Flare forecasting using Fully Convolutional Network

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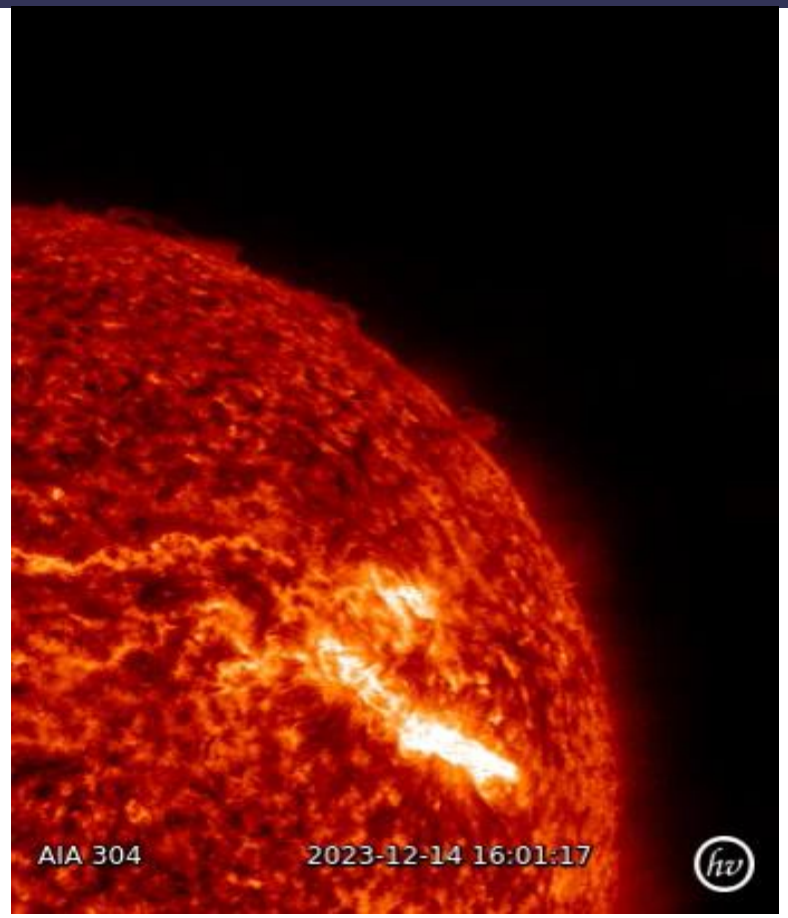
Solar Flares

- Energetic ejections of radiation
- Flares cause space weather which can affect radio communication (Schwenn, 2006)

