Deep learning for x-ray scatter correction in dedicated breast CT

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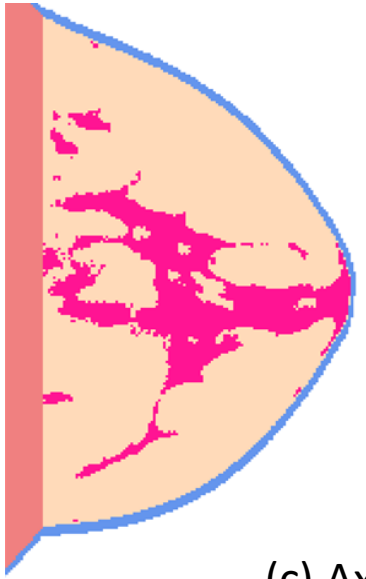
advanced
x-ray
tomographic
imaging

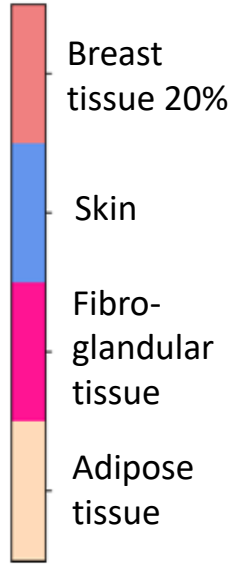
Radboudumc

(a) Sagittal

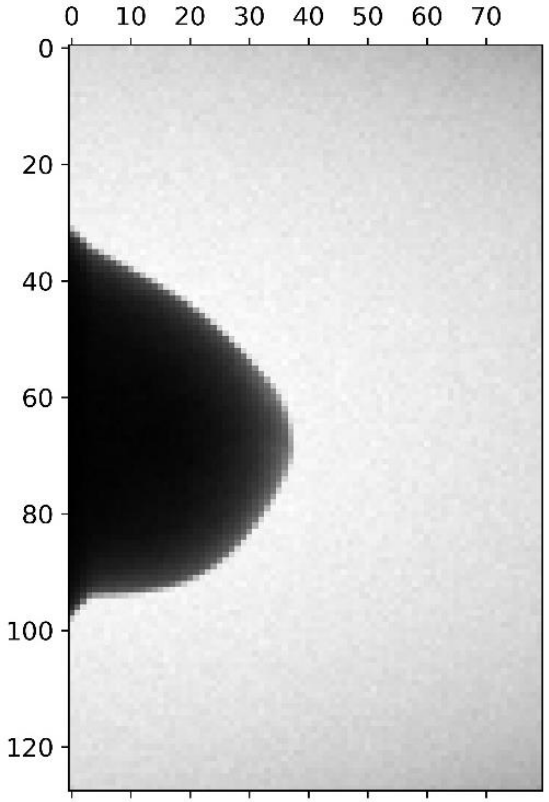
(b) Coronal

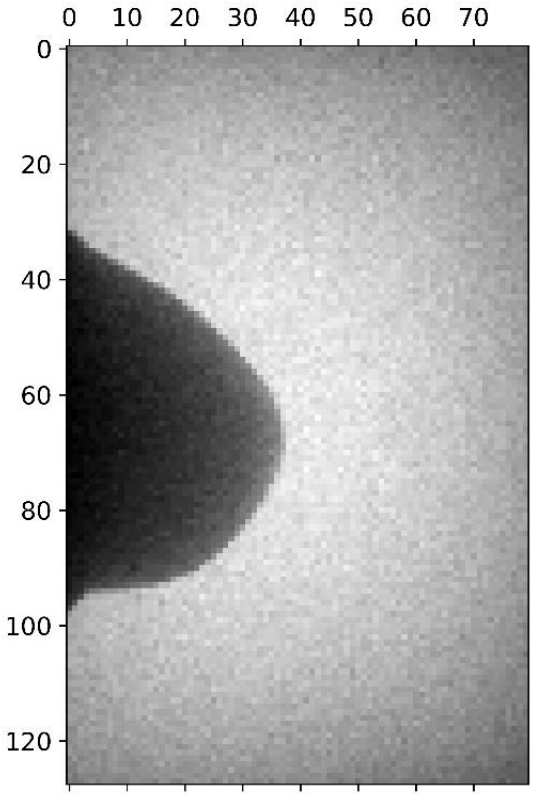


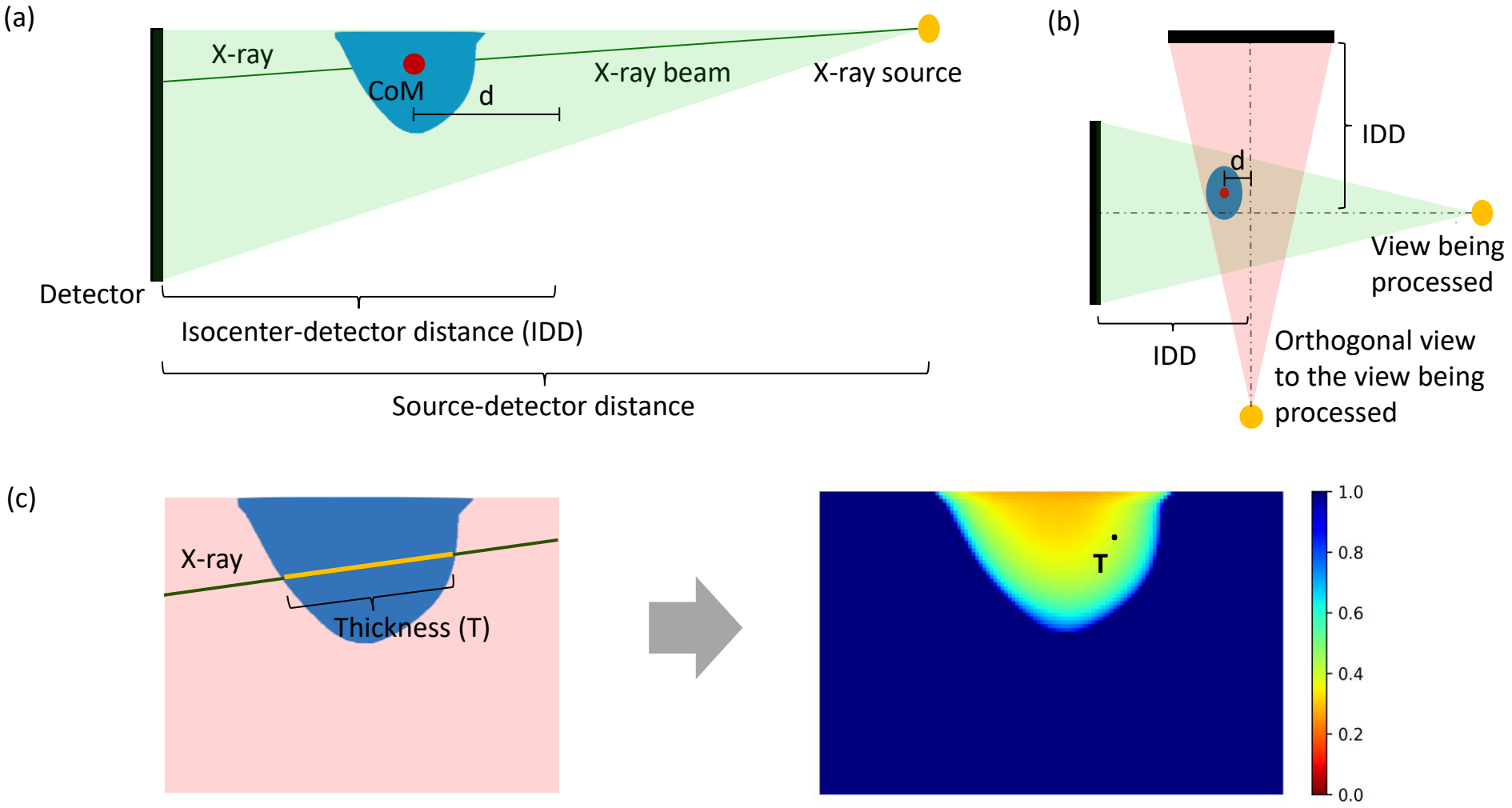
(c) Axial



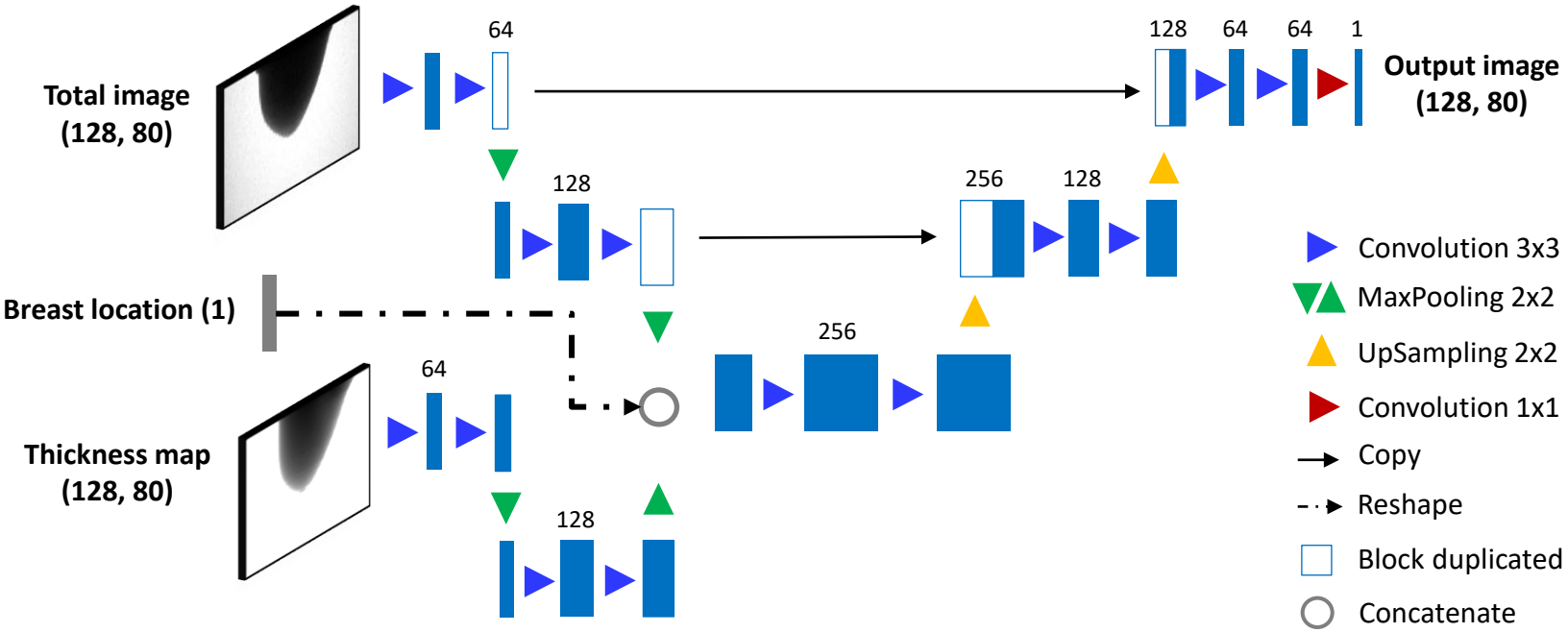
Primary and scatter Monte Carlo simulated images





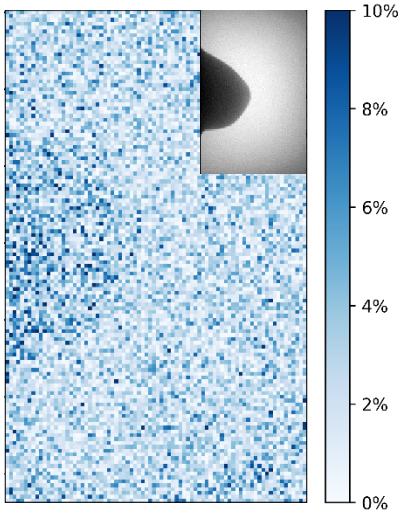

(a)
X-ray
