Are Speckle patterns crop-specific?

2nd Dec 2025

Hypothesis

A Neural Network can distinguish classes in normalized images.
→ This would mean distinguishing speckle patterns

Class A

Class B

Sentinel 1 GRD Acquisition (Raw)

Normalization:
X2 = X – Mean(X)

Normalized (Zeromean)

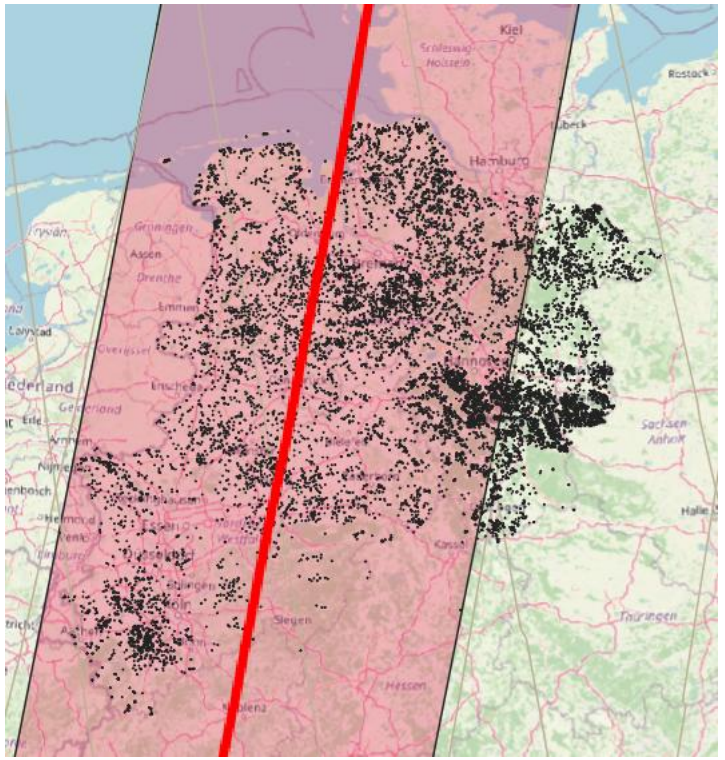
Test setup:

Class selection:




Meadows	Corn	Beet	Wheat
1	4	6	12

Region:
NRW + Niedersachesn



Data: Sentinel 1 GRD Orbit D139

Date: 11. Juni 2022 (und 23. Juni 2022)

N training samples both dates:

```
"train_samples":      54 212
"validation_samples": 17 756
"test_samples":       17 864
```

NN network NR. 1; „test_conv2d“

Model Architecture: test_conv2d

```
----------------------------------------------------------
      Layer (type)               Output Shape         Param #
==========================================================
          Conv2d-1          [-1, 32, 10, 10]             576
     BatchNorm2d-2          [-1, 32, 10, 10]              64
          Conv2d-3          [-1, 64, 10, 10]          18,432
     BatchNorm2d-4          [-1, 64, 10, 10]             128
          Conv2d-5         [-1, 128, 10, 10]          73,728
     BatchNorm2d-6         [-1, 128, 10, 10]             256
 AdaptiveAvgPool2d-7           [-1, 128, 1, 1]               0
         Dropout-8                 [-1, 128]               0
          Linear-9                   [-1, 4]             516
==========================================================
```

