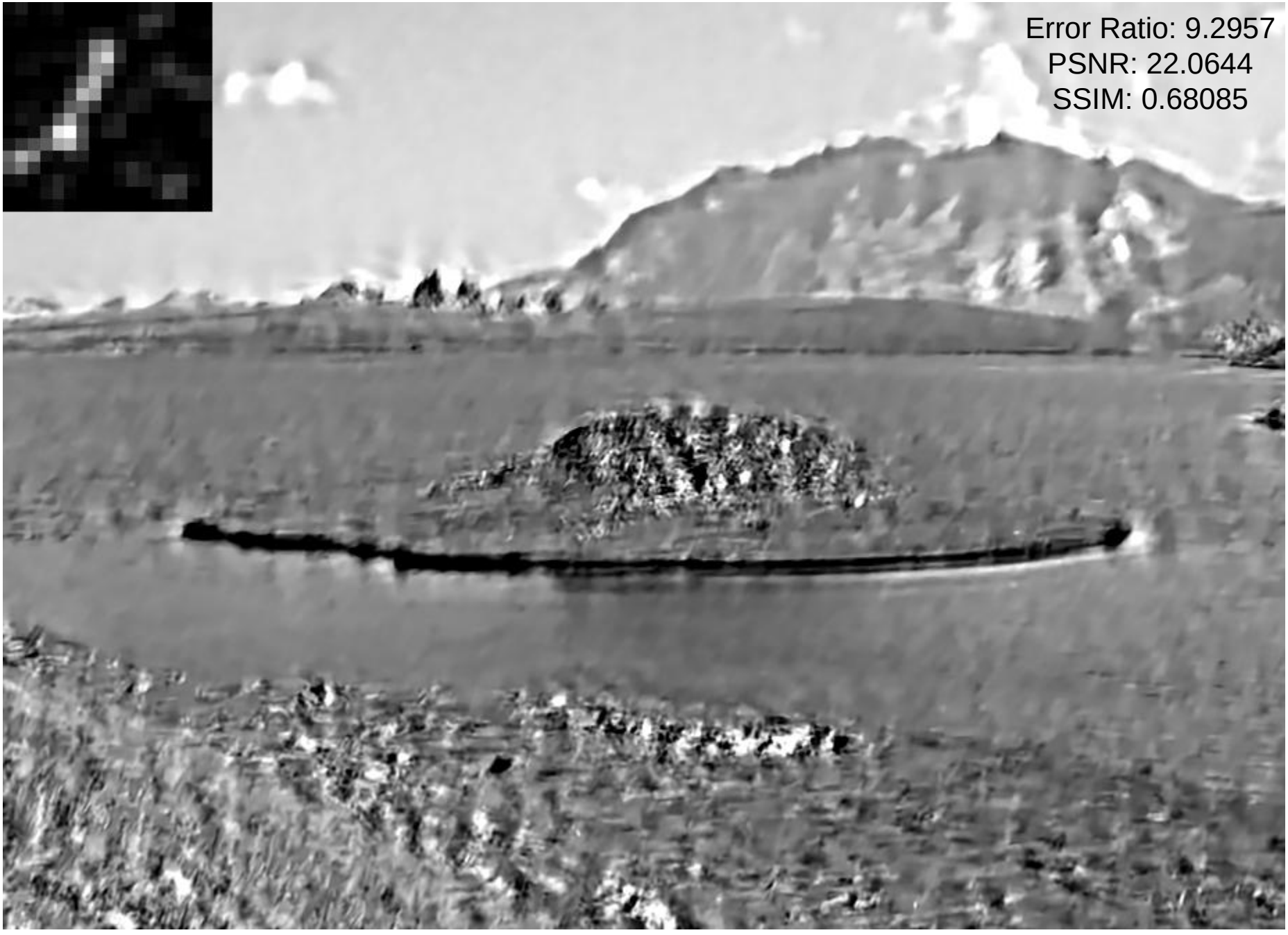

Error Ratio: 9.4051
PSNR: 22.0136
SSIM: 0.59185


Error Ratio: 28.805
PSNR: 17.1526
SSIM: 0.51308

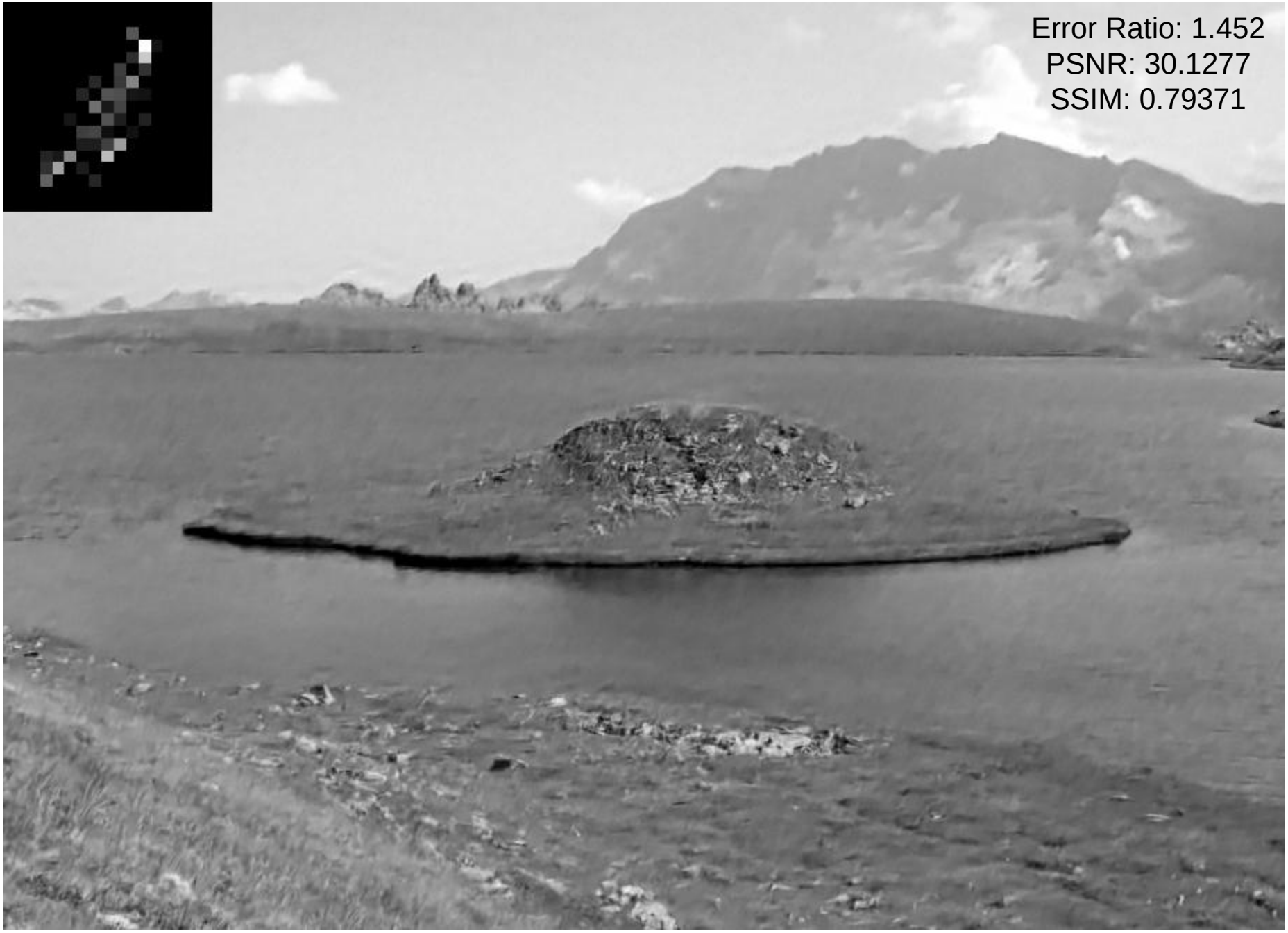