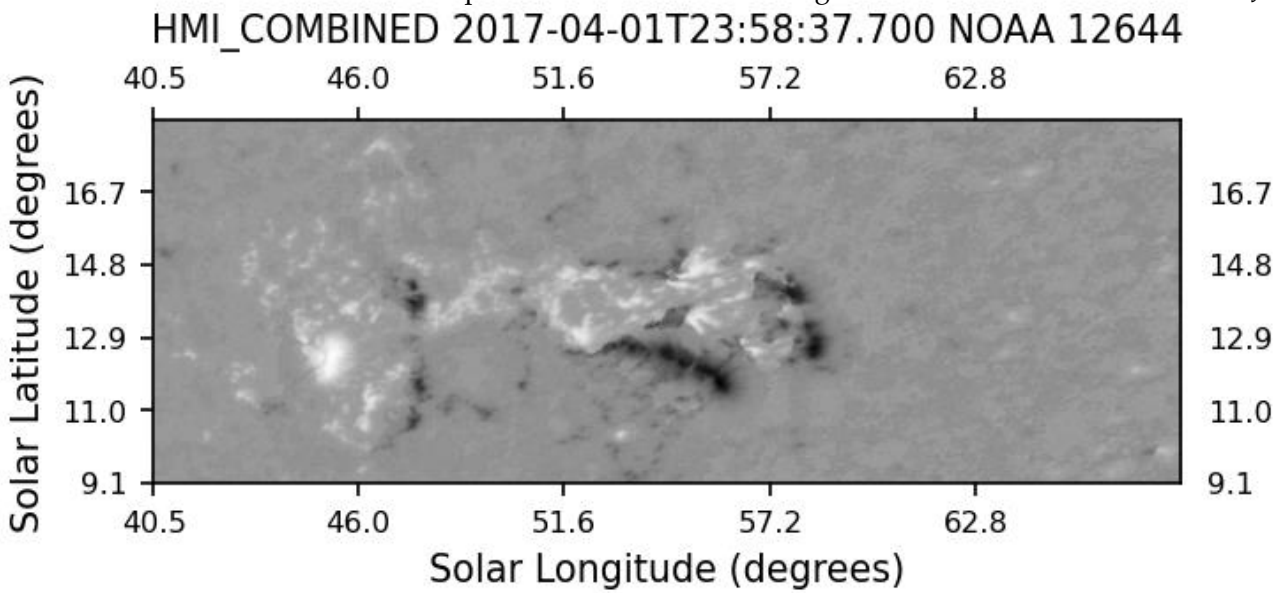


Helioviewer.org SDO AIA 304

Data - Images

- SHARP HMI B_R - component magnetogram (2013-2023) (Bobra et al. 2011)
  - Discard outside ±75°
  - Single NOAA number HARPs
  - 24h cadence taken at midnight
- One observation for every 24h – no overlap of prediction windows

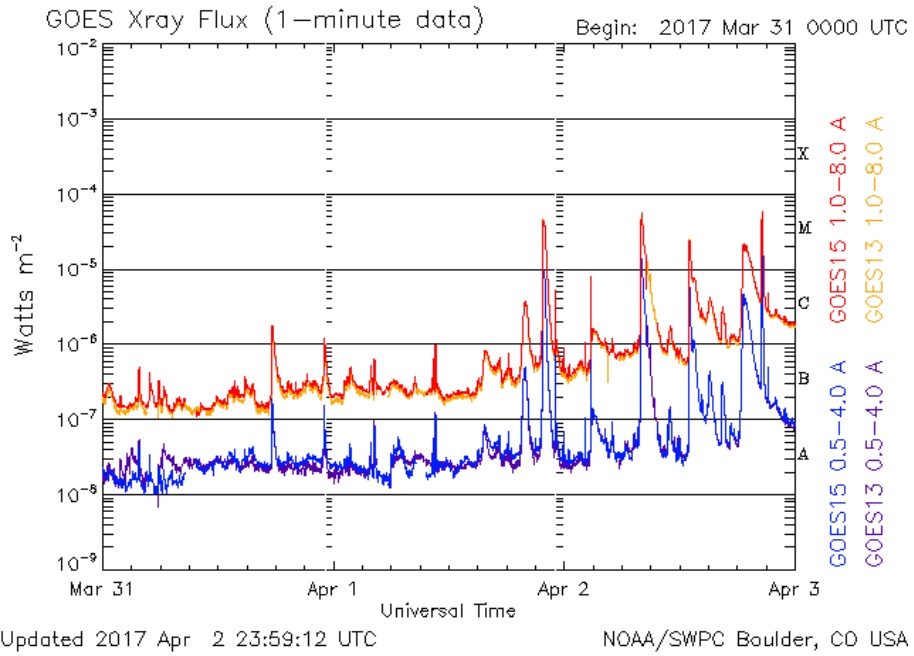
Spaceweather HMI Active Region Patch SHARP-CEA 720s from JSOC