CoM
d
X-ray beam
X-ray source
Detector
Isocenter-detector distance (IDD)
Source-detector distance
(b)
IDD
d
View being processed
IDD
Orthogonal view to the view being processed
(c)
X-ray
Thickness (T)
T
1.0
0.8
0.6
0.4
0.2
0.0

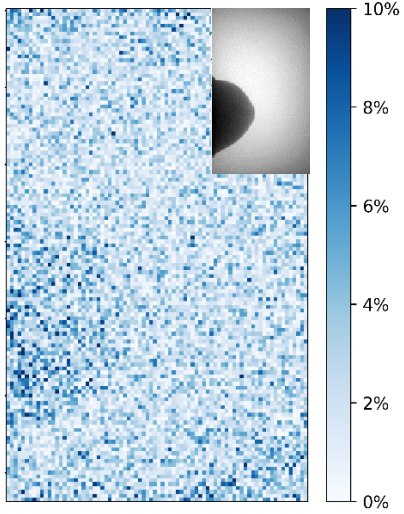
Deep learning architecture employed

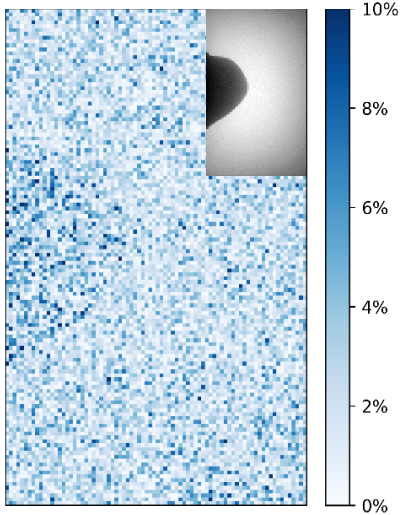


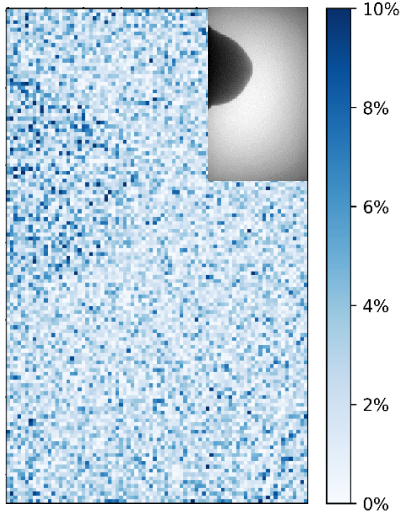
$$L = \frac{1}{n}\sum_{i=0}^{n}\left(10 * \left(y_{breast}^{(i)} - \hat{y}_{breast}^{(i)}\right)^2 + \left(y_{background}^{(i)} - \hat{y}_{background}^{(i)}\right)^2\right)$$