Levin *et al*



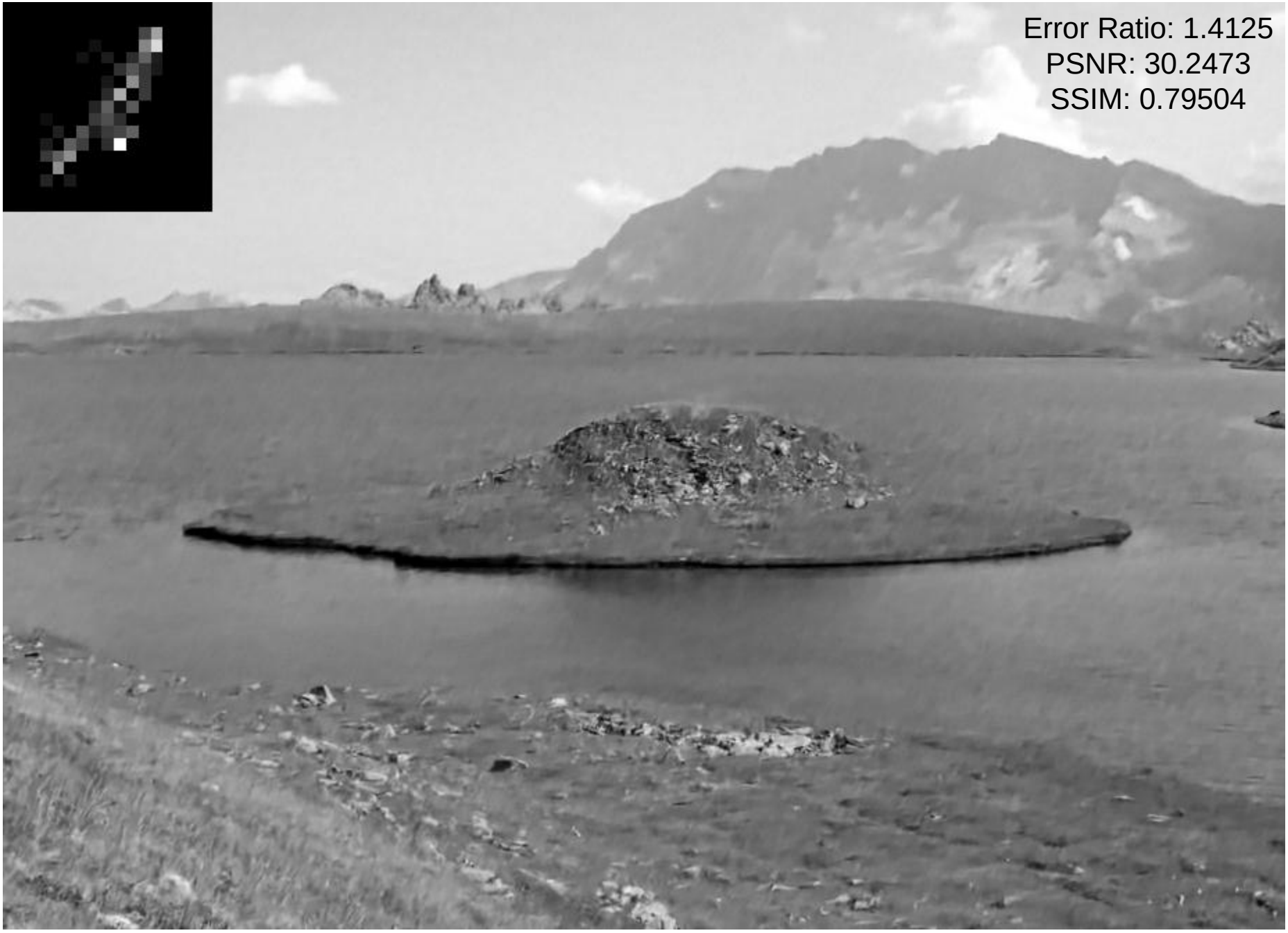
Xu & Jia



Our-Nat



Our-Synth



Ground truth image and kernel

Input (blurred, 1% noise) and ground truth kernel

