Supplementary File to "External Prior Guided Internal Prior Learning for Real-World Noisy Image Denoising"

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In this supplementary file, we provide:

1) More results on the 15 cropped real-world noisy images in dataset [1];
2) More results on the 60 cropped real-world noisy images in dataset [1];
3) More results on the 1000 cropped real-world noisy images in dataset [2];
4) More results on the 100 cropped real-world noisy images in our new dataset.

I. MORE RESULTS ON THE 15 CROPPED REAL-WORLD NOISY IMAGES IN DATASET [1]

In this section, we provide more comparisons of the proposed method with the state-of-the-art denoising methods on the 15 cropped real-world noisy images used in [1]. In this dataset, each scene was shot 500 times under the same camera and camera setting. The mean image of the 500 shots is roughly taken as the "ground truth", with which the PSNR and SSIM [3] can be computed. The average SSIM results of GAT-BM3D [4], CBM3D [5], WNNM [6], TID [7], MLP [8], CSF [9], TNRD [10], DnCNN [11], NI [12], NC [13], [14], CC [1], and the proposed method are listed in Table I. As can be seen from Figures 1-2, our proposed method achieves visually more pleasing results than the the competing methods.

TABLE I: SSIM [3] results of different methods on 15 cropped real-world noisy images used in [1].

Setting	GAT-BM3D	CBM3D	WNNM	TID	MLP	CSF	TNRD	DnCNN	NI	NC	CC	Ours
	0.9126	0.9778	0.9673	0.9515	0.9695	0.9434	0.9742	0.9389	0.9600	0.9689	0.9678	**0.9813**
Canon 5D Mark III	0.8427	0.9552	0.9210	0.9041	0.9458	0.9011	0.9491	0.8989	0.9308	0.9427	0.9359	**0.9572**
ISO = 3200	0.8017	**0.9660**	0.9110	0.9354	0.9599	0.9037	0.9617	0.9182	0.9463	0.9476	0.9478	0.9643
	0.7845	0.9330	0.9281	0.8913	0.9481	0.8792	0.9494	0.9123	0.9413	0.9497	0.9484	**0.9535**
Nikon D600	0.9028	0.9168	0.9432	0.8605	0.9469	0.9261	**0.9499**	0.8932	0.9251	0.9398	0.9293	0.9461
ISO = 3200	**0.9806**	0.9313	0.9737	0.8632	0.9726	0.9763	0.9742	0.8708	0.9481	0.9588	0.9799	0.9683
	0.8791	0.9339	0.9417	0.8832	0.9543	0.9148	0.9572	0.9060	0.9506	0.9533	0.9575	**0.9620**
Nikon D800	0.9534	0.9383	0.9748	0.8772	0.9743	0.9674	0.9774	0.8943	0.9615	0.9591	0.9767	**0.9779**
ISO = 1600	0.8795	0.9277	0.9311	0.8451	0.9354	0.9035	0.9410	0.8735	0.9229	0.9406	0.9427	**0.9531**
	0.9526	0.8866	**0.9656**	0.8356	0.9533	0.9654	0.9569	0.8463	0.9101	0.9466	0.9637	0.9613
Nikon D800	0.9078	0.8928	0.9416	0.7761	0.9381	0.9354	0.9394	0.8755	0.9194	0.9309	0.9477	**0.9521**
ISO = 3200	0.9707	0.8430	0.9664	0.7882	0.9548	**0.9712**	0.9576	0.7204	0.9001	0.9070	0.9544	0.9512
	0.8909	0.7952	0.9188	0.7118	0.8914	**0.9259**	0.8966	0.7847	0.7781	0.9024	0.9206	0.8958
Nikon D800	0.8328	0.8613	0.9050	0.7995	0.9137	0.9127	0.9142	0.8259	0.8649	0.9141	**0.9369**	0.9242
ISO = 6400	0.7773	0.8363	0.8818	0.7717	0.8958	0.8494	0.8960	0.7936	0.8295	0.8847	**0.9118**	0.9092
Average	0.8846	0.9063	0.9381	0.8463	0.9436	0.9250	0.9463	0.8635	0.9126	0.9364	0.9481	**0.9505**

II. MORE RESULTS ON THE 60 CROPPED REAL-WORLD NOISY IMAGES IN DATASET [1]

In this section, we provide more comparisons of the proposed method with the state-of-the-art denoising methods on the 60 real-world noisy images cropped from [1]. In this dataset, each scene was shot 500 times under the same camera and camera setting. The mean image of the 500 shots is roughly taken as the "ground truth", with which the PSNR and SSIM can be computed. The average SSIM results of GAT-BM3D [4], CBM3D [5], WNNM [6], MLP [8], CSF [9], TNRD [10], DnCNN [11], NI [12], NC [13], [14], and the proposed method are listed in Table II (CC is not compared since the code of [1] is not available). As can be seen from Figures 3-4, our proposed method achieves visually more pleasing results than the competing methods.

TABLE II: Average SSIM [3] results of different methods on 60 real-world noisy images cropped from [1].

Methods	GAT-BM3D	CBM3D	WNNM	MLP	CSF	TNRD	DnCNN	NI	NC	Ours
SSIM	0.9331	0.9251	0.9633	0.9653	0.9598	0.9670	0.8873	0.9241	0.9514	**0.9691**

III. More results on the 1000 cropped real-world noisy images in dataset [2]

In this section, we give more visual comparisons of the competing methods on the 1000 cropped real-world noisy images in [2]. In this dataset, each scene was shot twice, one at a high ISO value and the other at a low ISO value. The image captured at low ISO value (usually 100 or 125) is roughly taken as the "ground truth", with which the PSNR and SSIM [3] can be computed. The average SSIM results of GAT-BM3D [4], CBM3D [5], WNNM [6], MLP [8], CSF [9], TNRD [10], DnCNN [11], NI [12], NC [13], [14], and the proposed method are listed in Table III (CC is not compared since the code of [1] is not available). As can be seen from Figures 5-8, our proposed method achieves visually more pleasing results than the competing methods.