S052

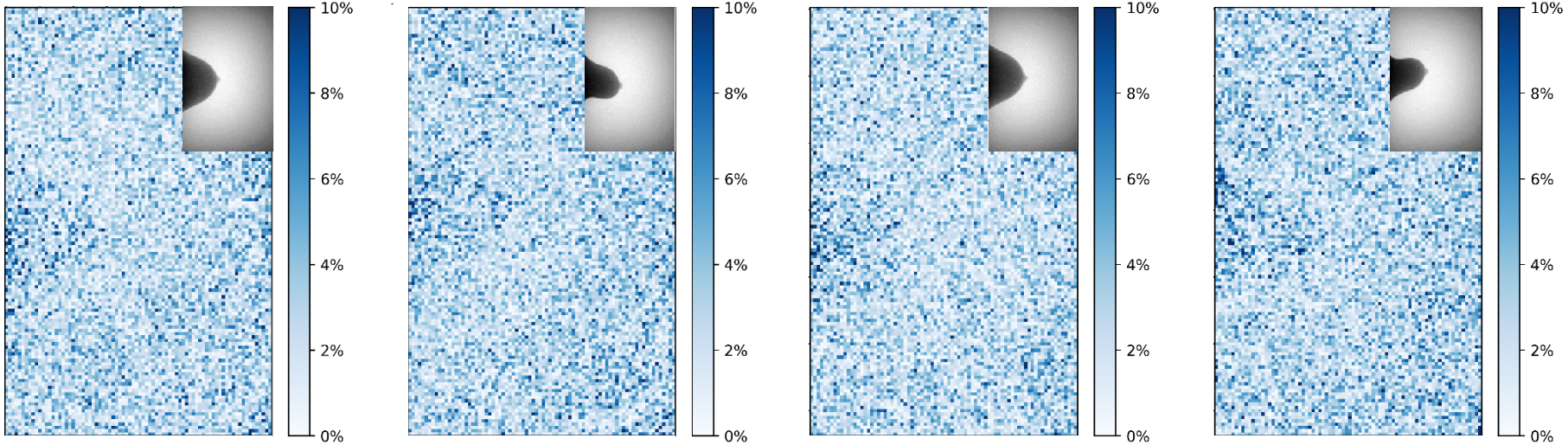


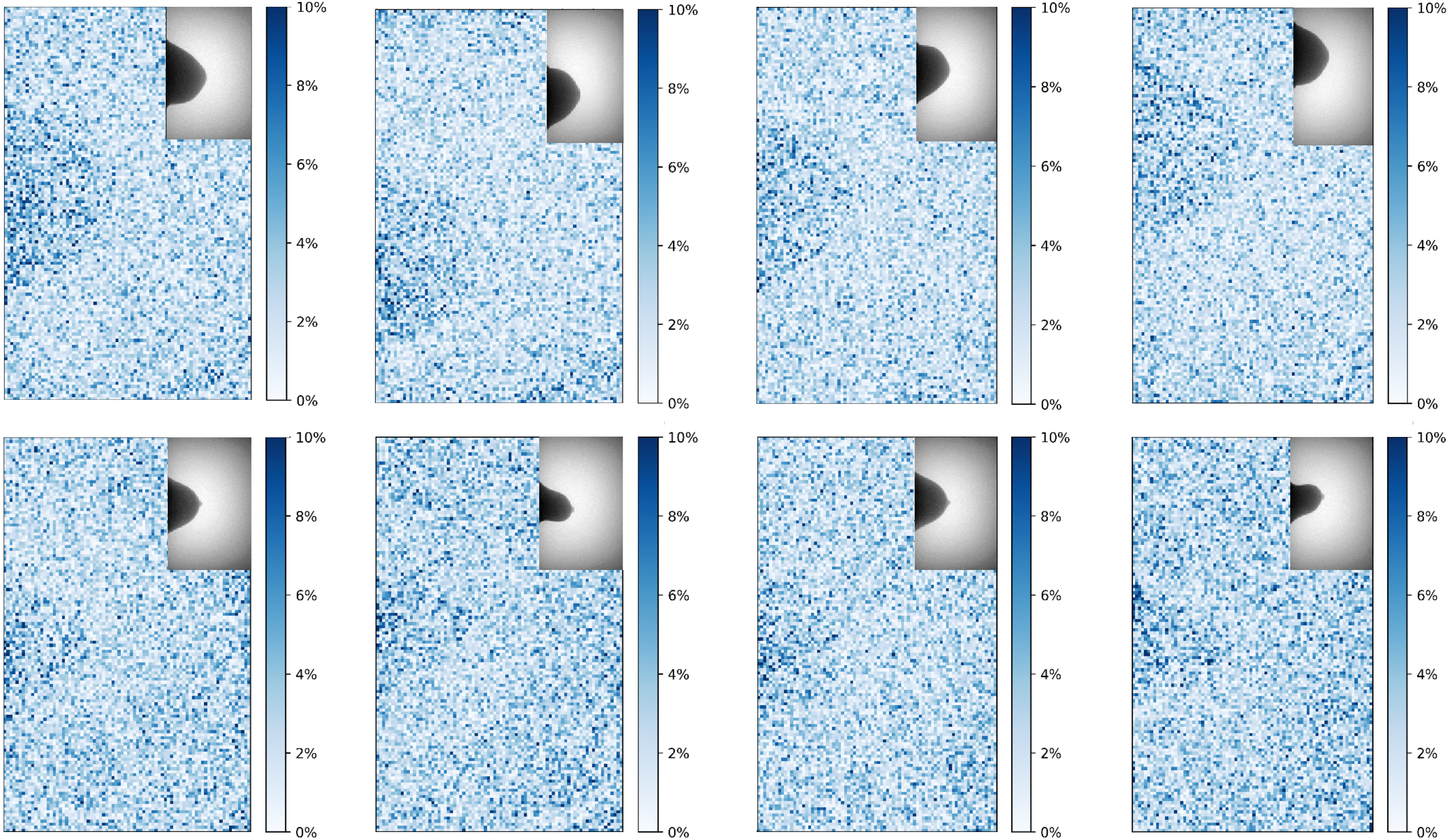


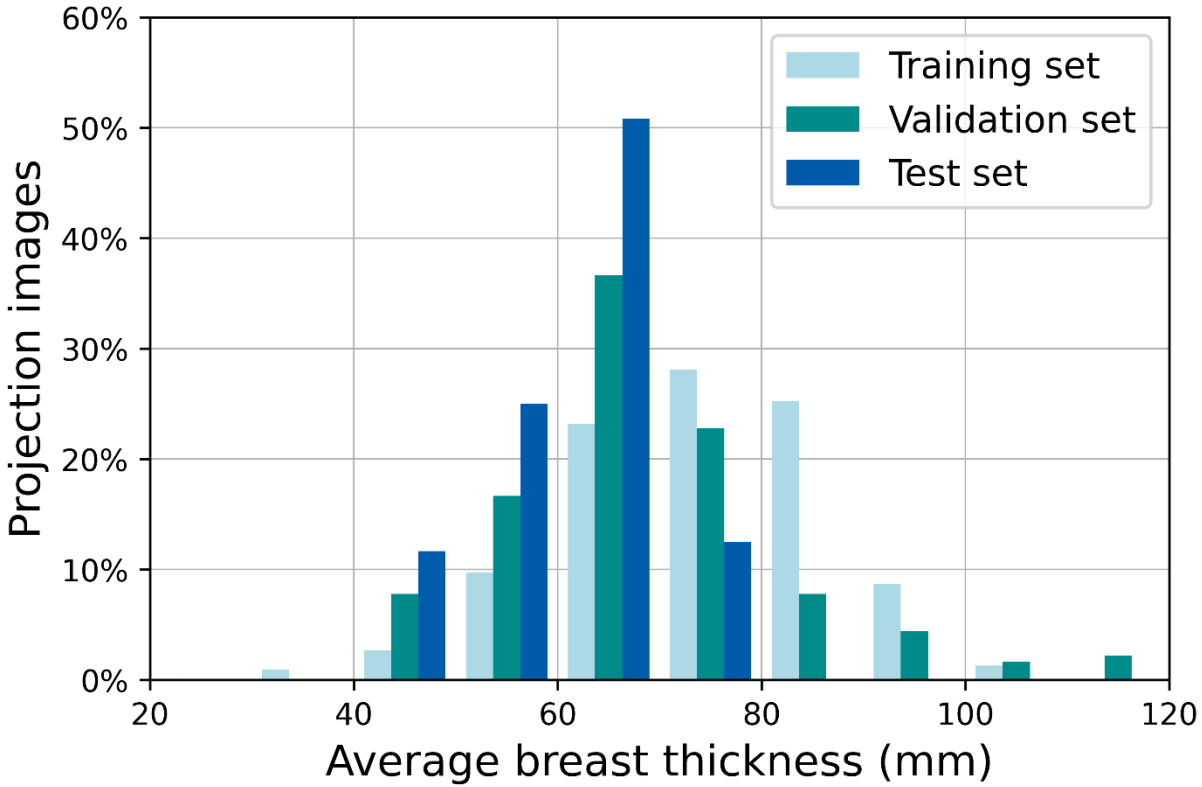


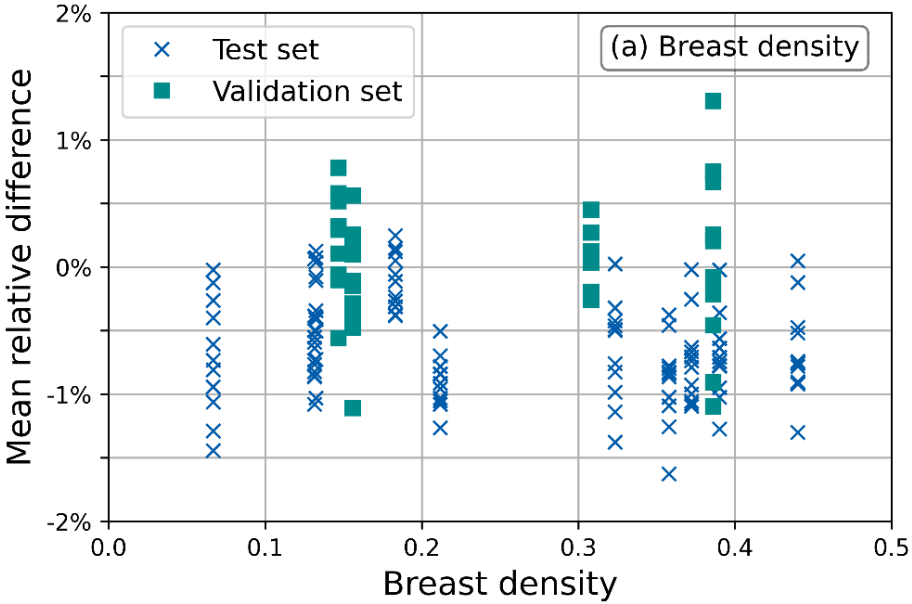


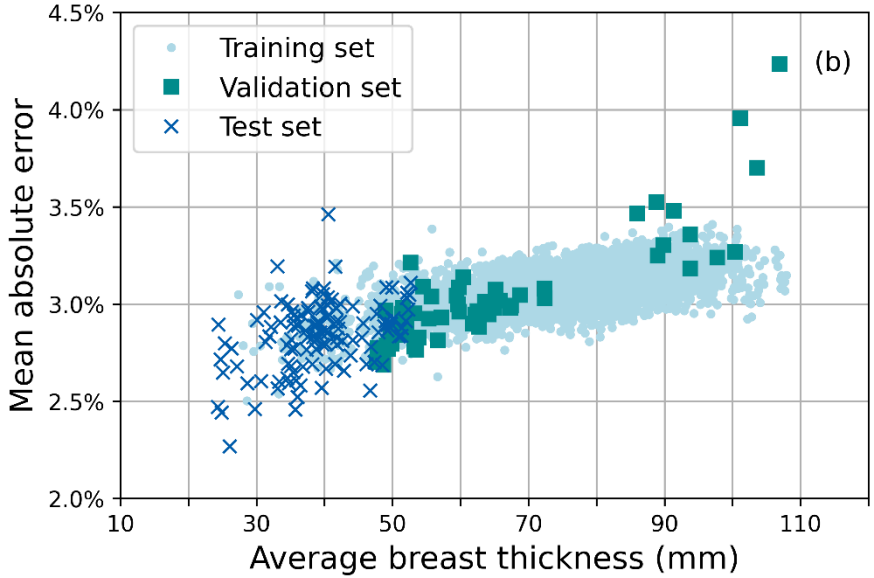
P33

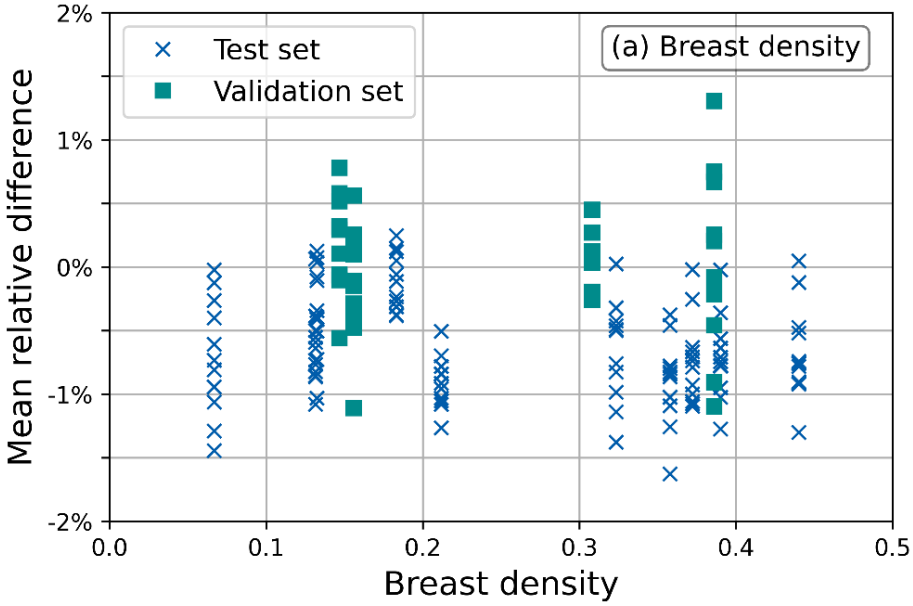