Error Ratio: 8.9357
PSNR: 24.694
SSIM: 0.70773

Known k

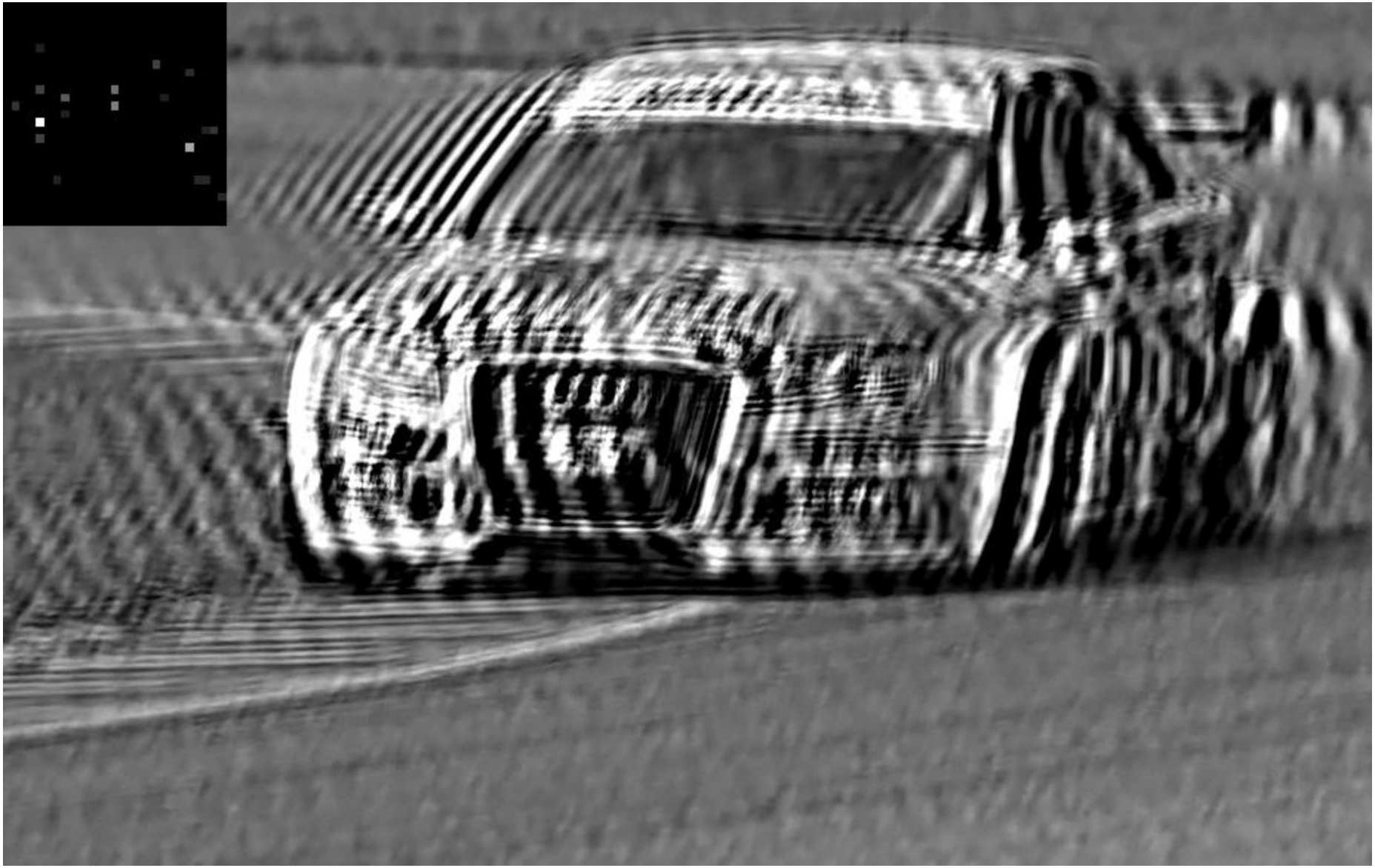
Error Ratio: 1
PSNR: 34.2053
SSIM: 0.90255