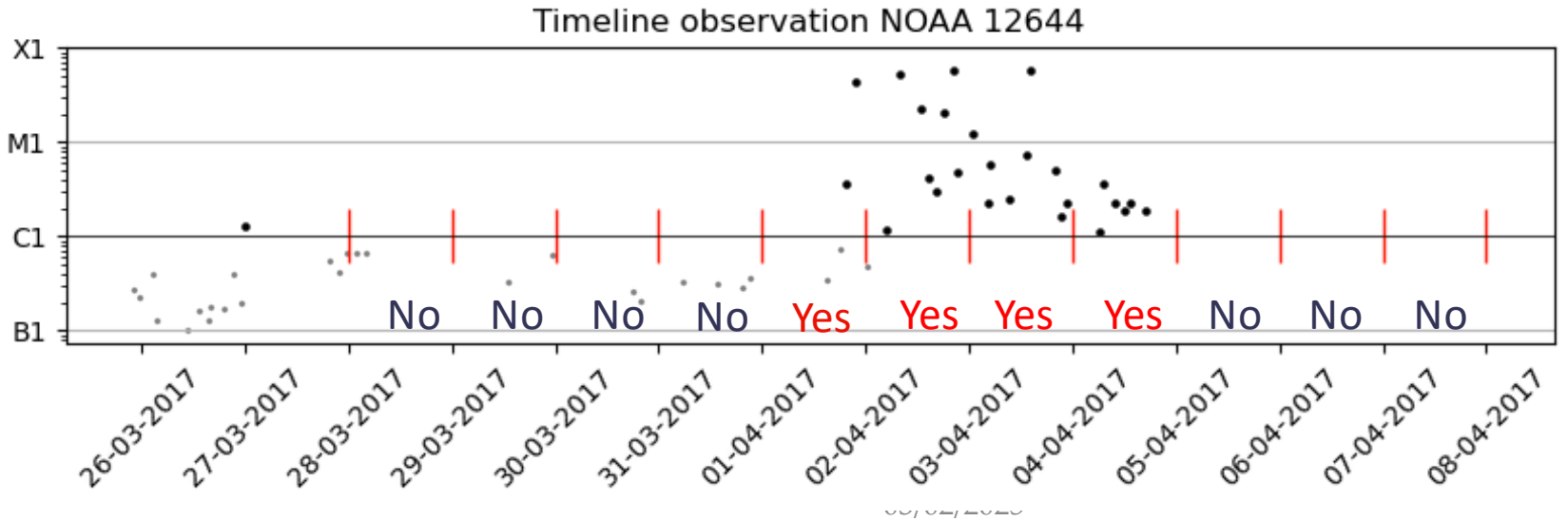


Data - labels

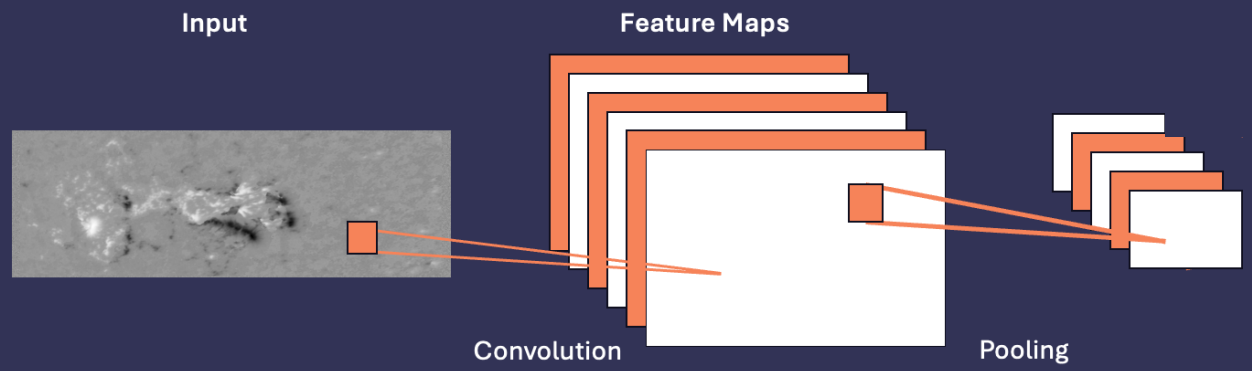
- Flare activity GOES X-ray flux ≥ C1-class
- SWPC event files for flare lists per NOAA region
- Flares occur close together -> leads to one ‘yes’ class in 24 hours