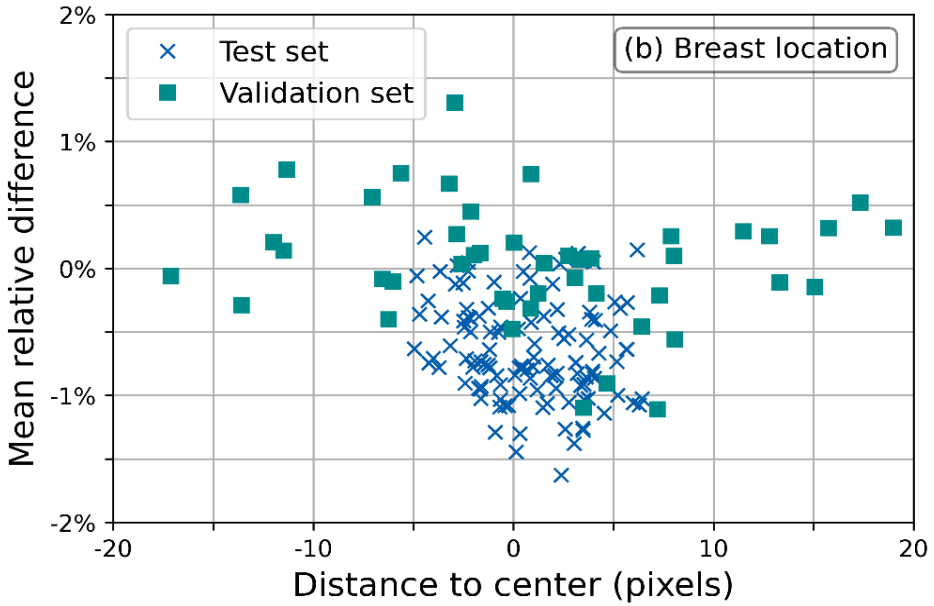

10%
8%
6%
4%
2%
0%

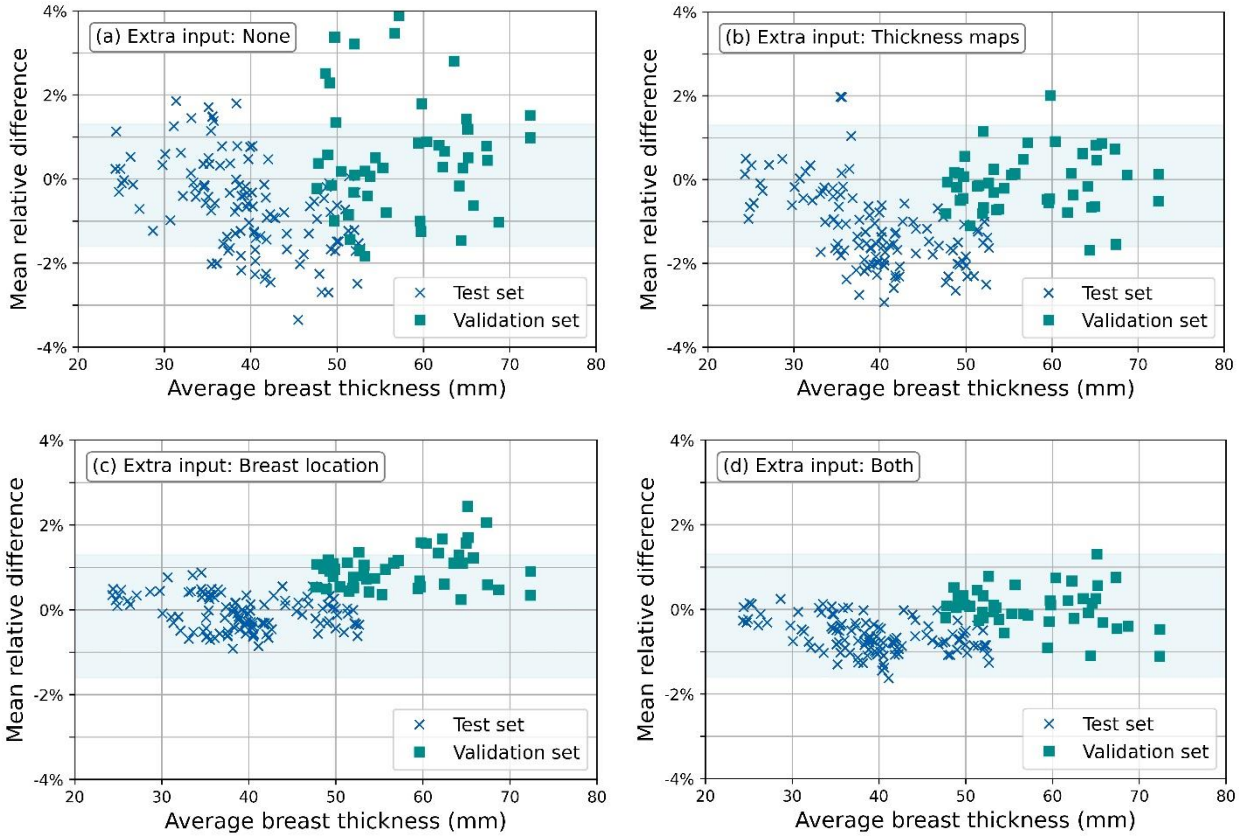

60%
50%
40%
30%
20%
10%
0%
Projection images
20
40
60
80
100
120
Average breast thickness (mm)
Training set
Validation set
Test set