Cho & Lee

Error Ratio: 4.7866
PSNR: 27.405
SSIM: 0.8565

Cho *et al*

Error Ratio: 56.8981
PSNR: 16.6543
SSIM: 0.49305



Krishnan *et al*

Error Ratio: 11.617
PSNR: 23.5543
SSIM: 0.79335

Levin *et al*

Error Ratio: 12.6956
PSNR: 23.1687
SSIM: 0.77931

Xu & Jia

Error Ratio: 3.9836
PSNR: 28.2025
SSIM: 0.86815

Our-Nat

Error Ratio: 2.4545
PSNR: 30.3056
SSIM: 0.88056

Our-Synth

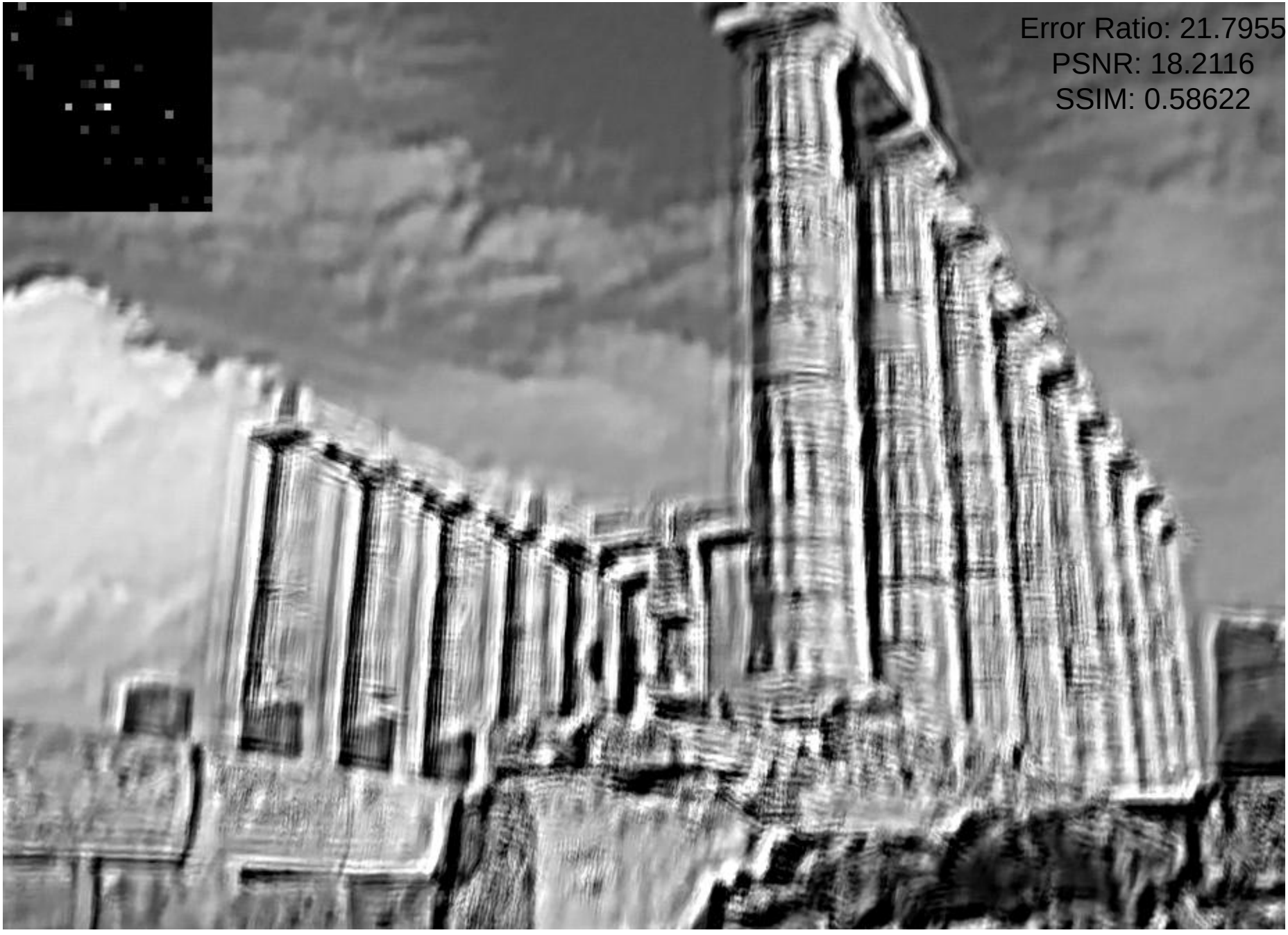
Error Ratio: 2.7363
PSNR: 29.8336
SSIM: 0.88245