Total params: 93,700
Trainable params: 93,700
Non-trainable params: 0

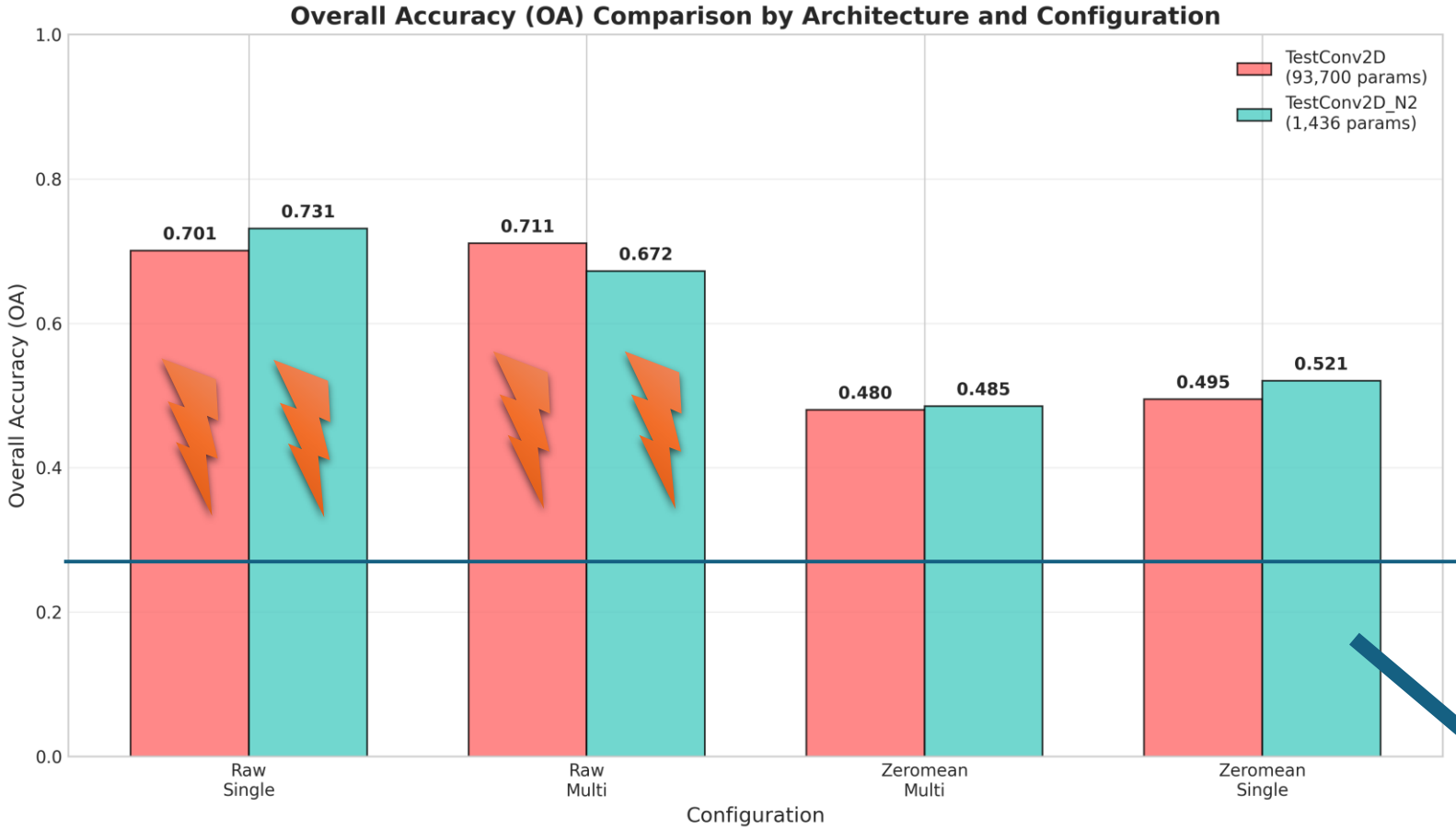
NN network Nr. 2: „test_conv2d_n2“

Model Architecture: test_conv2d_n2

```
----------------------------------------------------------------
      Layer (type)               Output Shape         Param #
================================================================
          Conv2d-1          [-1, 8, 10, 10]             152
     BatchNorm2d-2          [-1, 8, 10, 10]              16
          Conv2d-3         [-1, 16, 10, 10]           1,168
     BatchNorm2d-4         [-1, 16, 10, 10]              32
 AdaptiveAvgPool2d-5           [-1, 16, 1, 1]               0
         Dropout-6                 [-1, 16]               0
          Linear-7                  [-1, 4]              68
================================================================
```