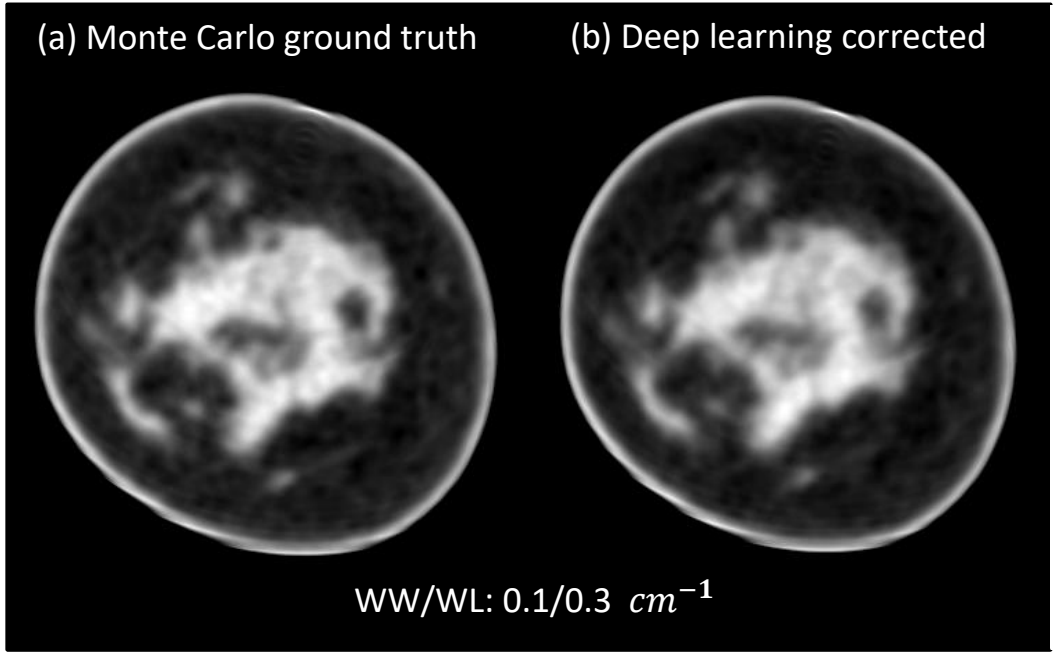

Test set
Validation set
(a) Breast density
Mean relative difference
Breast density
2%
1%
0%
-1%
-2%
0.0
0.1
0.2
0.3
0.4
0.5

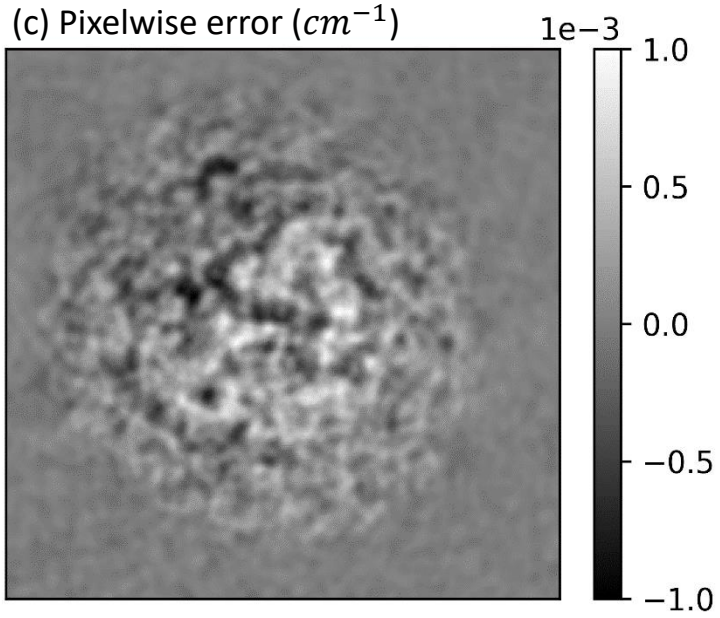

Training set
Validation set
Test set
(b)
Mean absolute error
Average breast thickness (mm)
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
10
30
50
70
90
110

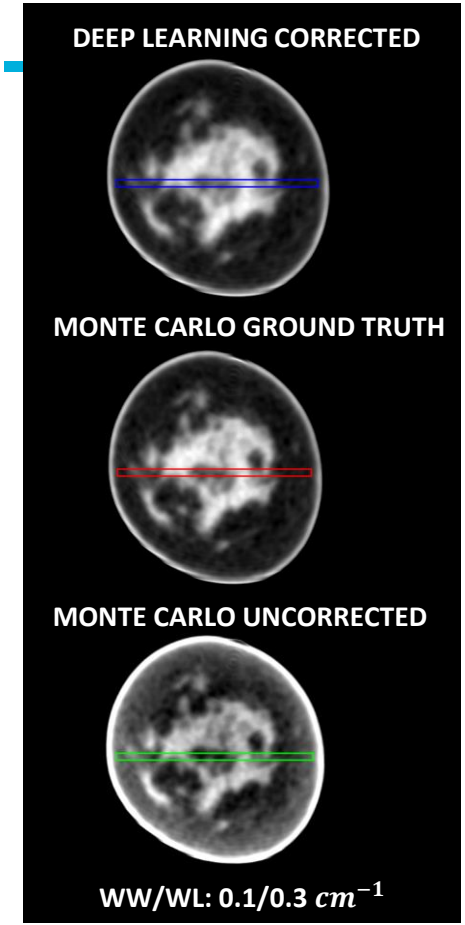

(a) Breast density
Test set
Validation set
Mean relative difference
Breast density
2%
1%
0%
-1%
-2%
0.0
0.1
0.2
0.3
0.4
0.5

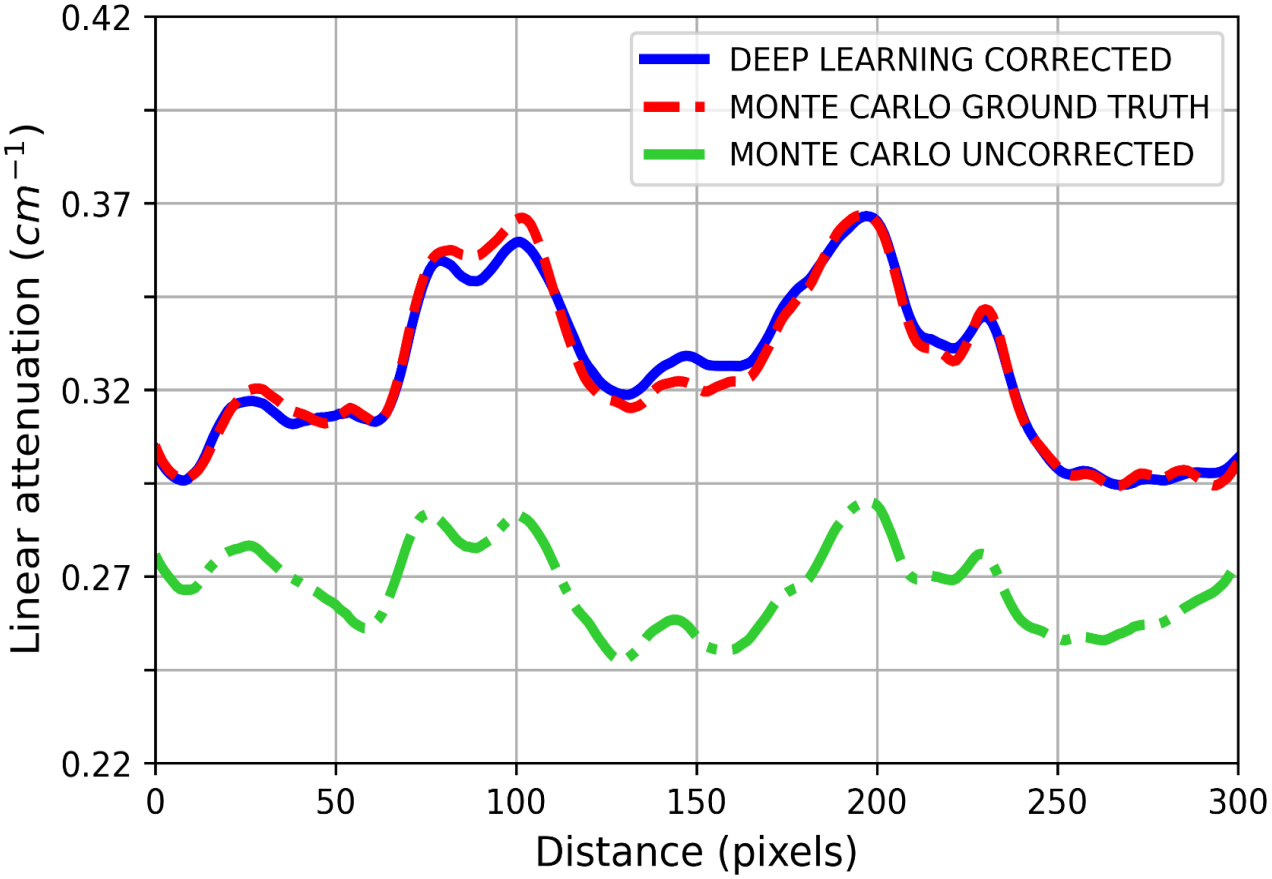

(b) Breast location
Test set
Validation set
Mean relative difference
Distance to center (pixels)
2%
1%
0%
-1%
-2%
-20
-10
0
10
20