Ground truth image and kernel

Input (blurred, 1% noise) and ground truth kernel

Known k

Cho & Lee


Error Ratio: 21.7955
PSNR: 18.2116
SSIM: 0.58622

Krishnan *et al*

Levin *et al*

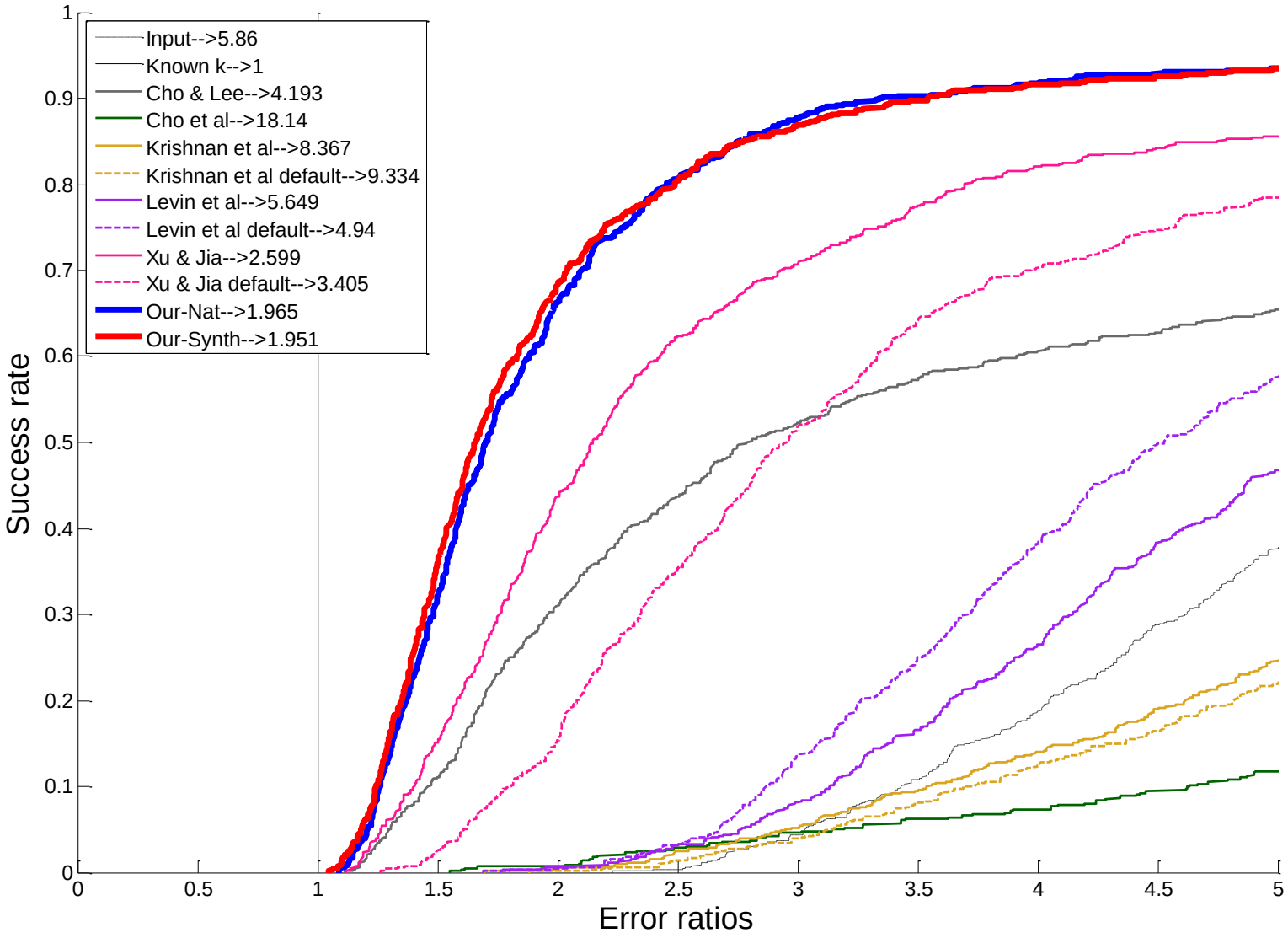
Xu & Jia

Our-Nat

Our-Synth

Ground truth image and kernel

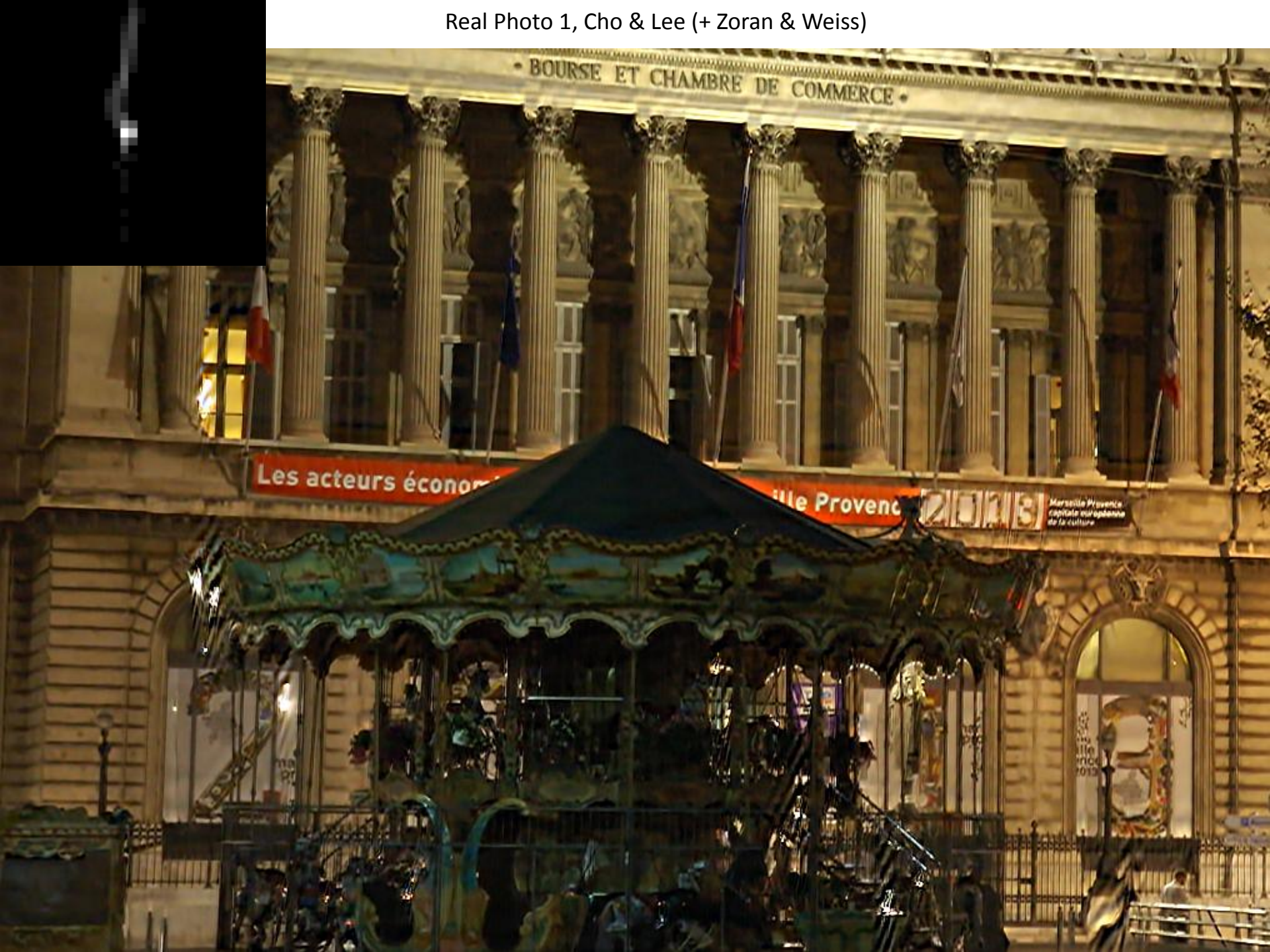