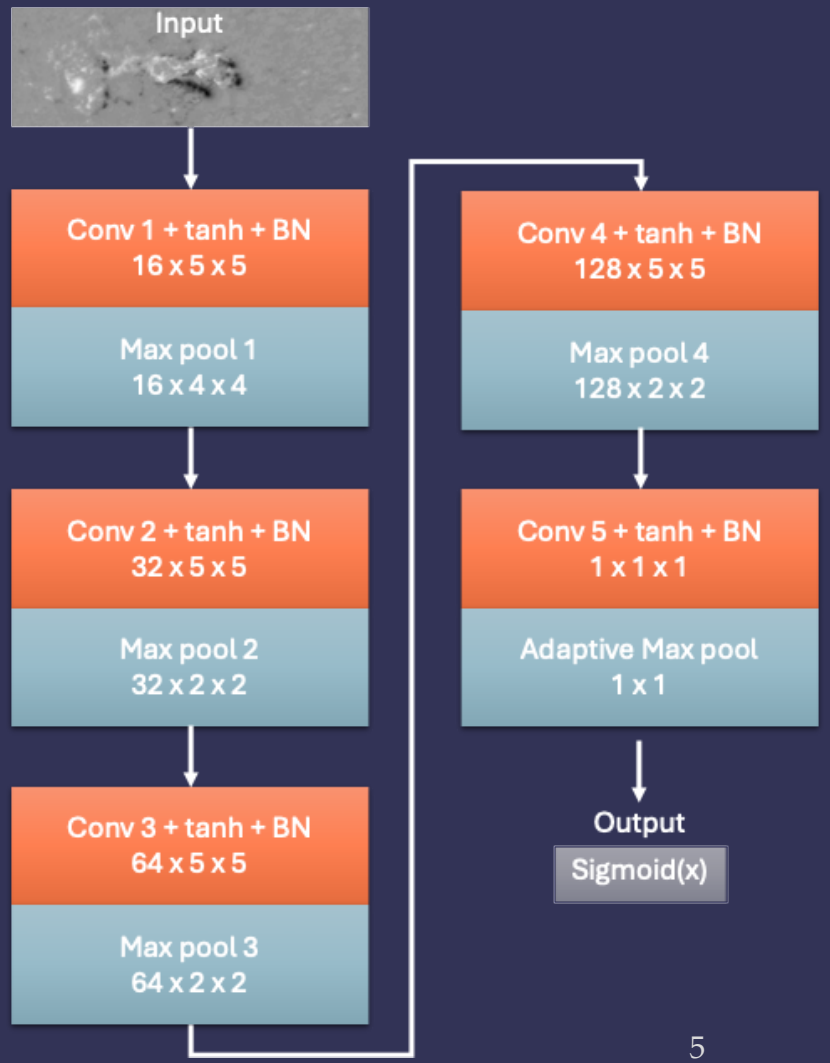
GOES X-ray flux data from NOAA SWPC



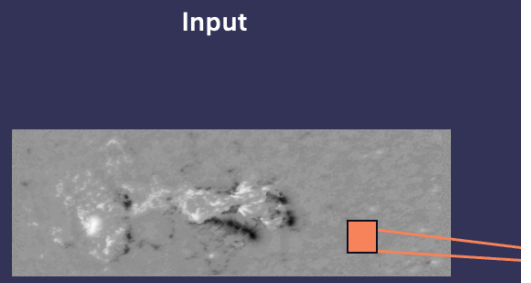


FCN model (Long et al., 2015)