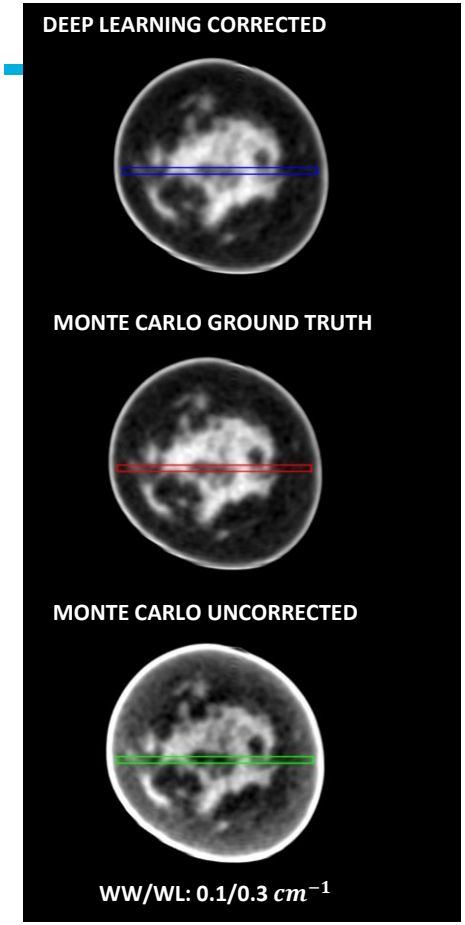

(a) Extra input: None
(b) Extra input: Thickness maps
(c) Extra input: Breast location
(d) Extra input: Both
Test set
Validation set
Mean relative difference
Average breast thickness (mm)
4%
2%
0%
-2%
-4%
20
30
40
50
60
70
80