Complete Evaluation on Our Synthetic Dataset (640 images)



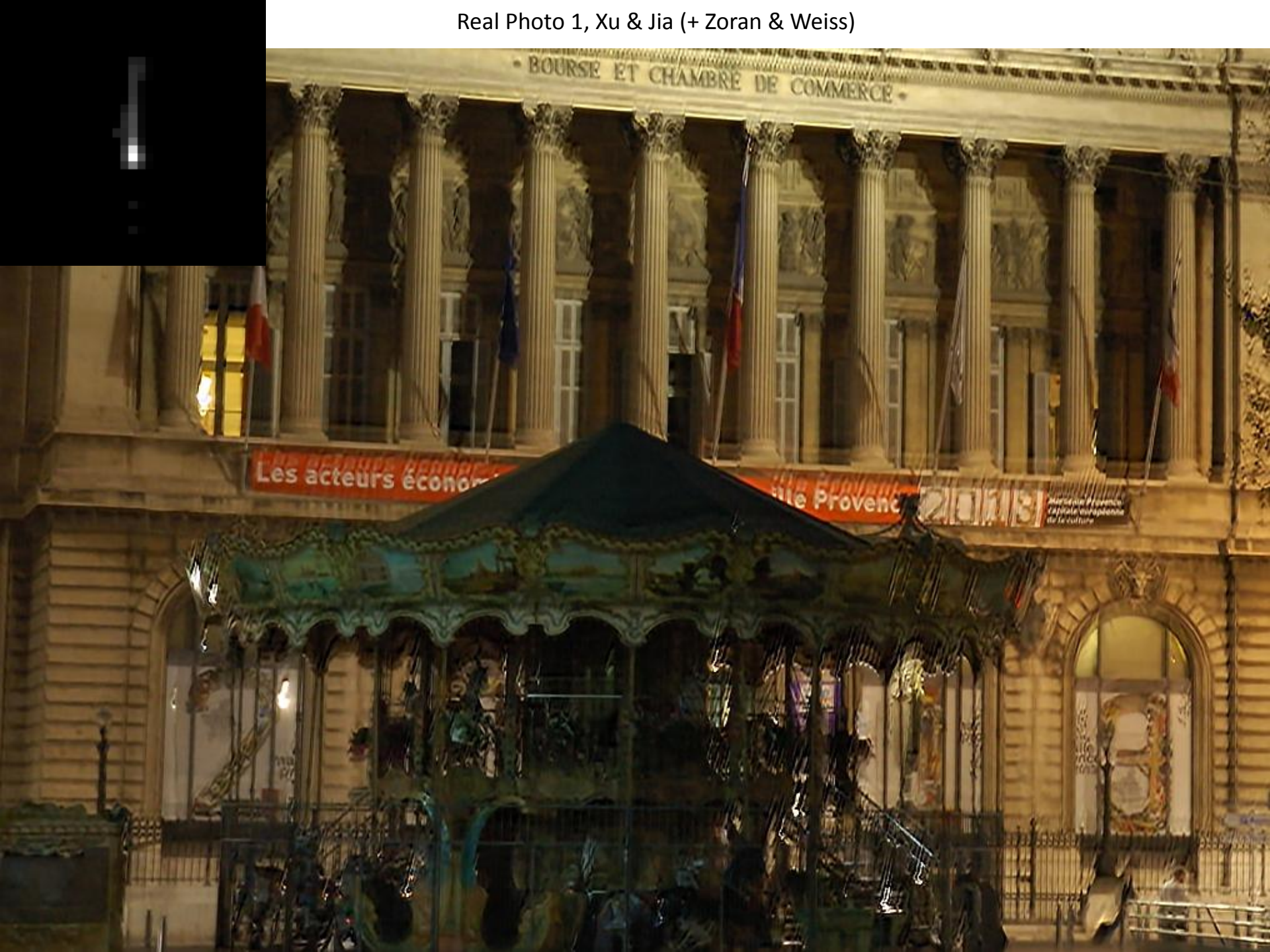
- Geometric mean of error ratios are shown in the legend. Lower is better.
- "Default" means that we use method$_i$ as is, no modifications. Otherwise Zoran & Weiss is used to deconvolve the image using the estimated kernel from method$_i$.