Total params: 1,436
Trainable params: 1,436
Non-trainable params: 0

Results : Overall accuracy



Raw = no Normalization

Zeromean = Normalized

Single = 11.06.2022

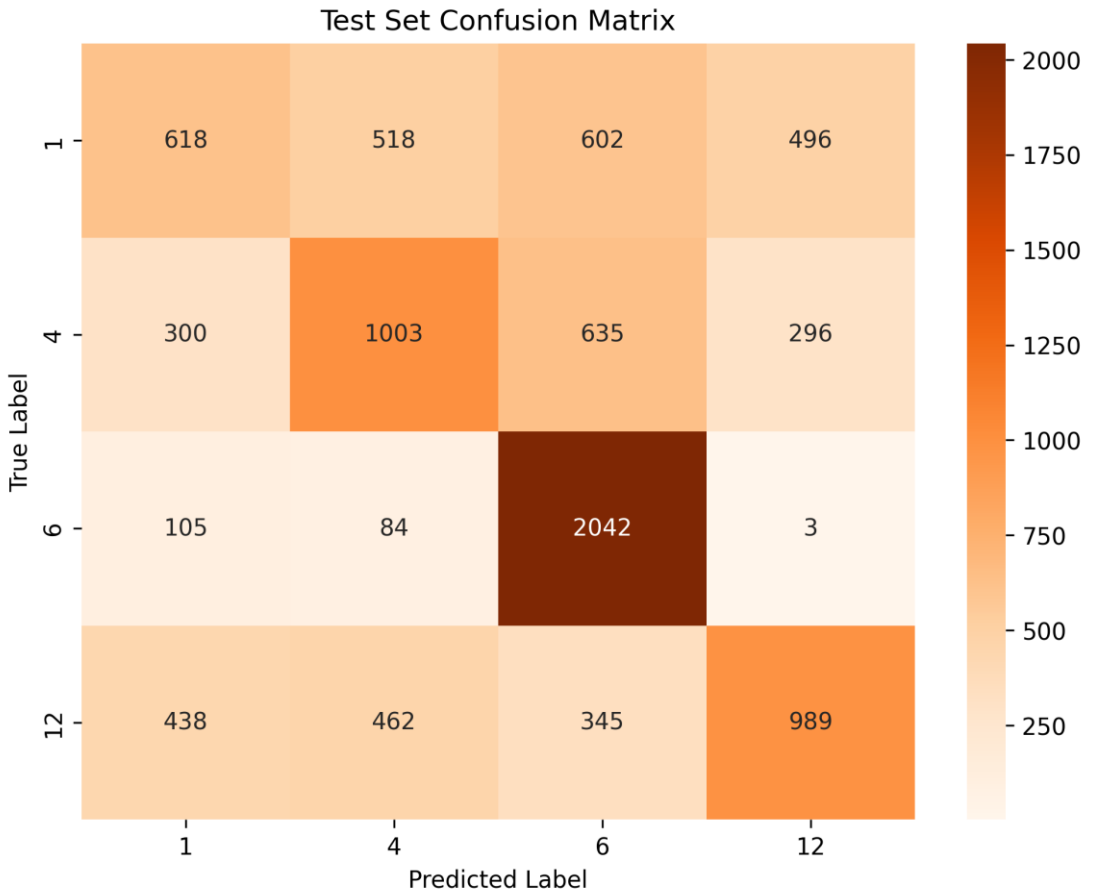
Multi = 11.06.2022 and 23.06.2022

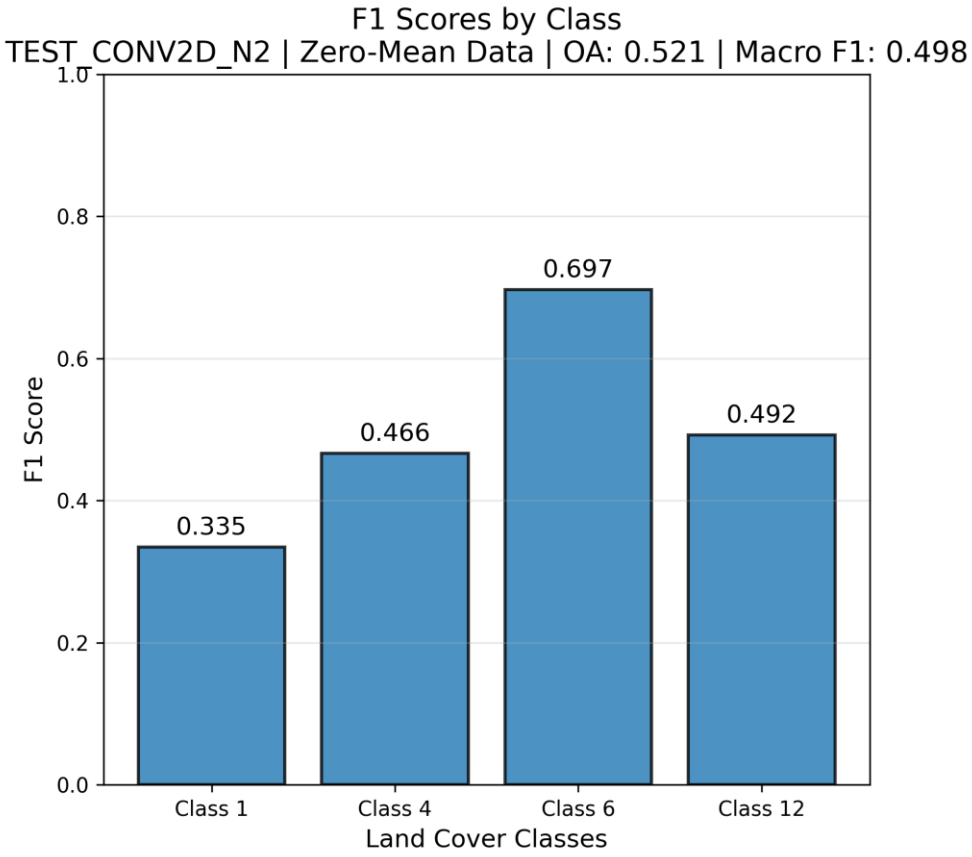
Mean included
→ do not use for speckle information interpretation