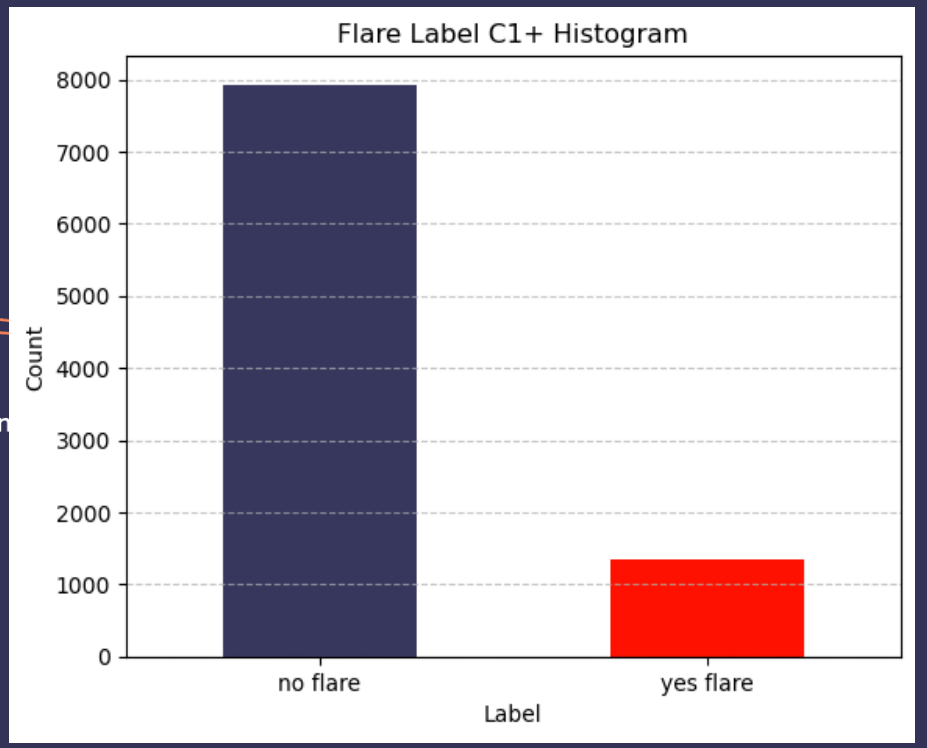


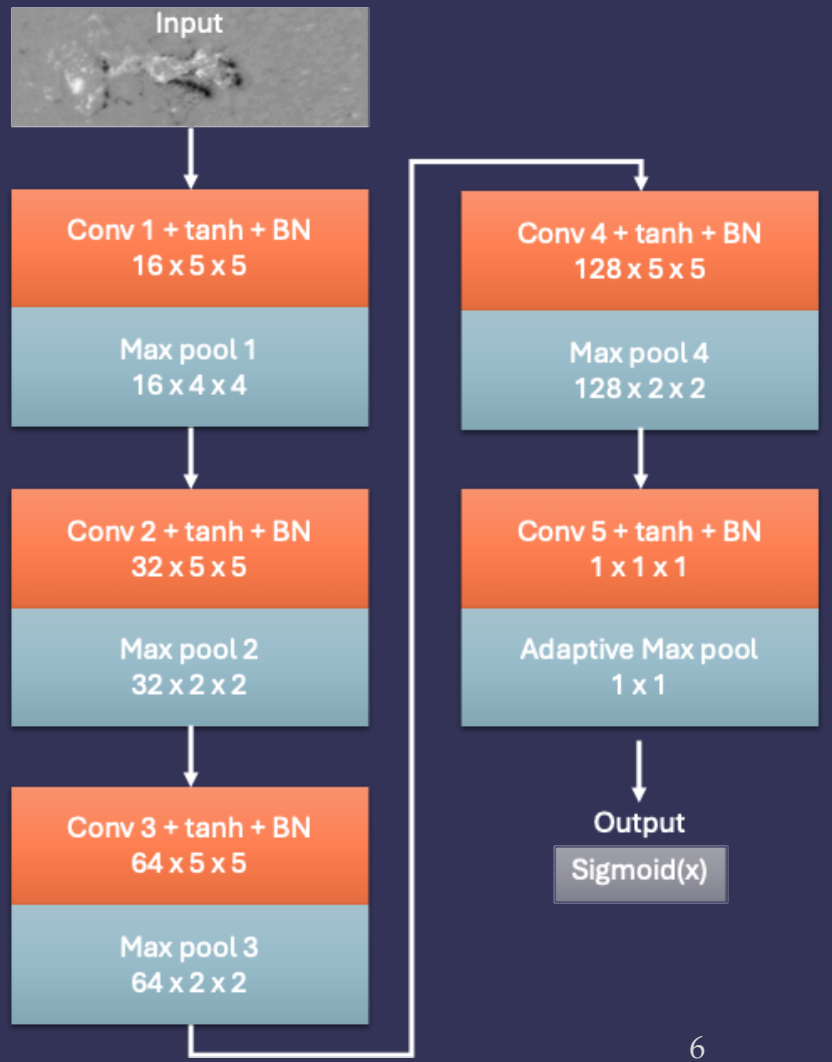


FCN model (Long et al., 2015)



