Supplementary material: Training deep learning based denoisers without ground truth data

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Table S1: Results of denoising methods on both BSD68 and Set12 datasets combined (performance in dB). For the DnCNN-BM3D method, the network was trained by optimizing the MSE between BM3D-denoised images and the output images of DnCNN. This method achieved the worst performance among all denoisers.

Methods	BM3D	DnCNN-BM3D	DnCNN-SURE	DnCNN-SURE-T	DnCNN-MSE-GT
$\sigma = 25$	28.77	28.70	**29.14**	**29.17**	29.38
$\sigma = 50$	25.78	25.56	**26.04**	**26.06**	26.35
$\sigma = 75$	24.30	24.17	**24.37**	**24.44**	24.76

Table S2: Results of denoising methods at low noise levels on the Set12 dataset (performance in dB).

Methods	BM3D	DnCNN-SURE	DnCNN-MSE-GT
$\sigma = 5$	38.03	**38.16**	38.23
$\sigma = 10$	34.37	**34.58**	34.72
$\sigma = 15$	**32.36**	**32.36**	32.78

Table S3: Results of denoising methods at low noise levels on the BSD68 dataset (performance in dB).

Methods	BM3D	DnCNN-SURE	DnCNN-MSE-GT
$\sigma = 5$	37.56	**37.81**	37.87
$\sigma = 10$	33.38	**33.72**	33.82
$\sigma = 15$	31.07	**31.34**	31.66

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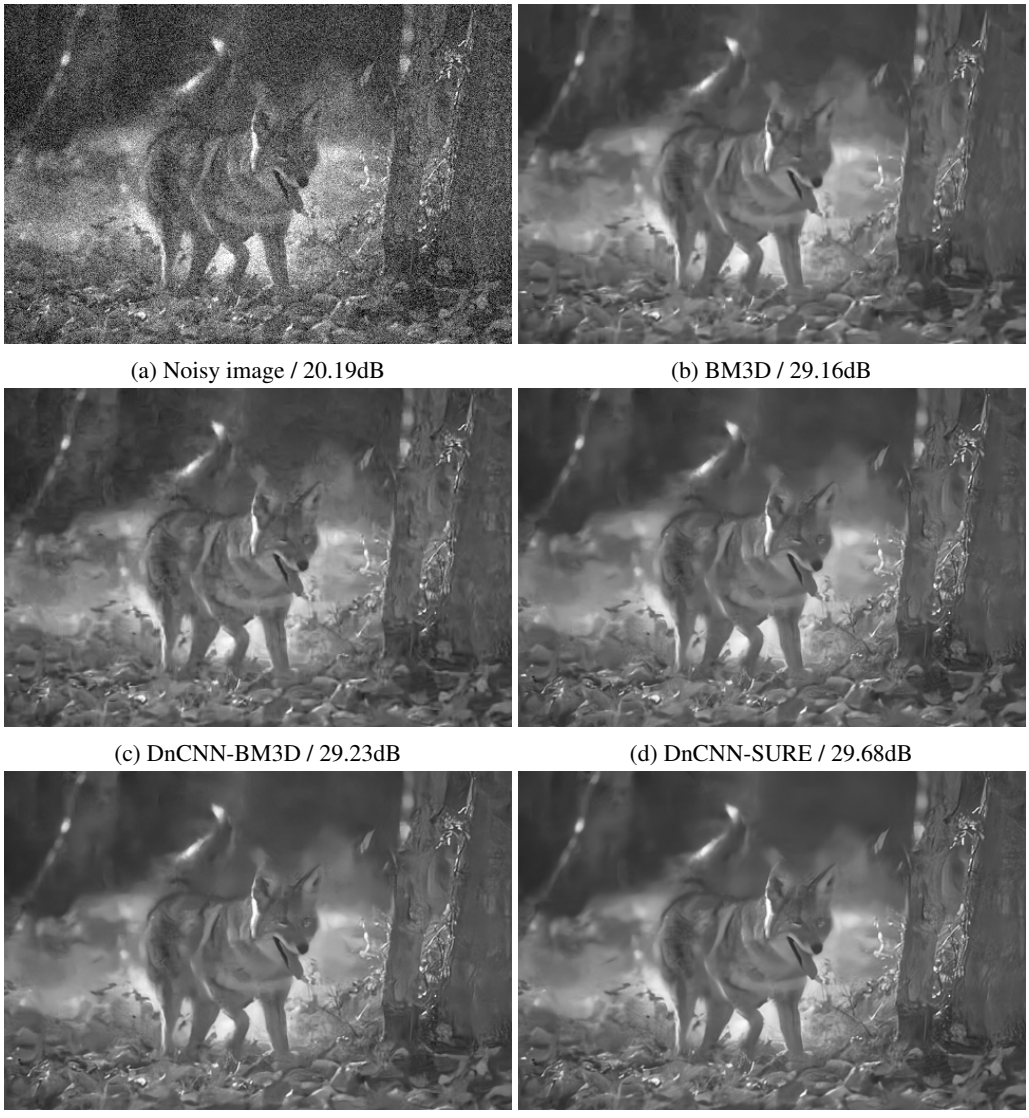