25% → Accuracy of a random classifier

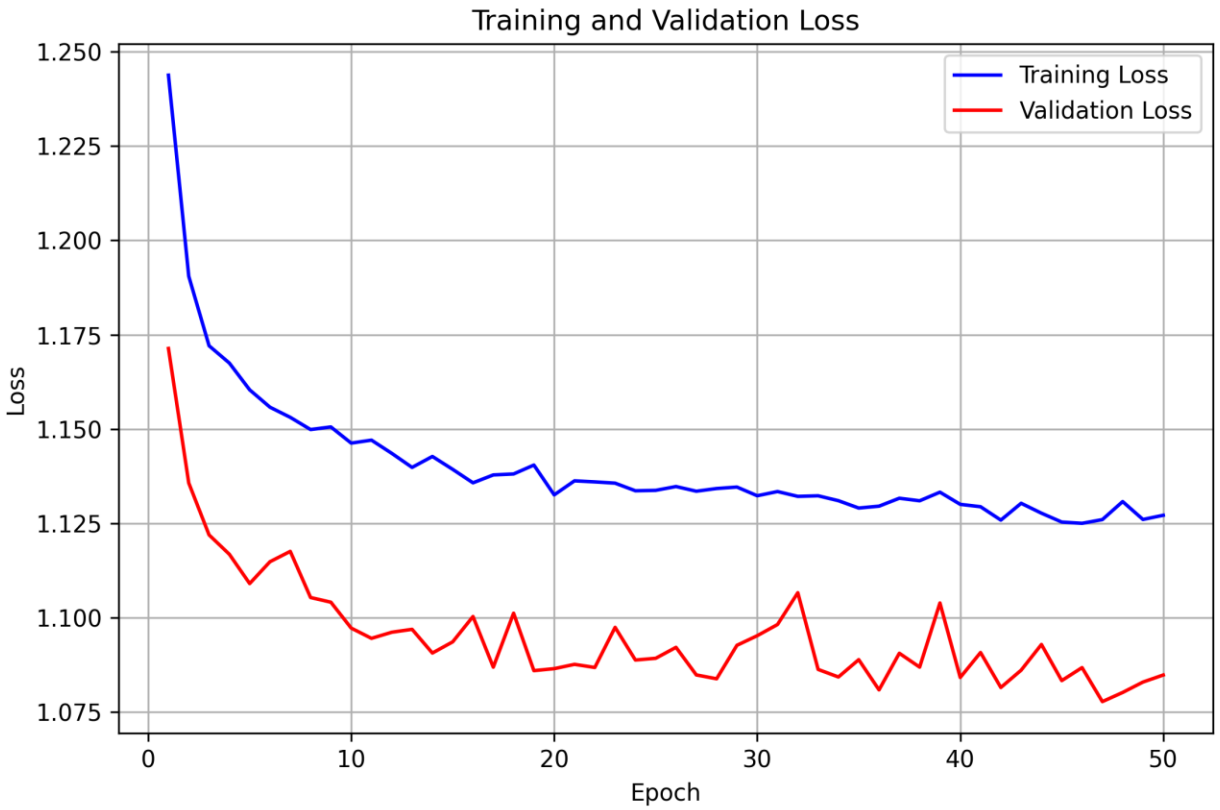
Next slide

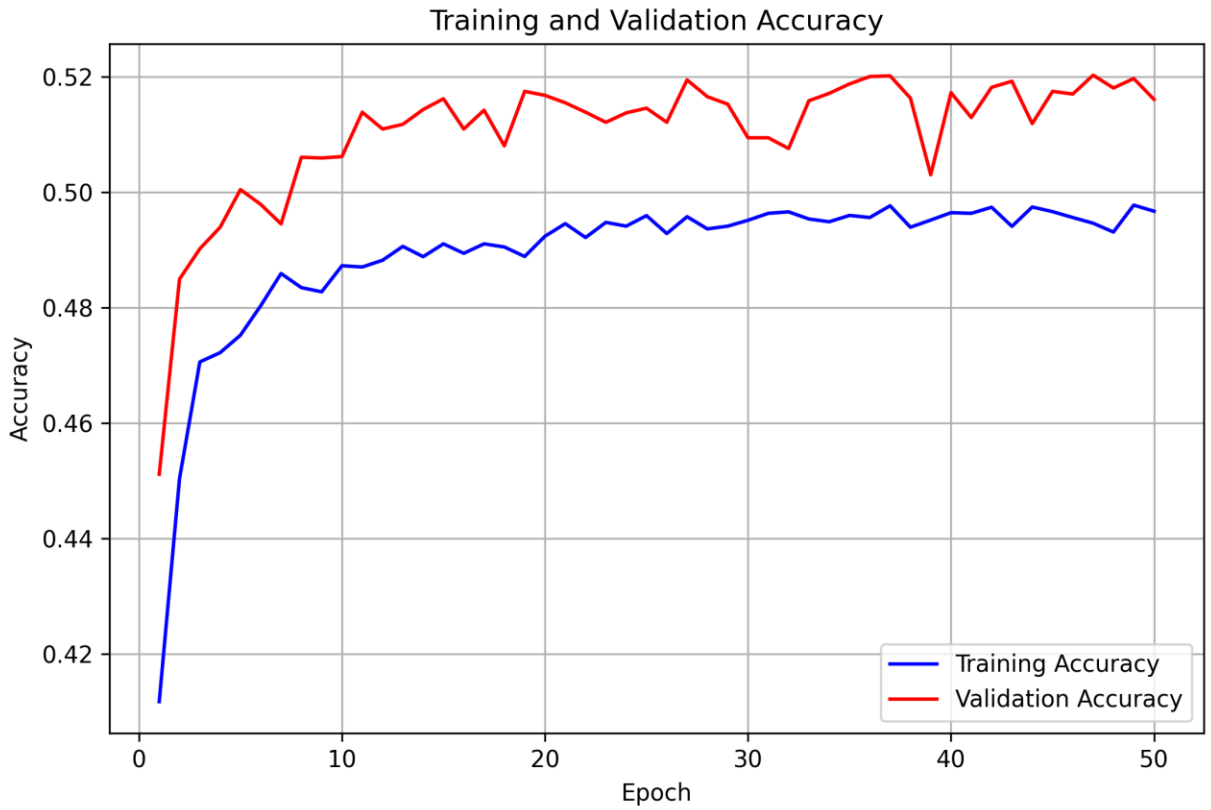
Results: zeromean, 1 date, test_conv2d_n2





Results: zeromean, 1 date, test_conv2d_n2





Data leak check

Model: zeromean, 1 date, test_conv2d_n2

All class labels are shuffled at the raw-data level

→ The whole script is run to test if a data leak causes the high accuracies

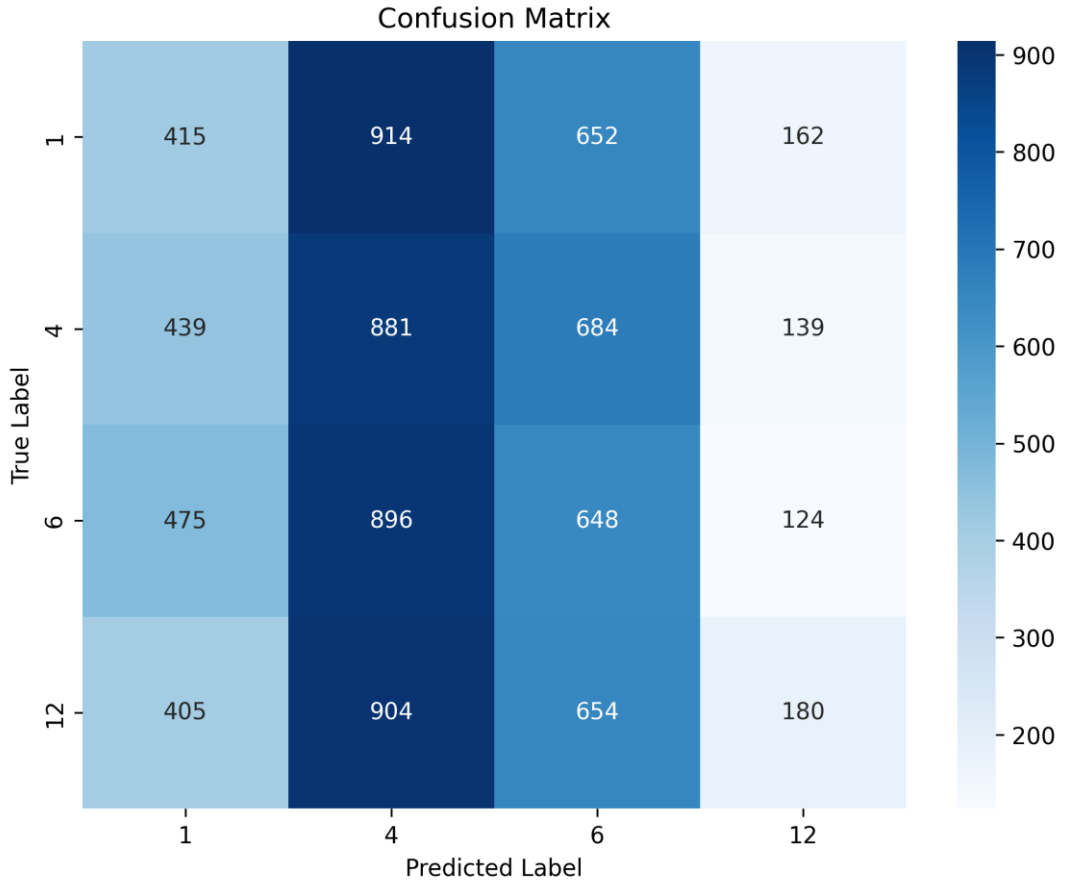
Results:

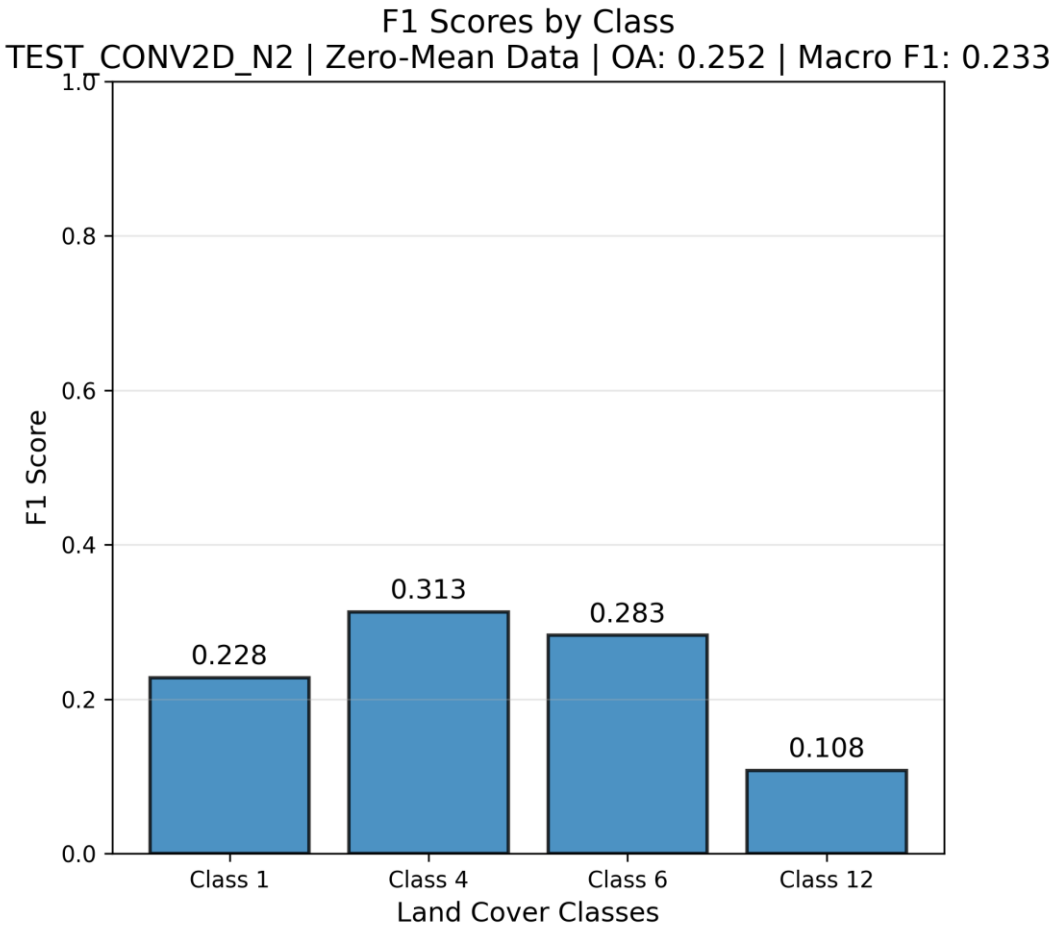
Overall accuracy: 25.2 %

Mean F1 score: 23.3 %

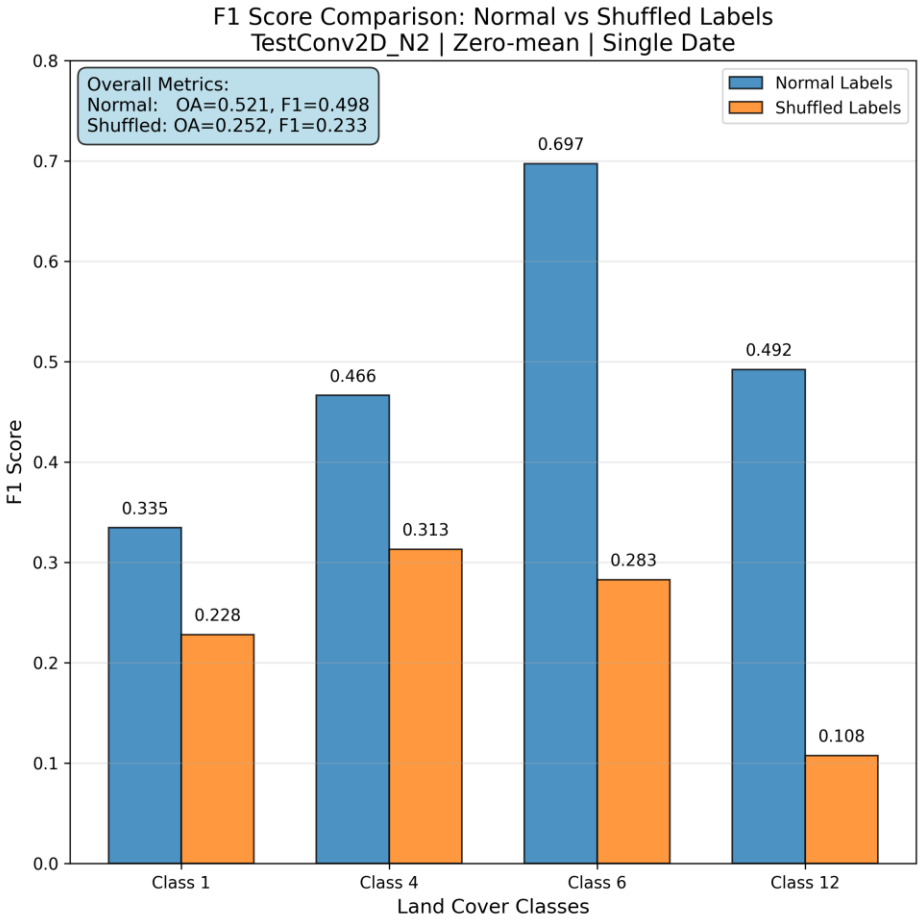
Data leak check

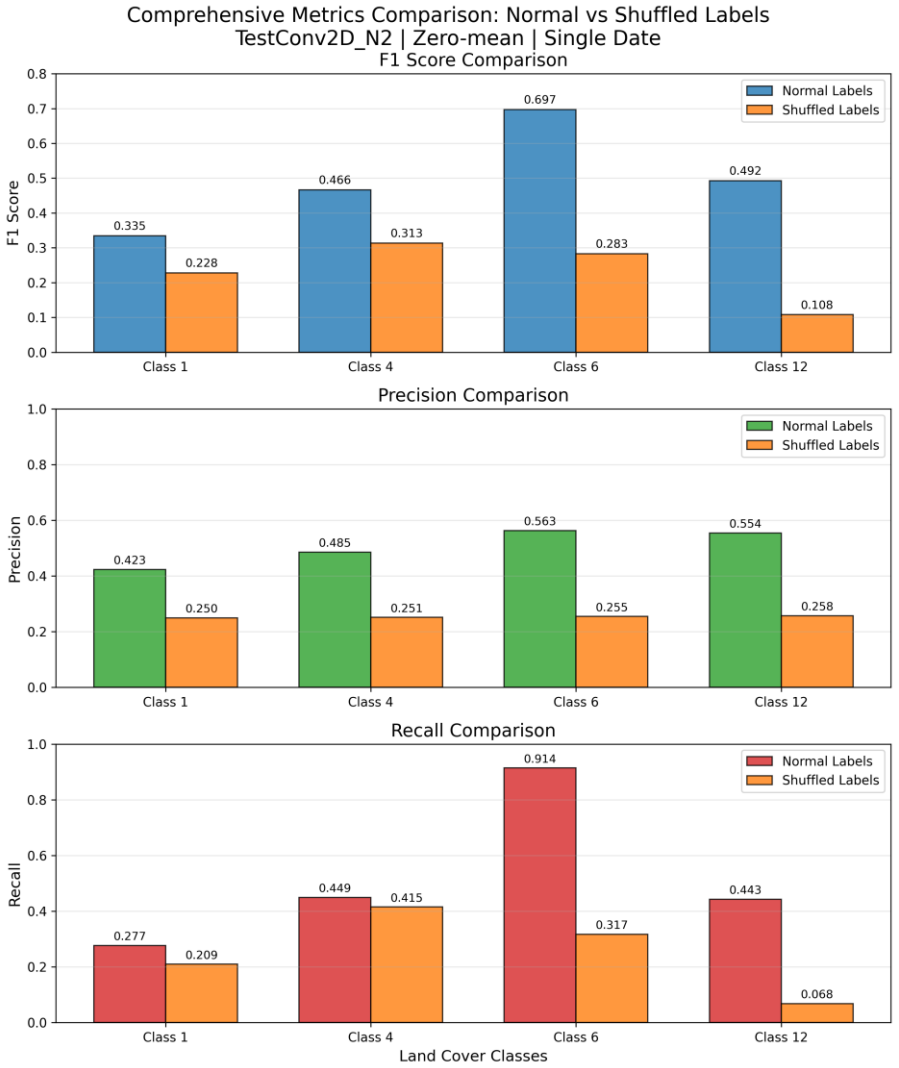
Model: zeromean, 1 date, test_conv2d_n2





F1 score gain best model vs random model

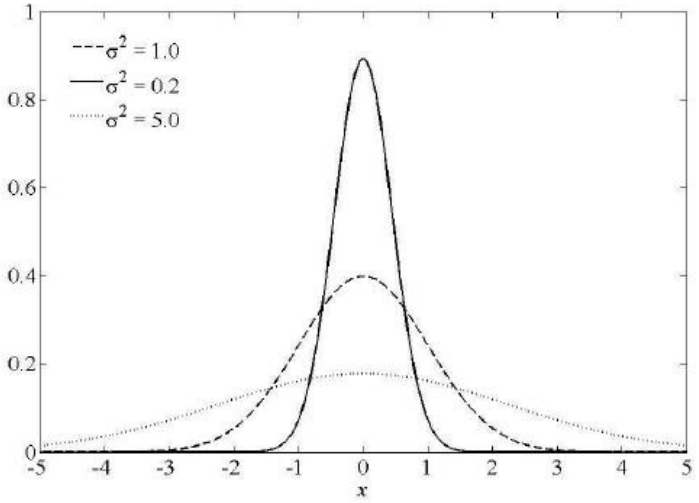




Ok, speckle contains info. But where?