TABLE III: Average SSIM [3] results of different methods on 1000 real-world noisy images cropped from the dataset [2].

Methods	GAT-BM3D	CBM3D	WNNM	MLP	CSF	TNRD	DnCNN	NI	NC	Ours
SSIM	0.7564	0.7773	0.8012	0.8201	0.8128	0.8271	0.7897	0.8778	0.9013	**0.9101**

IV. More results on the 100 cropped real-world noisy images in our new dataset

In this section, we provide more comparisons of the proposed method with the state-of-the-art denoising methods on the 100 real-world noisy images cropped from the new dataset we constructed. In this dataset, each scene was shot 500 times under the same camera and camera setting. The mean image of the 500 shots is roughly taken as the "ground truth", with which the PSNR and SSIM can be computed. The average SSIM results of GAT-BM3D [4], CBM3D [5], WNNM [6], MLP [8], CSF [9], TNRD [10], DnCNN [11], NI [12], NC [13], [14], and the proposed method are listed in Table IV (CC is not compared since the code of [1] is not available). As can be seen from Figures 9-10, our proposed method achieves visually more pleasing results than the competing methods.

TABLE IV: Average SSIM [3] results of different methods on 100 real-world noisy images cropped from our new dataset.

Methods	GAT-BM3D	CBM3D	WNNM	MLP	CSF	TNRD	DnCNN	NI	NC	Ours
SSIM	0.8881	0.9494	0.9290	0.9453	0.9398	0.9486	0.8852	0.9190	0.9356	**0.9529**