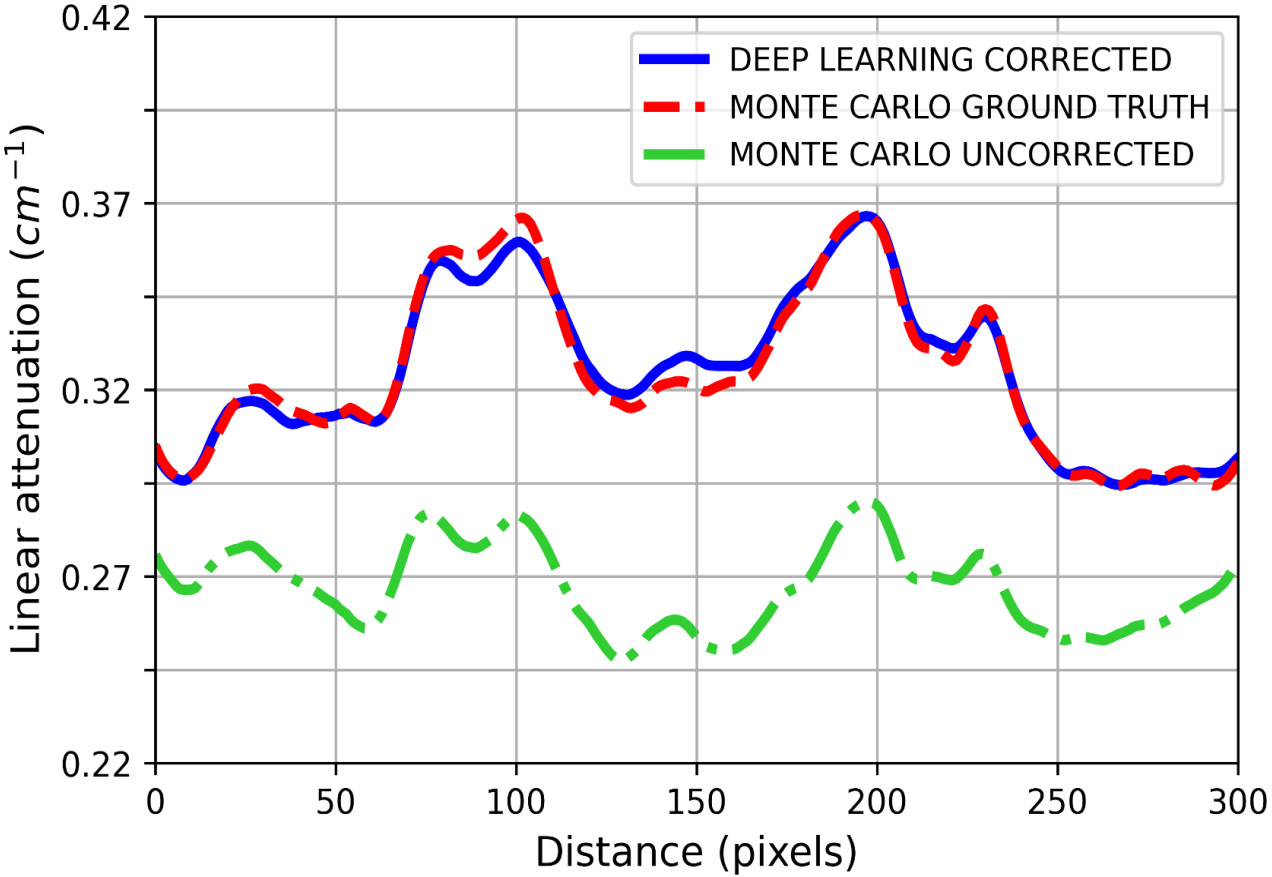

(a) Monte Carlo ground truth
(b) Deep learning corrected
WW/WL: 0.1/0.3 cm^{-1}

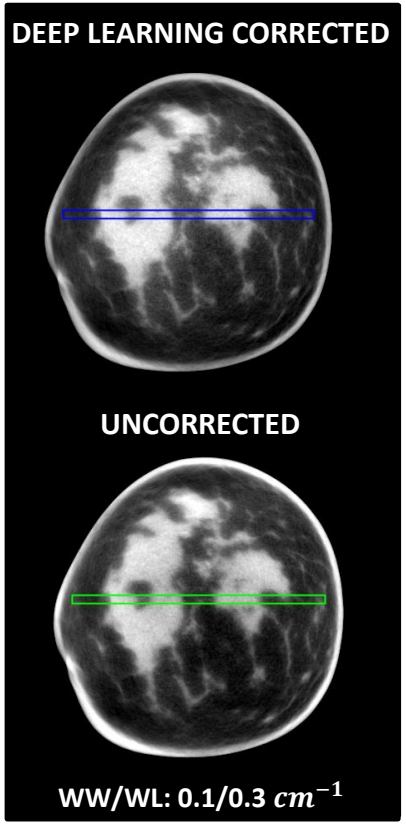

(c) Pixelwise error (cm^{-1})
1e−3
1.0
0.5
0.0
−0.5
−1.0

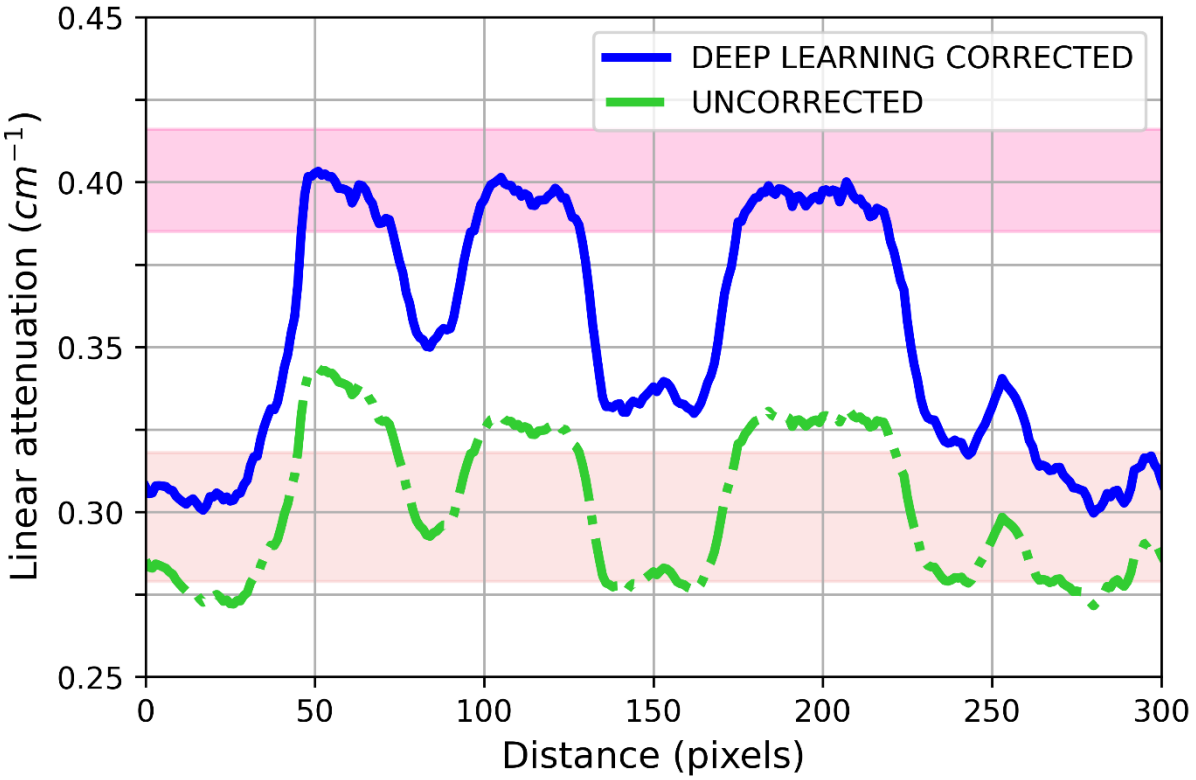

DEEP LEARNING CORRECTED
MONTE CARLO GROUND TRUTH
MONTE CARLO UNCORRECTED
WW/WL: 0.1/0.3 cm^{-1}

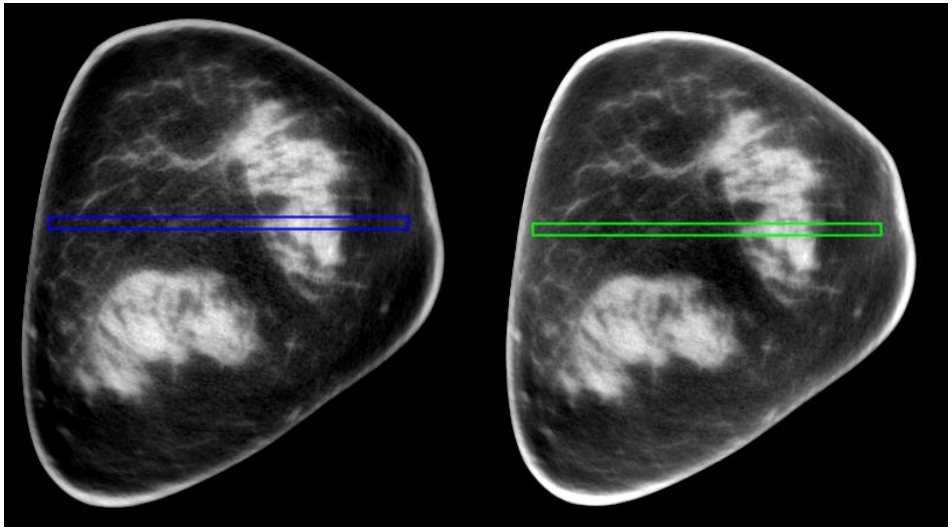

DEEP LEARNING CORRECTED
MONTE CARLO GROUND TRUTH
MONTE CARLO UNCORRECTED
Linear attenuation (cm^{-1})
0.42
0.37
0.32
0.27
0.22
0
50
100
150
200
250
300
Distance (pixels)

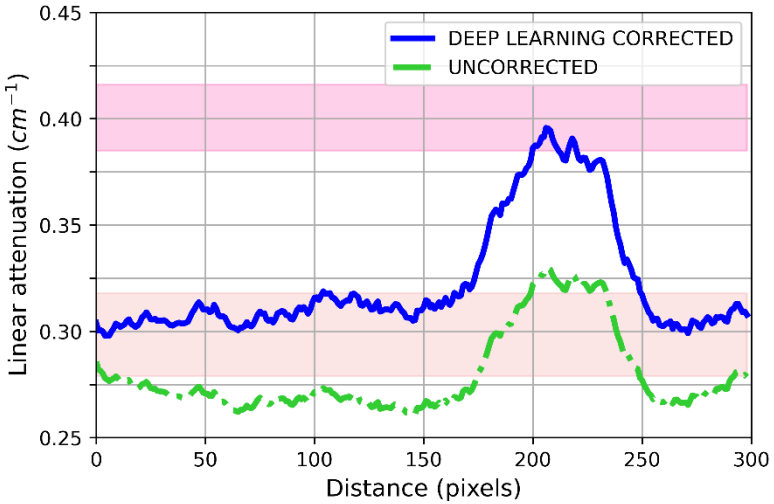

DEEP LEARNING CORRECTED
MONTE CARLO GROUND TRUTH
MONTE CARLO UNCORRECTED
WW/WL: 0.1/0.3 cm^{-1}

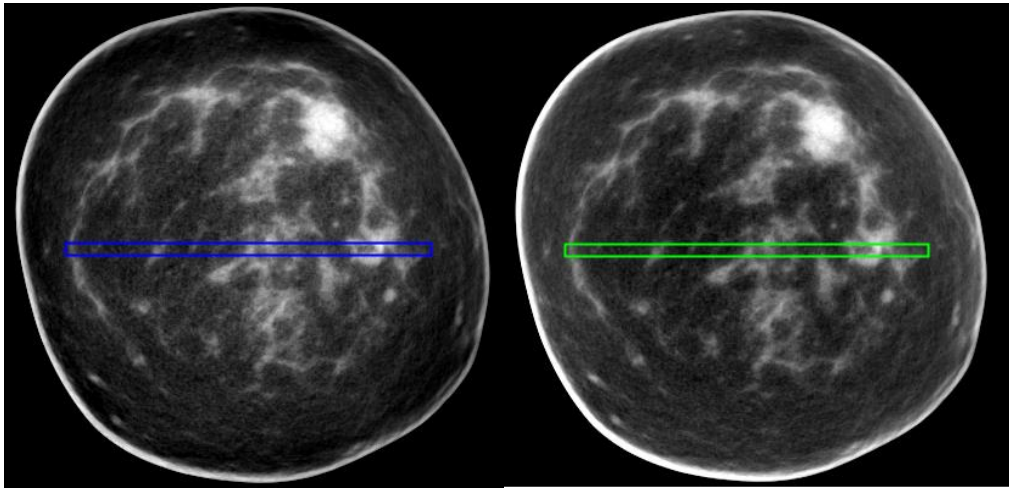

DEEP LEARNING CORRECTED
MONTE CARLO GROUND TRUTH
MONTE CARLO UNCORRECTED
Linear attenuation (cm^{-1})
0.42
0.37
0.32
0.27
0.22
0
50
100
150
200
250
300
Distance (pixels)