(a) Noisy image / 20.19dB (b) BM3D / 29.16dB

(c) DnCNN-BM3D / 29.23dB (d) DnCNN-SURE / 29.68dB

(e) DnCNN-SURE-T / 29.69dB (f) DnCNN-MSE-G / 29.81dB

Figure S1: Denoising results of an image from the BSD68 dataset at σ=25. Deep learning based methods yielded sharper images compared to BM3D.

(a) Noisy image / 14.76dB

(b) BM3D / 27.19dB

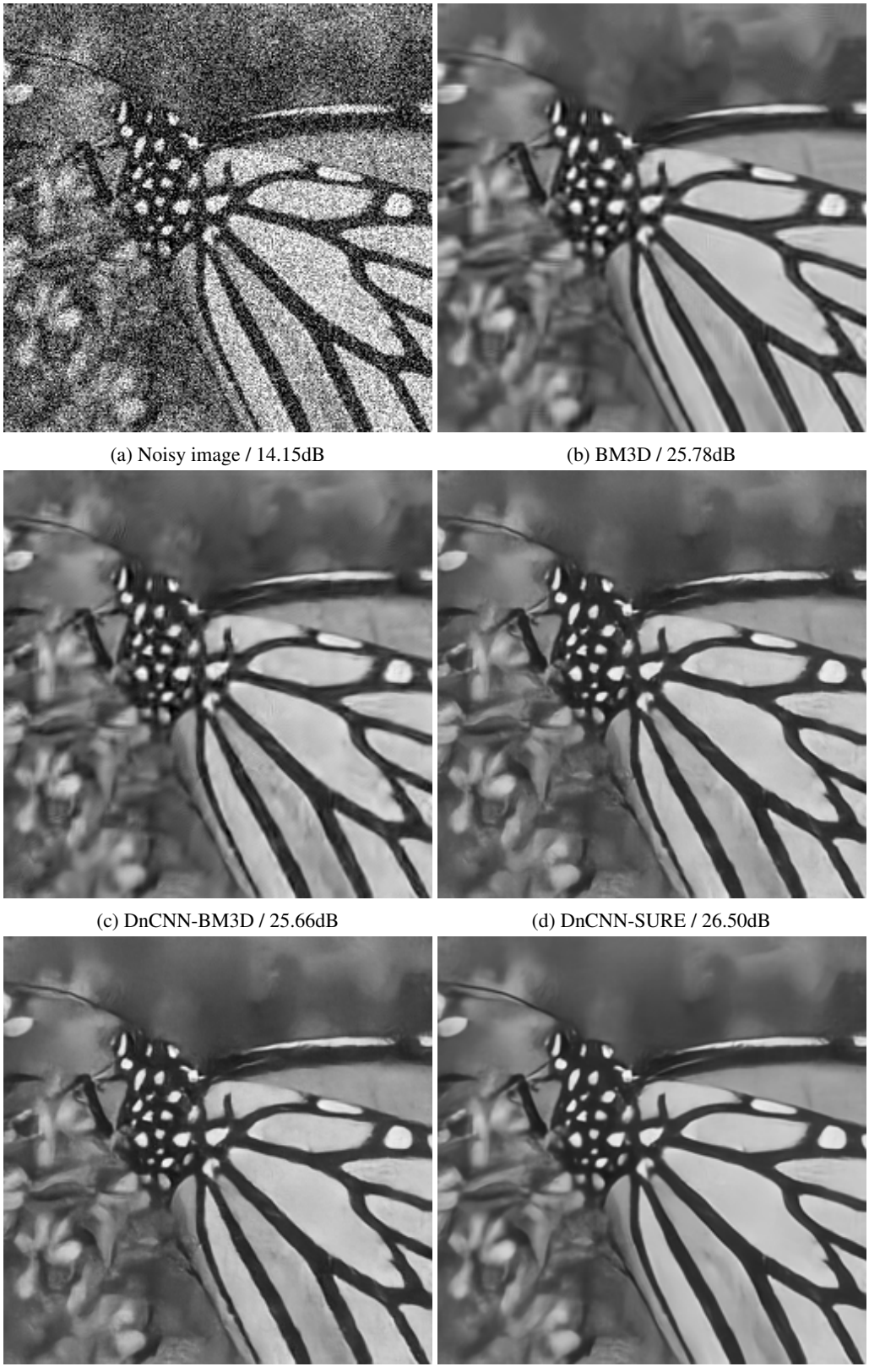
(c) DnCNN-BM3D / 25.30dB

(d) DnCNN-SURE / 24.86dB

(e) DnCNN-SURE-T / 25.23dB

(f) DnCNN-MSE-G / 26.17dB

Figure S2: Denoising results of "Barbara" image at σ=50. BM3D yielded exceptionally good performance on this image owing to many repeated patterns. It even outperformed DnCNN-MSE-G for this special case.