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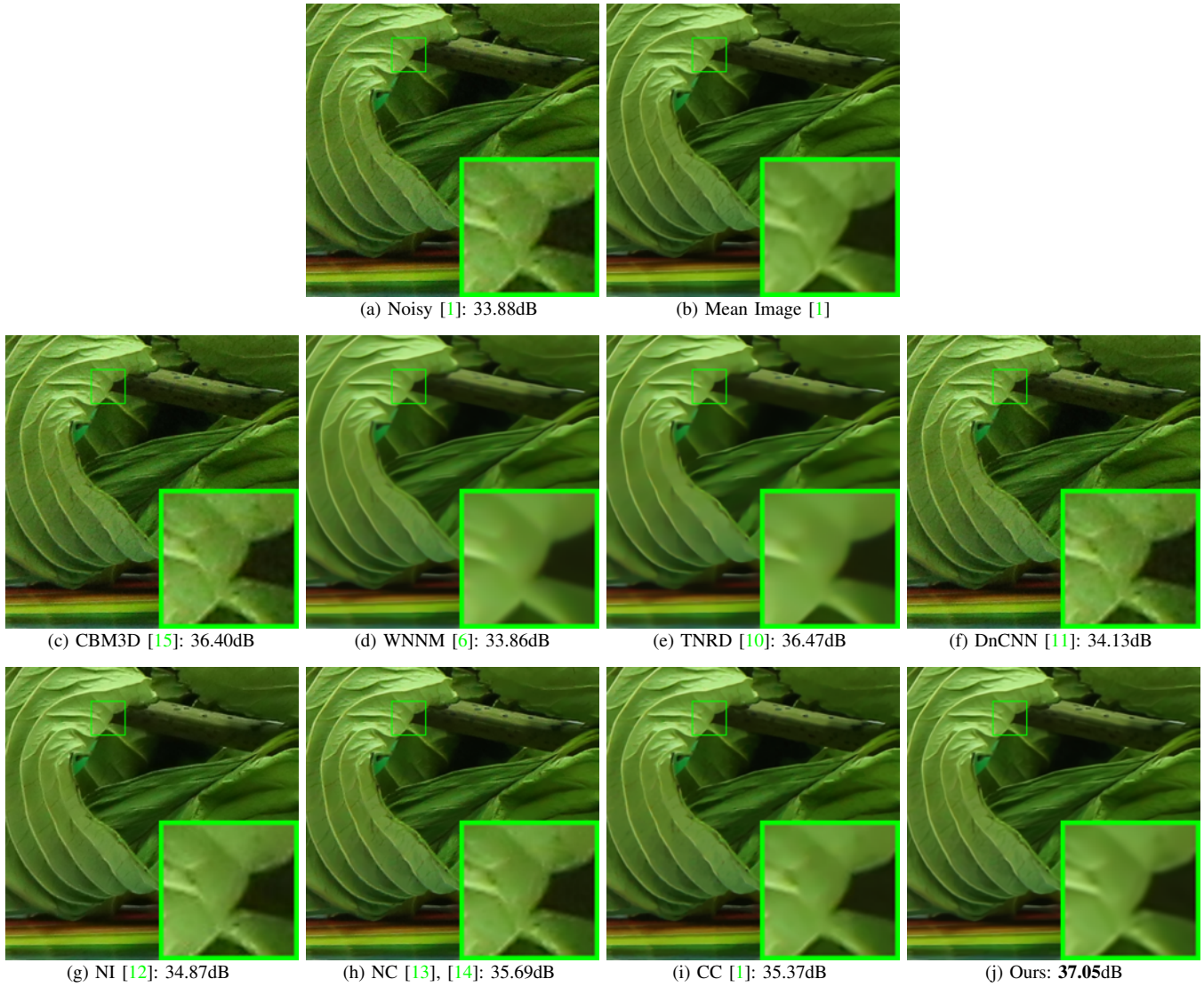
Fig. 1: Denoised images of a region cropped from the real-world noisy image "Canon 5D Mark 3 ISO 3200 2" [1] by different methods. The images are better to be zoomed-in on screen.
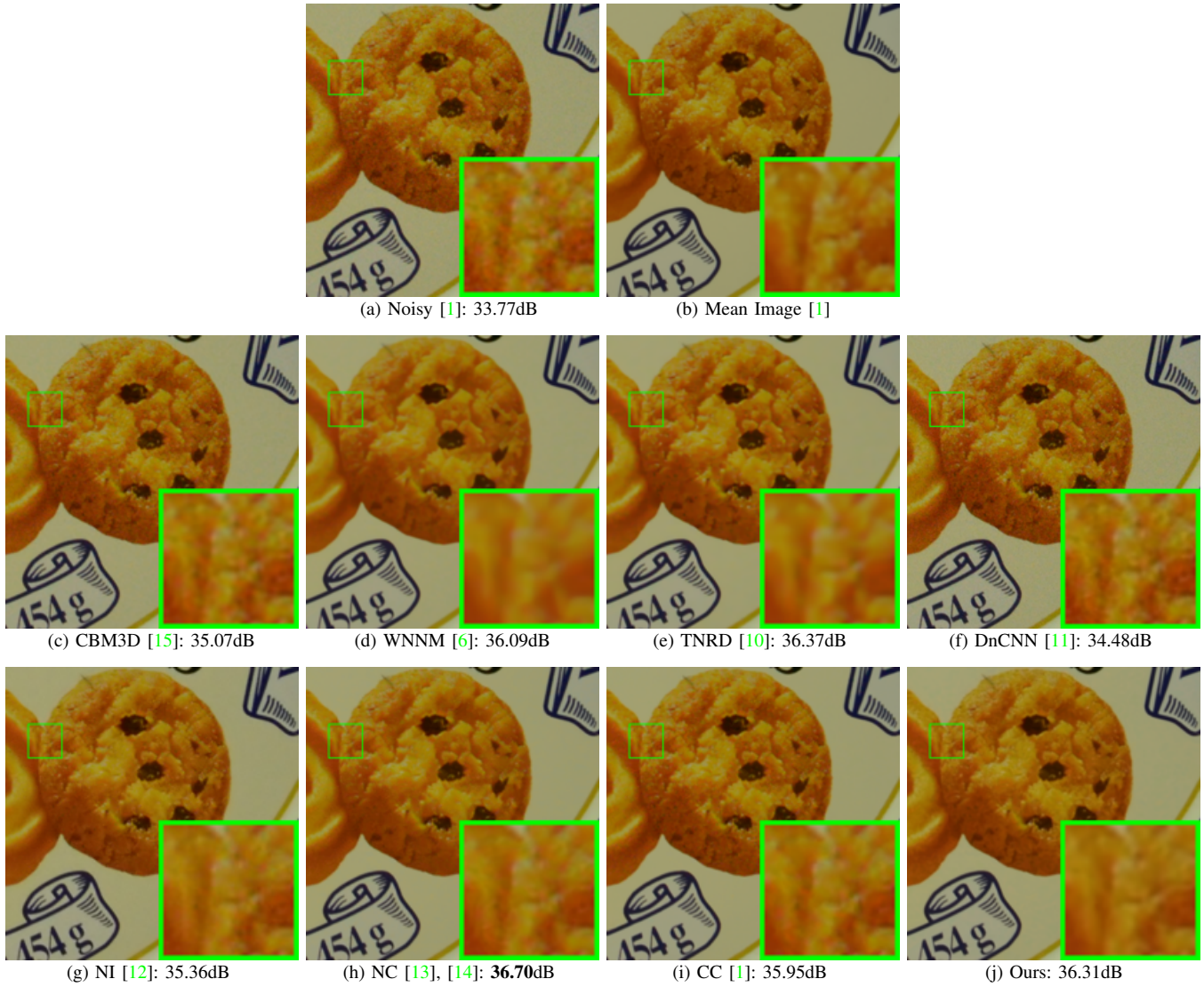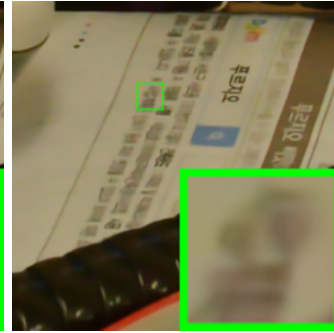
(a) Noisy [1]: 33.77dB

(b) Mean Image [1]

(c) CBM3D [15]: 35.07dB

(d) WNNM [6]: 36.09dB

(e) TNRD [10]: 36.37dB

(f) DnCNN [11]: 34.48dB

(g) NI [12]: 35.36dB

(h) NC [13], [14]: **36.70**dB

(i) CC [1]: 35.95dB

(j) Ours: 36.31dB

Fig. 2: Denoised images of a region cropped from the real-world noisy image "Nikon D600 ISO 3200 2" [1] by different methods. The images are better to be zoomed-in on screen.

(a) Noisy [1]: 35.21dB   (b) Mean Image [1]

(c) CBM3D [15]: 37.71dB   (d) WNNM [6]: 39.61dB   (e) CSF [9]: 38.14dB   (f) TNRD [10]: 39.04dB

(g) DnCNN [11]: 35.68dB   (h) NI [12]: 37.41dB   (i) NC [13], [14]: 39.53dB   (j) Ours: **39.96**dB