Real Photo 1, input with unknown camera shake

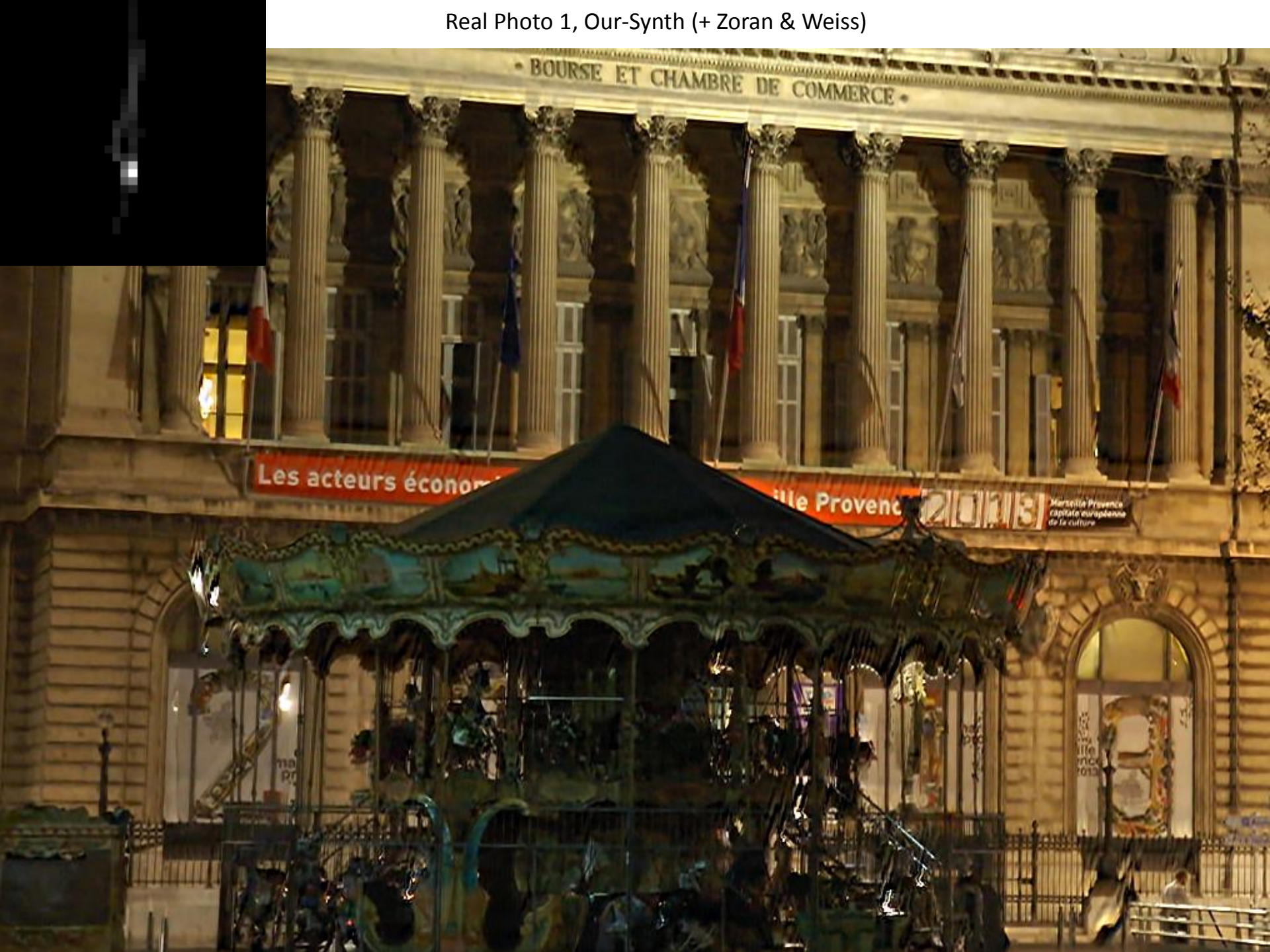
Real Photo 1, Cho & Lee (+ Zoran & Weiss)