(a) Noisy image / 14.15dB

(b) BM3D / 25.78dB

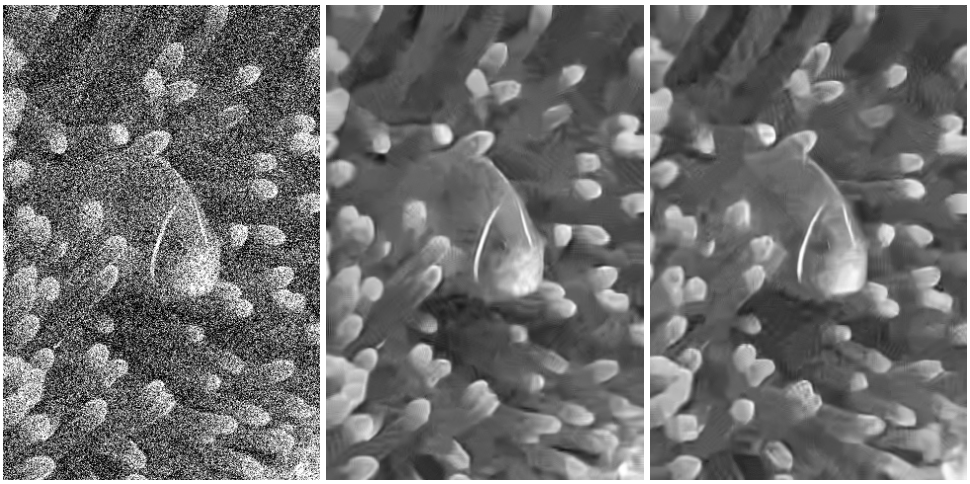
(c) DnCNN-BM3D / 25.66dB

(d) DnCNN-SURE / 26.50dB

(e) DnCNN-SURE-T / 26.53dB

(f) DnCNN-MSE-G / 26.95dB

Figure S3: Denoising results of "Monarch" image at σ=50. Deep learning based methods yielded sharper images compared to the BM3D.



(a) Noisy image / 11.77dB (b) BM3D / 26.21dB (c) DnCNN-BM3D / 25.83dB

(d) DnCNN-SURE / 26.64dB (e) DnCNN-SURE-T / 26.67dB (f) DnCNN-MSE-G / 27.10dB

Figure S4: Denoising results of an image from the BSD68 dataset at σ=75. Deep learning based methods yielded sharper images compared to the BM3D.