Fig. 3: Denoised images of a region cropped from the real-world noisy image "Nikon D800 ISO 1600 B2" [1] by different methods. The images are better viewed by zooming in on screen.
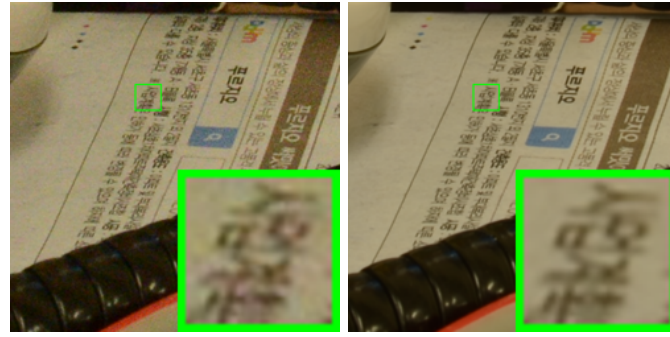
(a) Noisy [1]: 34.02dB   (b) Mean Image [1]
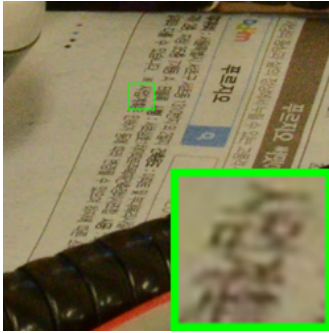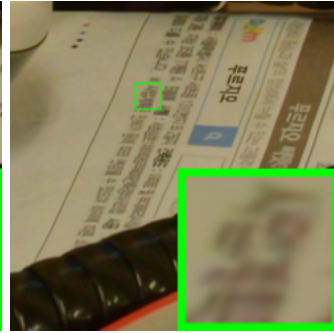
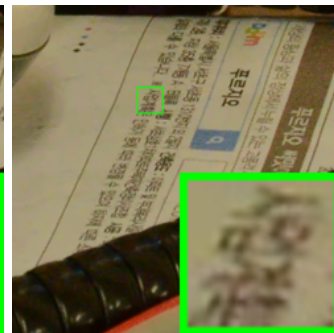(c) CBM3D [15]: 35.45dB   (d) WNNM [6]: 34.60dB   (e) CSF [9]: 32.94dB   (f) TNRD [10]: 33.48dB
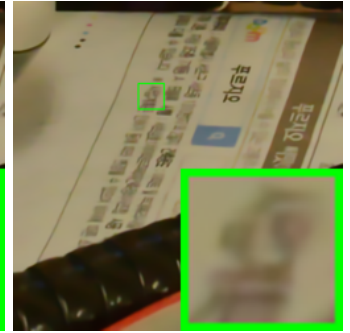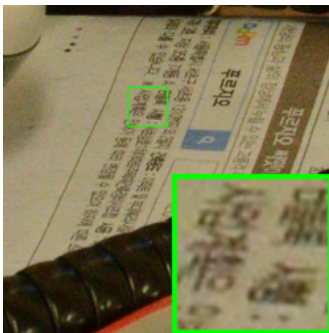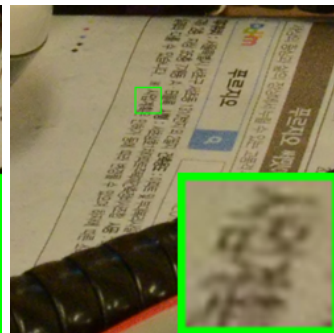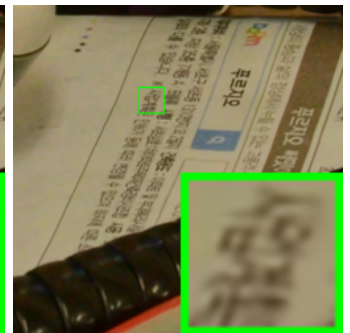
(g) DnCNN [11]: 34.30dB   (h) NI [12]: 36.04dB   (i) NC [13], [14]: 35.89dB   (j) Ours: **37.50**dB

Fig. 4: Denoised images of a region cropped from the real-world noisy image "Nikon D800 ISO 3200 A1" [1] by different methods. The images are better viewed by zooming in on screen.
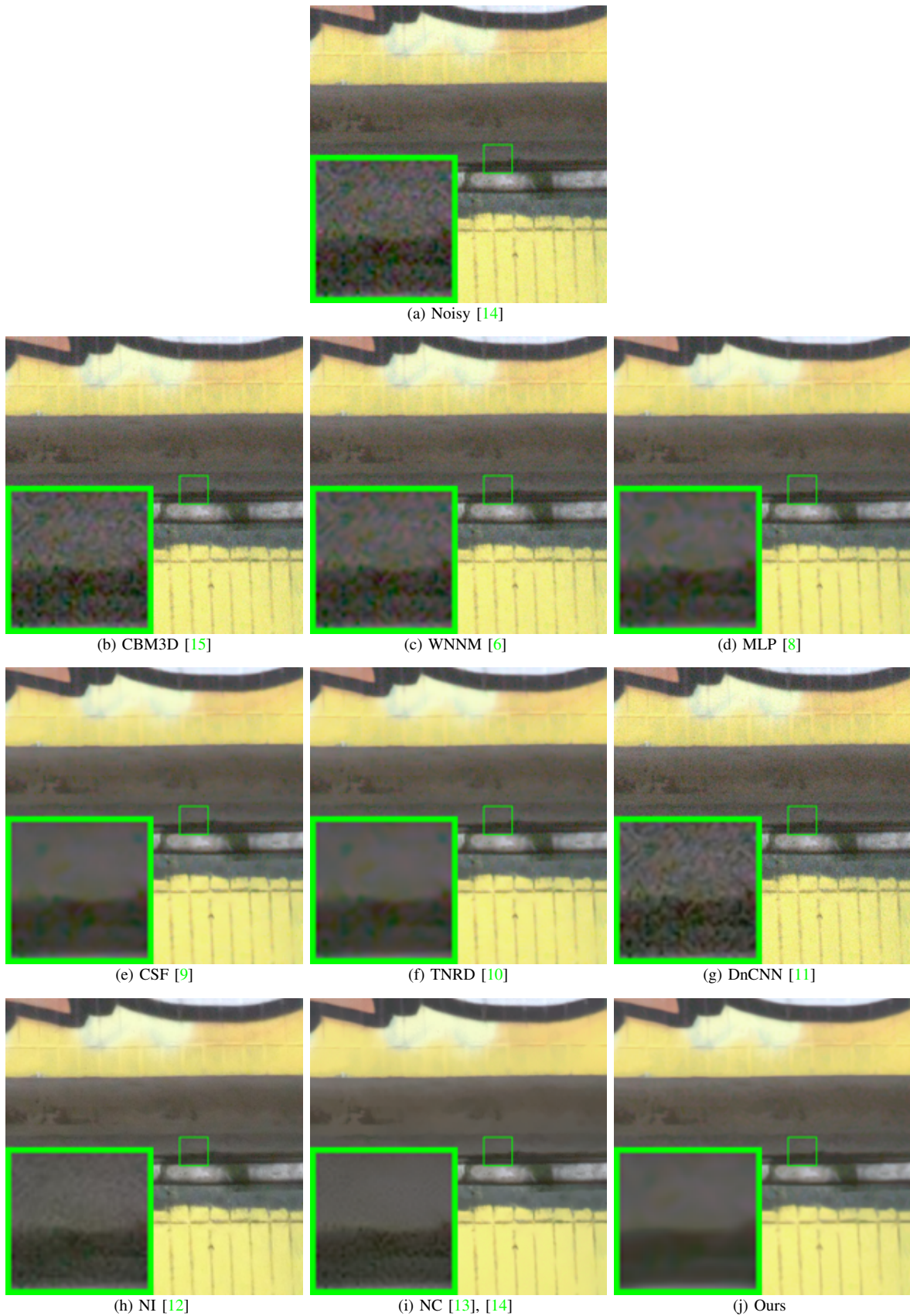
Fig. 5: Denoised images by different methods of the real-world noisy image "0002_10" captured by a Huawei Nexus 6P phone [2]. Note that the ground-truth clean image of the noisy input is not publicly released yet.