Real Photo 1, Xu & Jia (+ Zoran & Weiss)

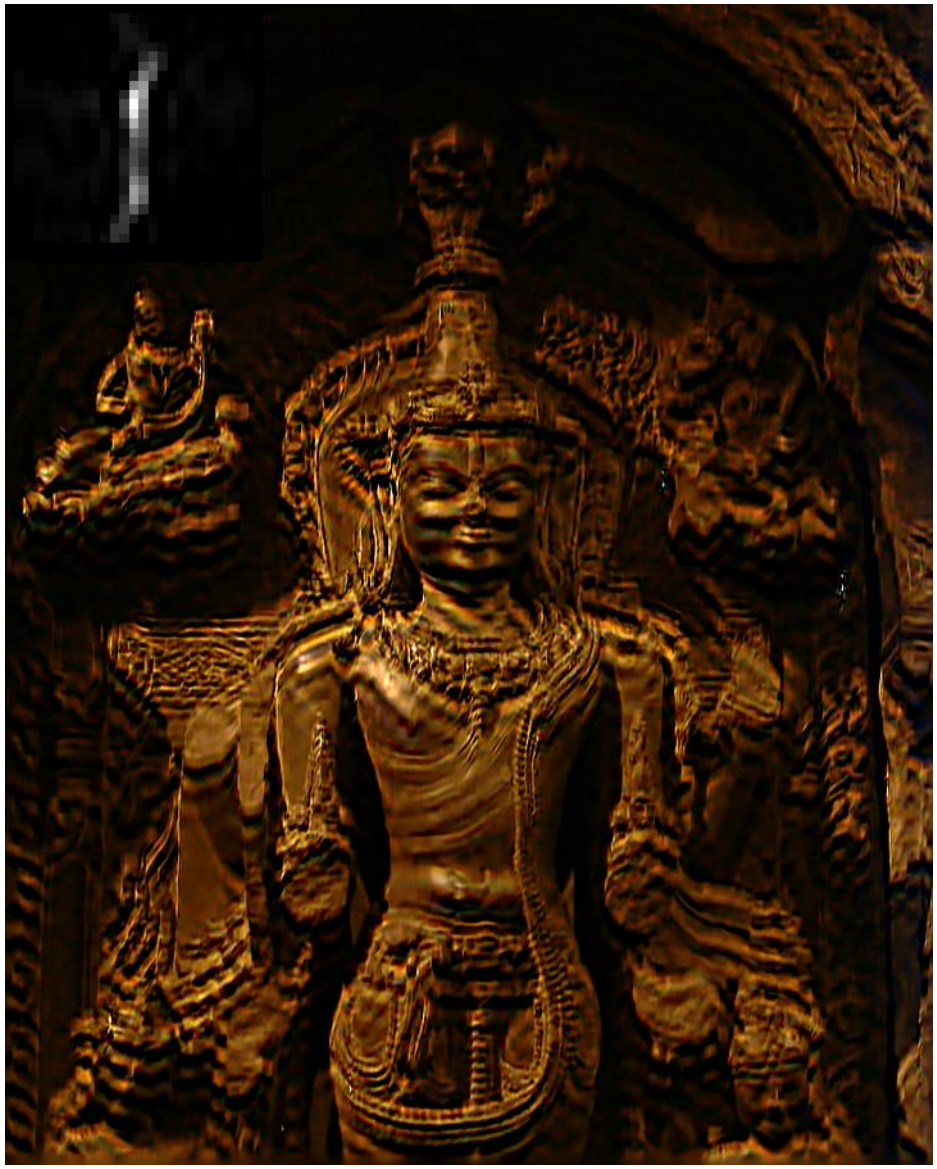


Real Photo 1, Our-Synth (+ Zoran & Weiss)



Real Photo 2, input with unknown camera shake

Real Photo 2, Krishnan *et al* (+ Zoran & Weiss)



Real Photo 2, Cho & Lee (+ Zoran & Weiss)

Real Photo 2, Xu & Jia (+ Zoran & Weiss)

Real Photo 2, Our-Synth (+ Zoran & Weiss)

Real Photo 3
input with unknown camera shake

Real Photo 3
Our-Synth (+ Zoran & Weiss)

Real Photo 3
Krishnan *et al* (+ Zoran & Weiss)

Real Photo 3
Cho & Lee (+ Zoran & Weiss)

Real Photo 3
Xu & Jia (+ Zoran & Weiss)

Real Photo 4, input with unknown camera shake

Real Photo 4, Cho & Lee (+ Zoran & Weiss)

Real Photo 4, Xu & Jia (+ Zoran & Weiss)

Real Photo 4, Our-Synth (+ Zoran & Weiss)