Option A: Spectral info

→ The info is inside the intensity distribution of the speckle



To test this we introduce this modus:

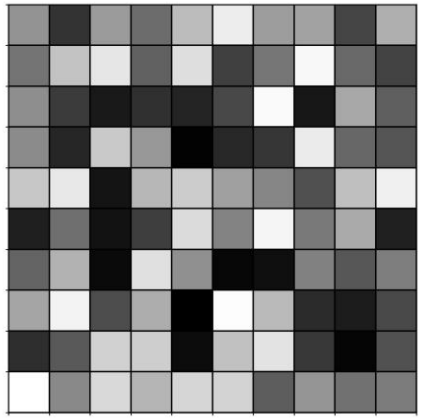
quantiles: Transform each patch to quantiles (0.00, 0.01, ..., 1.00) to test spatial info without spectral

Option B: Spatial info

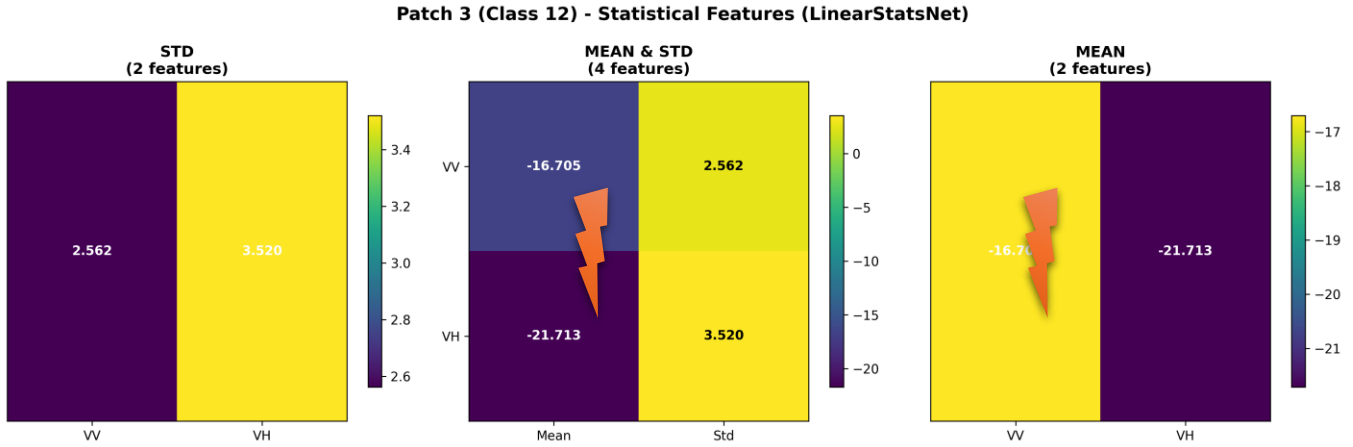
→ The info is inside the spatial distribution of the specke

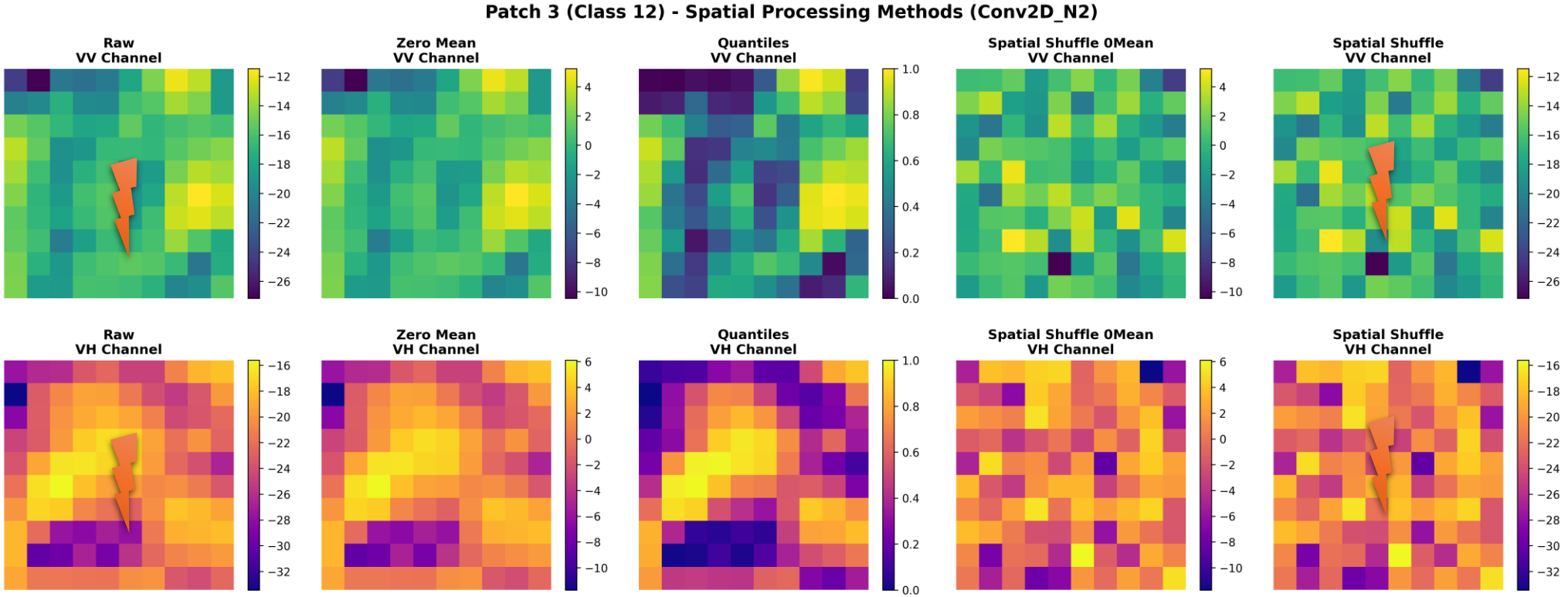
To test this we introduce this modus:

spatial_shuffle: Shuffle pixels within each patch to test spectral info without spatial structure