(a) Noisy [14]

(b) CBM3D [15]

(c) WNNM [6]

(d) MLP [8]

(e) CSF [9]

(f) TNRD [10]

(g) DnCNN [11]

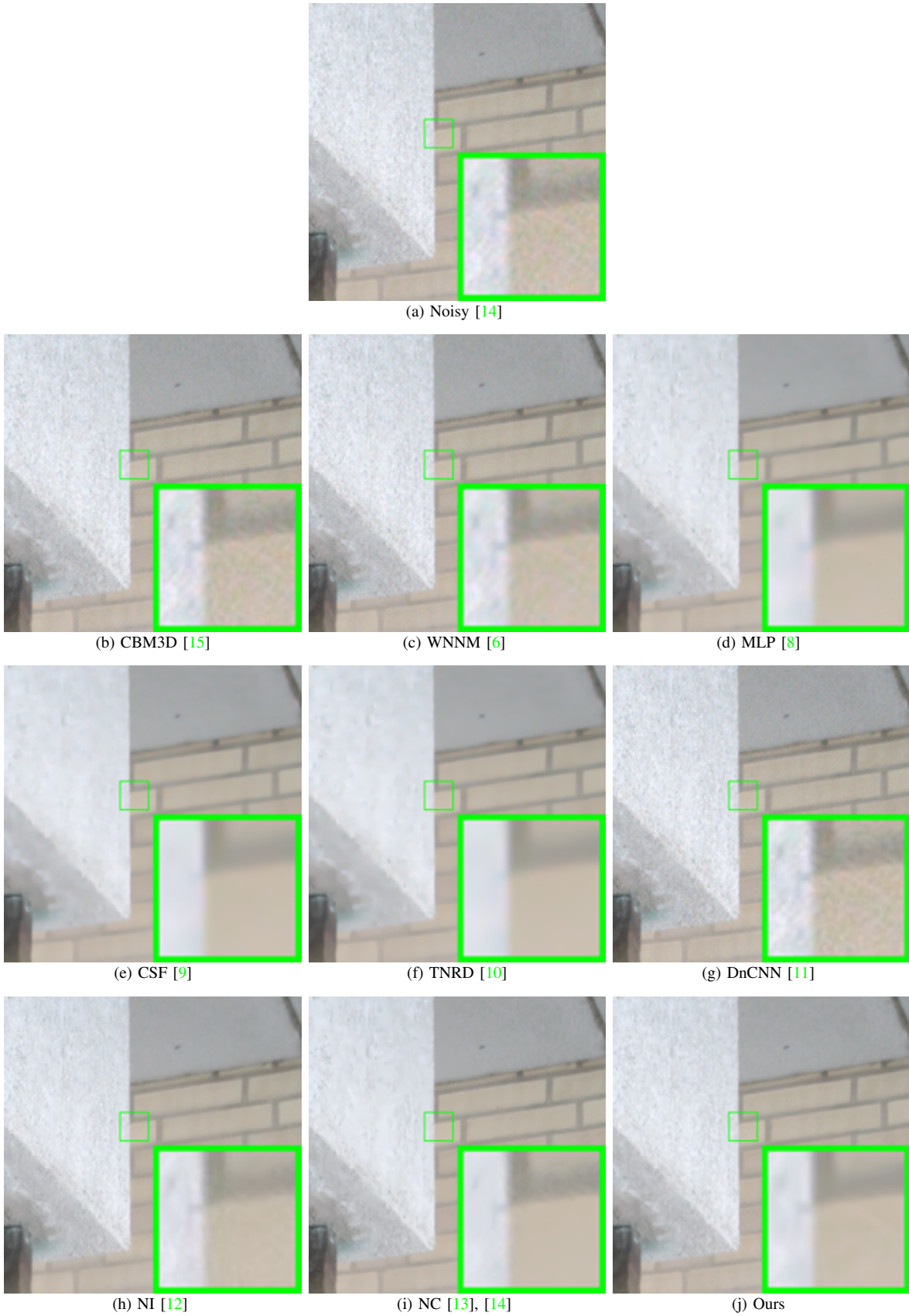(h) NI [12]

(i) NC [13], [14]

(j) Ours

Fig. 6: Denoised images by different methods of the real-world noisy image "0003_5" captured by a Huawei Nexus 6P phone [2]. Note that the ground-truth clean image of the noisy input is not publicly released yet.