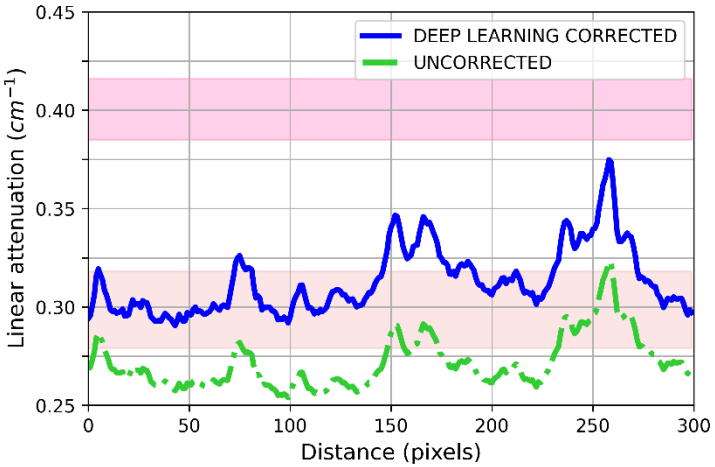

DEEP LEARNING CORRECTED
UNCORRECTED
WW/WL: 0.1/0.3 cm^{-1}

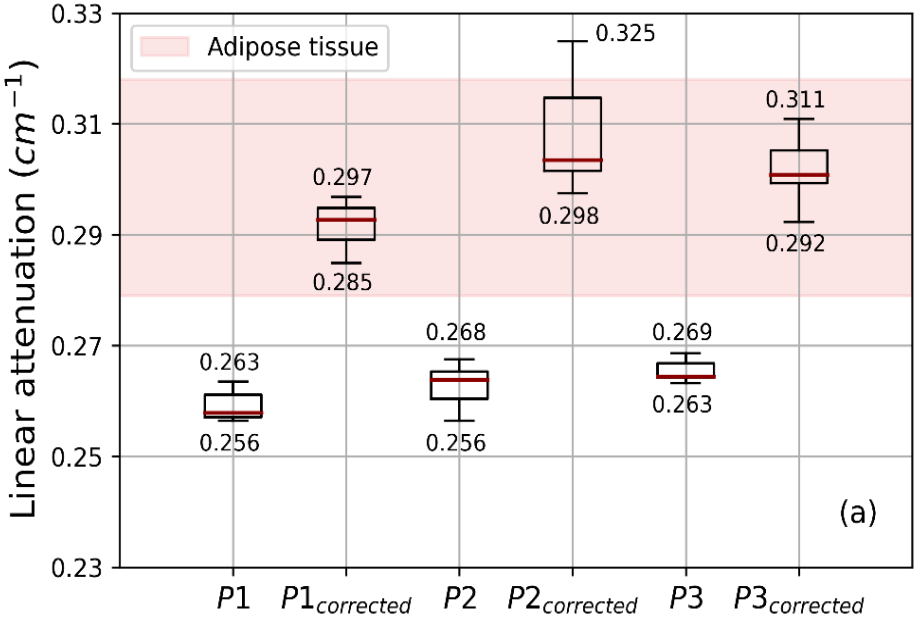

DEEP LEARNING CORRECTED
UNCORRECTED
Linear attenuation (cm^{-1})
0.45
0.40
0.35
0.30
0.25
0
50
100
150
200
250
300
Distance (pixels)

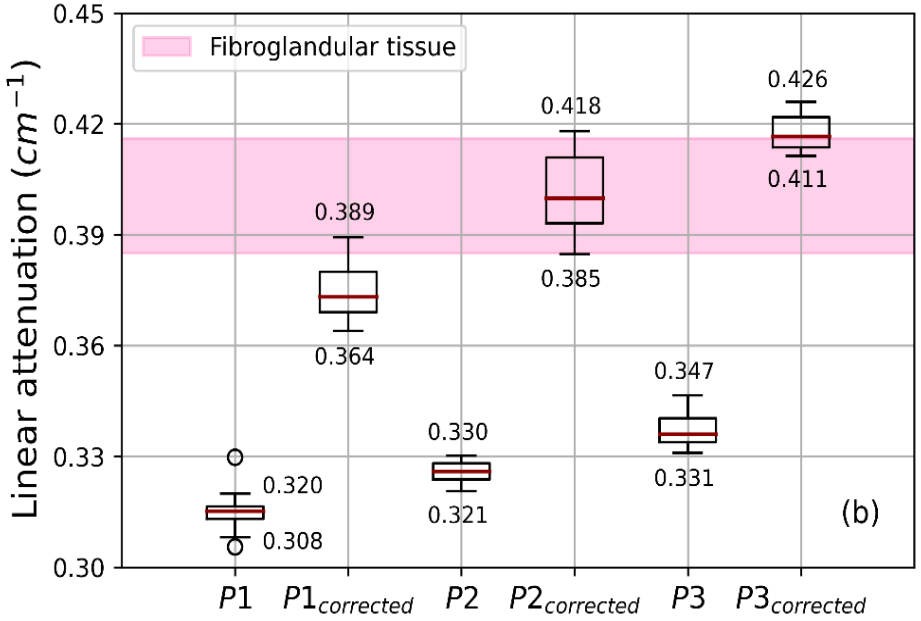


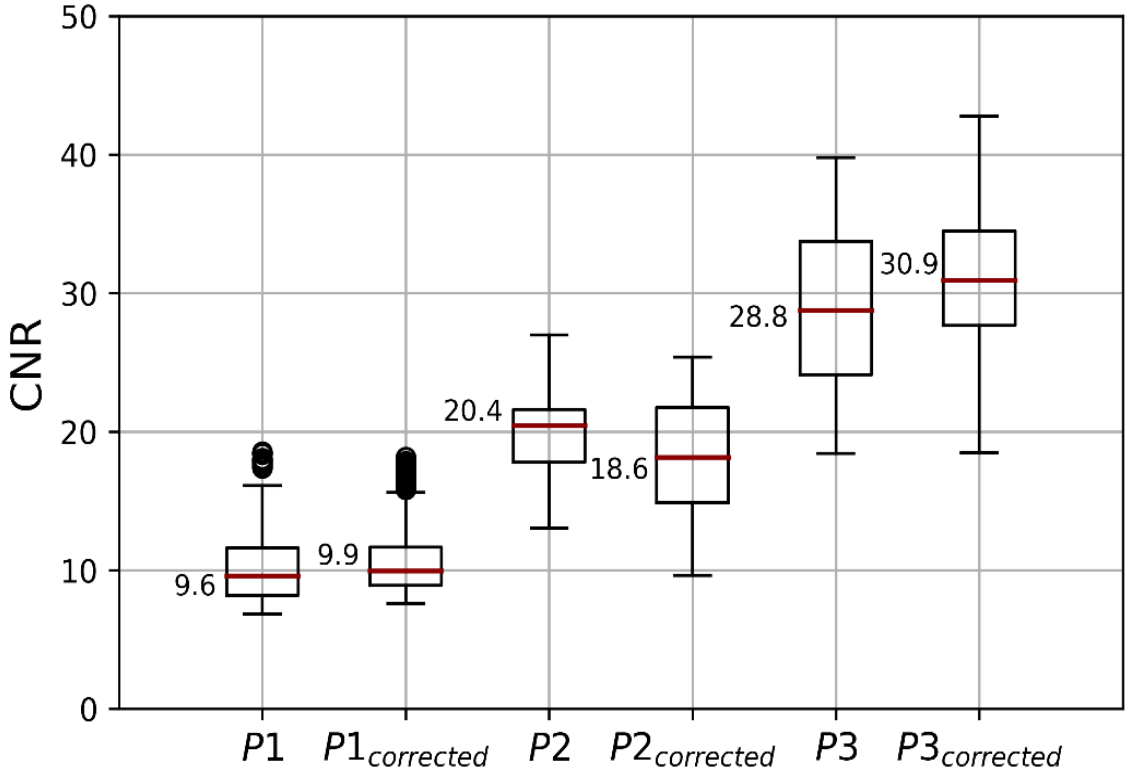

DEEP LEARNING CORRECTED
UNCORRECTED
Linear attenuation (cm^{-1})
0.45
0.40
0.35
0.30
0.25
0
50
100
150
200
250
300
Distance (pixels)




DEEP LEARNING CORRECTED
UNCORRECTED
Linear attenuation (cm^{-1})
0.45
0.40
0.35
0.30
0.25
0
50
100
150
200
250
300
Distance (pixels)


Adipose tissue
Linear attenuation (cm^{-1})
0.33
0.31
0.29
0.27
0.25
0.23
0.263
0.256
0.297
0.285
0.268
0.256
0.325
0.298
0.269
0.263
0.311
0.292
(a)
$P1$
$P1_{corrected}$
$P2$
$P2_{corrected}$
$P3$
$P3_{corrected}$


Fibroglandular tissue
Linear attenuation (cm^{-1})
0.45
0.42
0.39
0.36
0.33
0.30
0.320
0.308
0.389
0.364
0.330
0.321
0.418
0.385
0.347
0.331
0.426
0.411
(b)
$P1$
$P1_{corrected}$
$P2$
$P2_{corrected}$
$P3$
$P3_{corrected}$


50
40
30
20
10
0
CNR
9.6
9.9
20.4
18.6
28.8
30.9
P1
P1corrected
P2
P2corrected
P3
P3corrected

Thank you for your attention