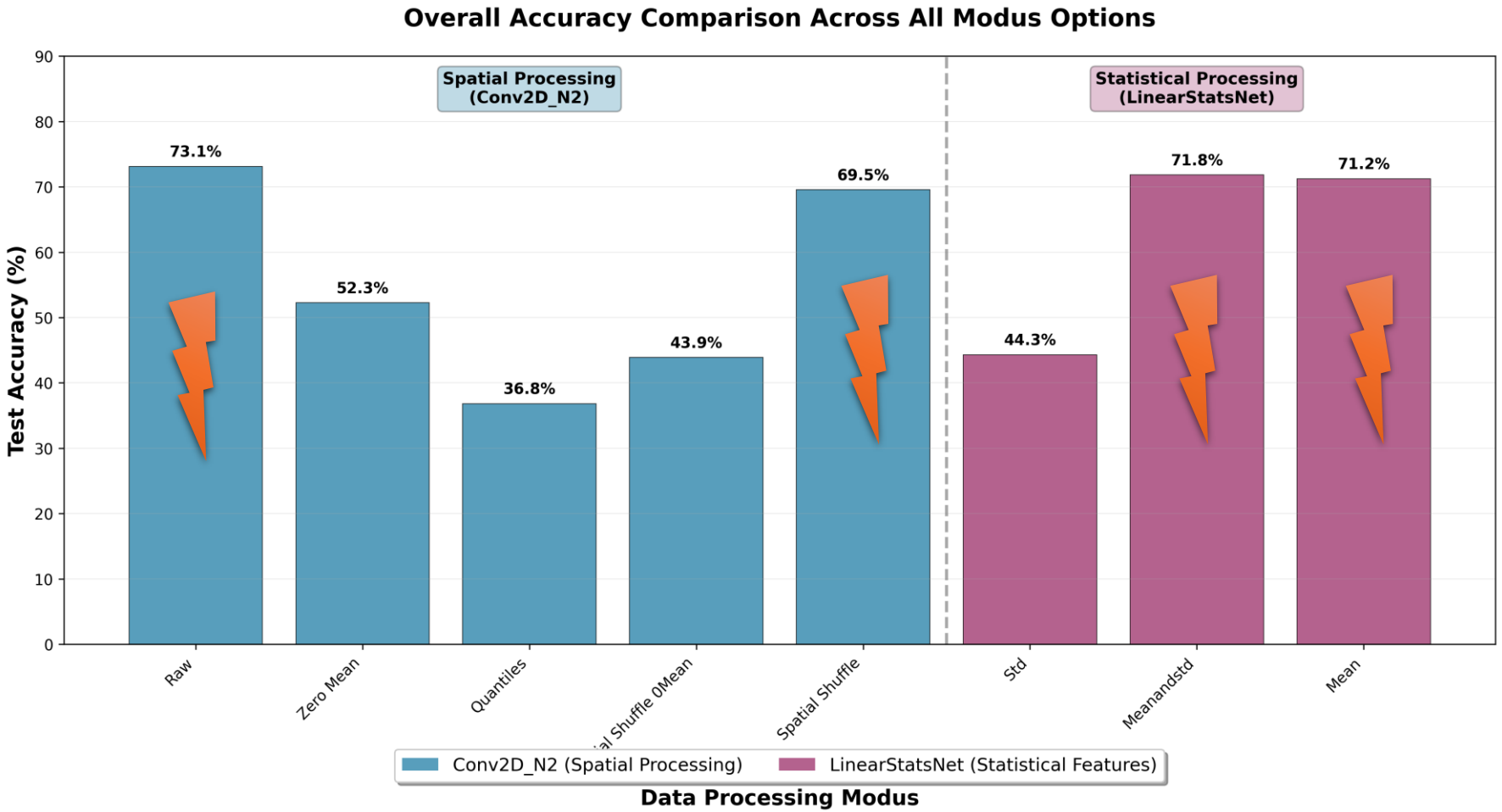
New Modi:


Patch 3 (Class 12) - Statistical Features (LinearStatsNet)
STD
(2 features)
2.562
3.520
VV
VH
MEAN & STD
(4 features)
-16.705
2.562
-21.713
3.520
Mean
Std
MEAN
(2 features)
-21.713
VV
VH


Patch 3 (Class 12) - Spatial Processing Methods (Conv2D_N2)
Raw
VV Channel
Zero Mean
VV Channel
Quantiles
VV Channel
Spatial Shuffle 0Mean
VV Channel
Spatial Shuffle
VV Channel
Raw
VH Channel
Zero Mean
VH Channel
Quantiles
VH Channel
Spatial Shuffle 0Mean
VH Channel
Spatial Shuffle
VH Channel

Results

Mean included
→ do not use for speckle information interpretation

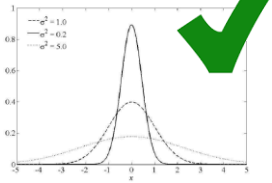


Best Spatial: Raw (73.1%) | Best Statistical: Meanandstd (71.8%)

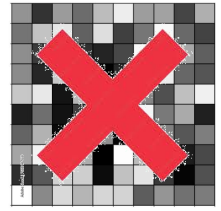
Conclusion

Beets can be distinguished from meadow, corn and wheat with speckle!

Different speckle



The information of the **speckle is mainly in the spectral dimension,** the spectral distribution of the pixels



The **spatial distribution of the values is not very meaningful.**

The absolute **(mean) amplitude has most of the information**. mean()