(a) Noisy [14]

(b) CBM3D [15]

(c) WNNM [6]

(d) MLP [8]

(e) CSF [9]

(f) TNRD [10]

(g) DnCNN [11]

(h) NI [12]
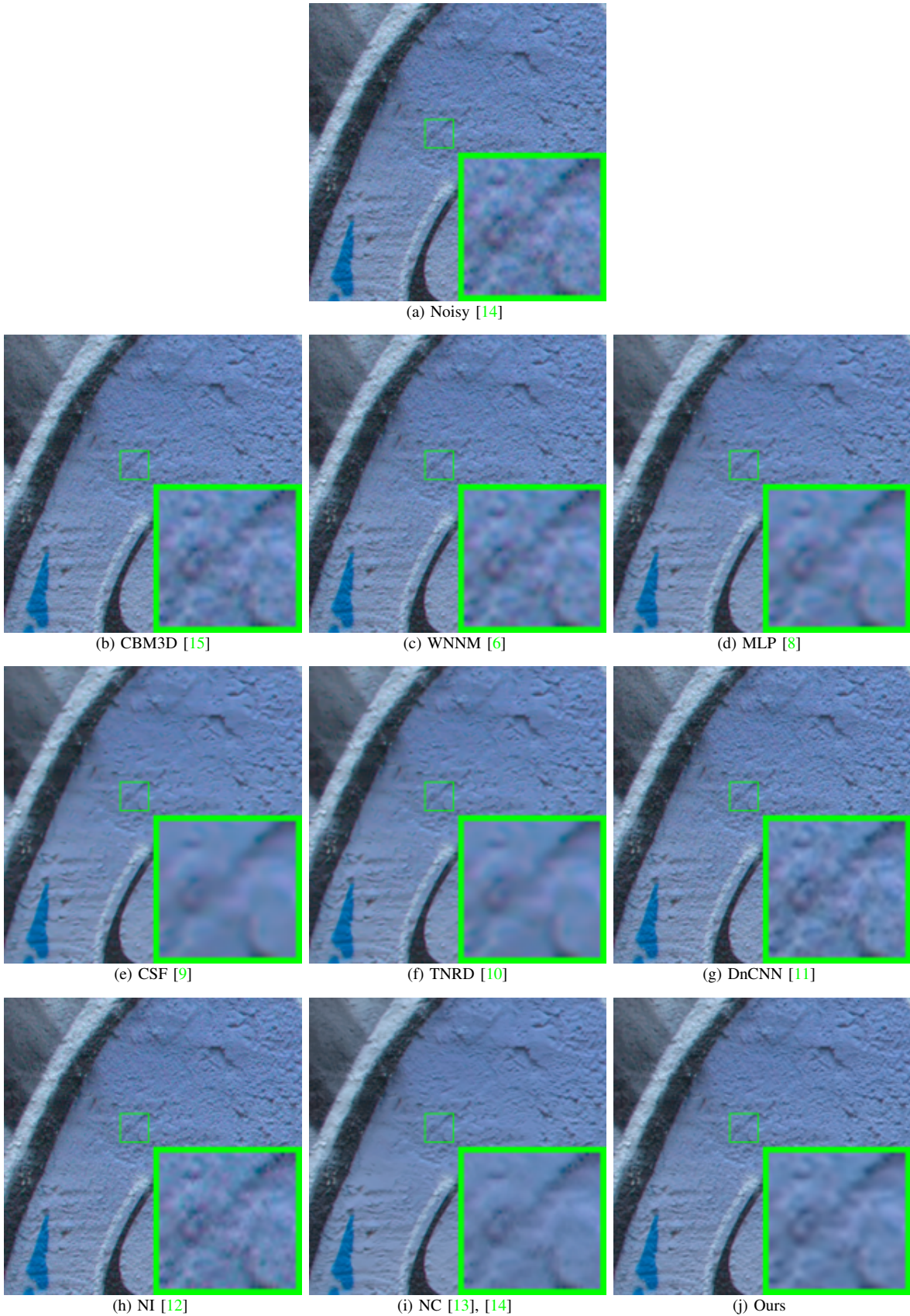
(i) NC [13], [14]

(j) Ours

Fig. 7: Denoised images by different methods of the real-world noisy image "0006_18" captured by a Sony A7R camera [2]. Note that the ground-truth clean image of the noisy input is not publicly released yet.
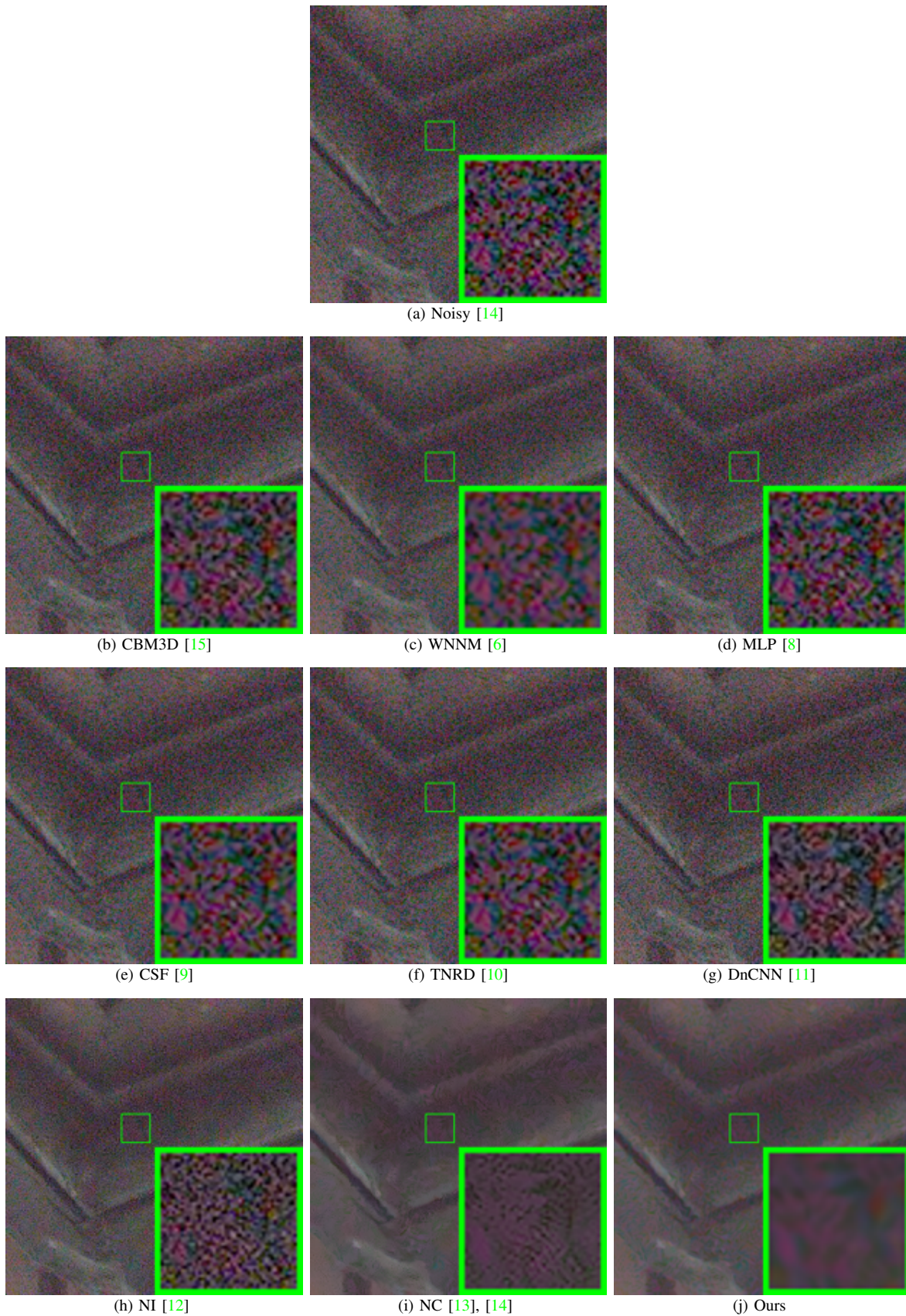
Fig. 8: Denoised images by different methods of the real-world noisy image "0049_4" captured by a Huawei Nexus 6P phone [2]. Note that the ground-truth clean image of the noisy input is not publicly released yet.

(a) Noisy [1]: 37.25dB   (b) Mean Image

(c) CBM3D [15]: 39.39dB   (d) WNNM [6]: 41.24dB   (e) CSF [9]: 41.71dB   (f) TNRD [10]: 41.87dB

(g) DnCNN [11]: 37.24dB   (h) NI [12]: 39.86dB   (i) NC [13], [14]: 39.54dB   (j) Ours: **41.95**dB
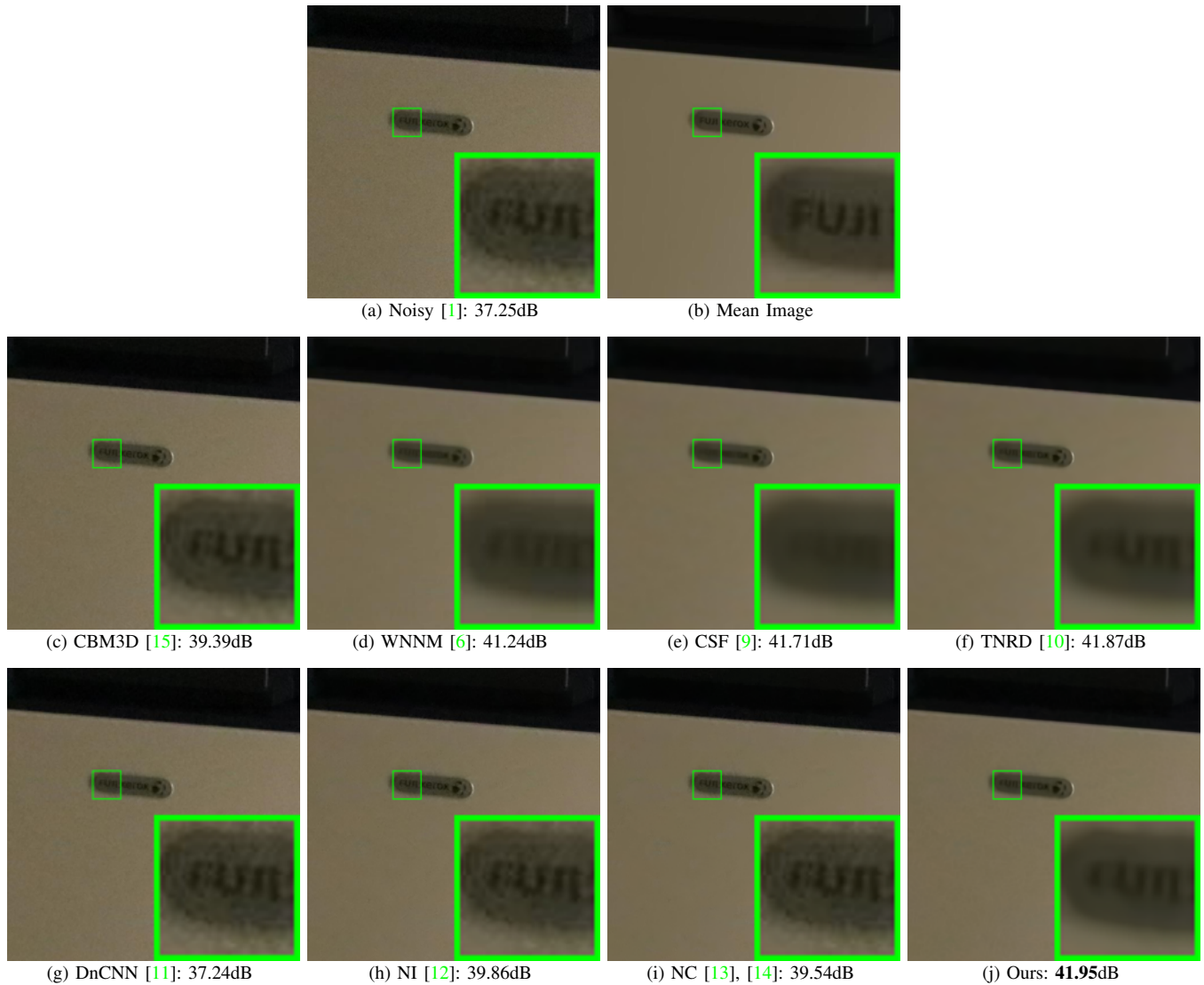
Fig. 9: Denoised images of a region cropped from the real-world noisy image "Canon 80D ISO 12800 IMG2360" in our new dataset by different methods. The images are better viewed by zooming in on screen.

(a) Noisy [1]: 37.35dB

(b) Mean Image

(c) CBM3D [15]: 41.95dB

(d) WNNM [6]: 41.92dB

(e) CSF [9]: 40.92dB

(f) TNRD [10]: 41.83dB

(g) DnCNN [11]: 37.35dB

(h) NI [12]: 38.28dB

(i) NC [13], [14]: 39.54dB
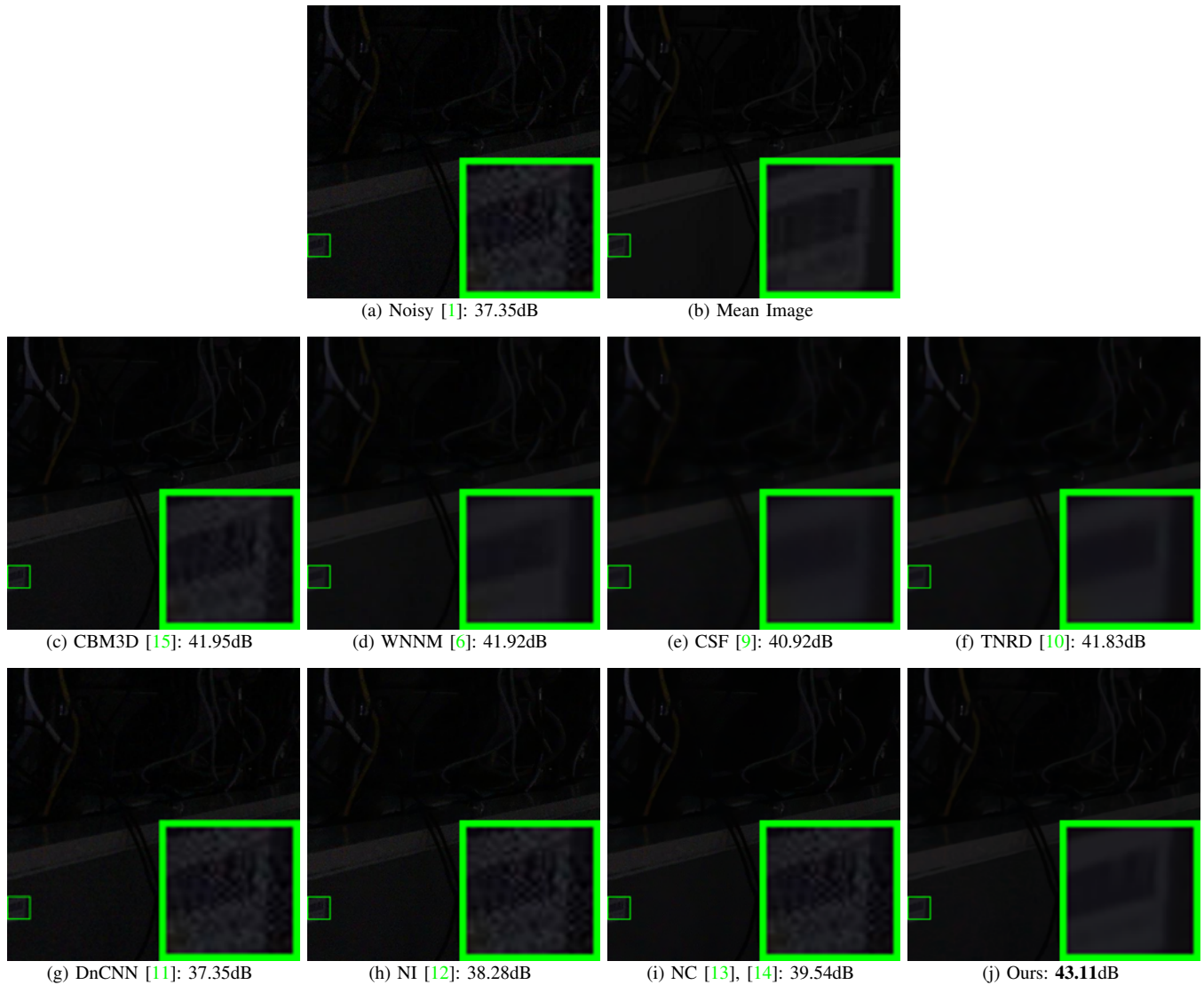
(j) Ours: **43.11**dB

Fig. 10: Denoised images of a region cropped from the real-world noisy image "SONY A7II ISO 6400 DSC03017" in our new dataset by different methods. The images are better viewed by zooming in on screen.