Input image (Variable size)





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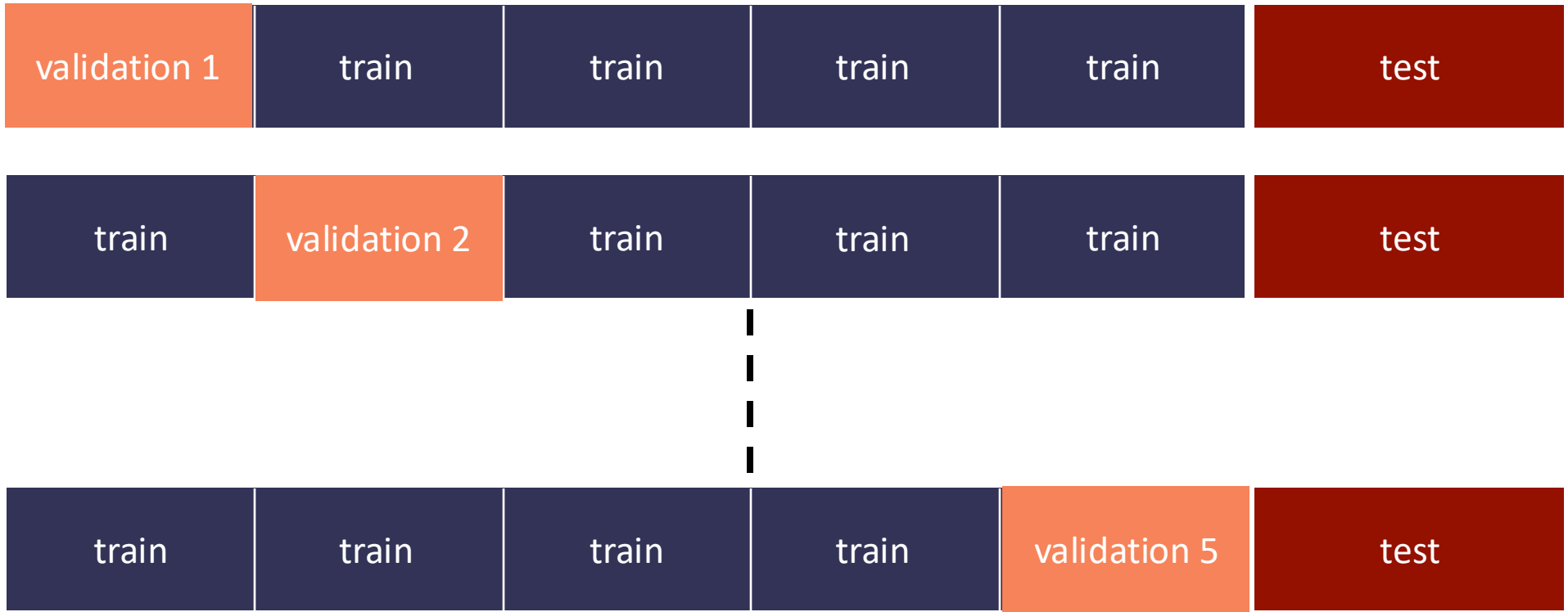
Training the model

- Splitting based on HARP number and maximum flare strength.
- 80 : 20 for training/validation : testing
- 5-fold cross-validation



Example results from fold 1

- Performance metrics (Jolliffe and Stephenson. 2011)

$$Accuracy = \frac{TP+TN}{TP+FN+FP+TN} = 0.77$$

- Probability of Detection

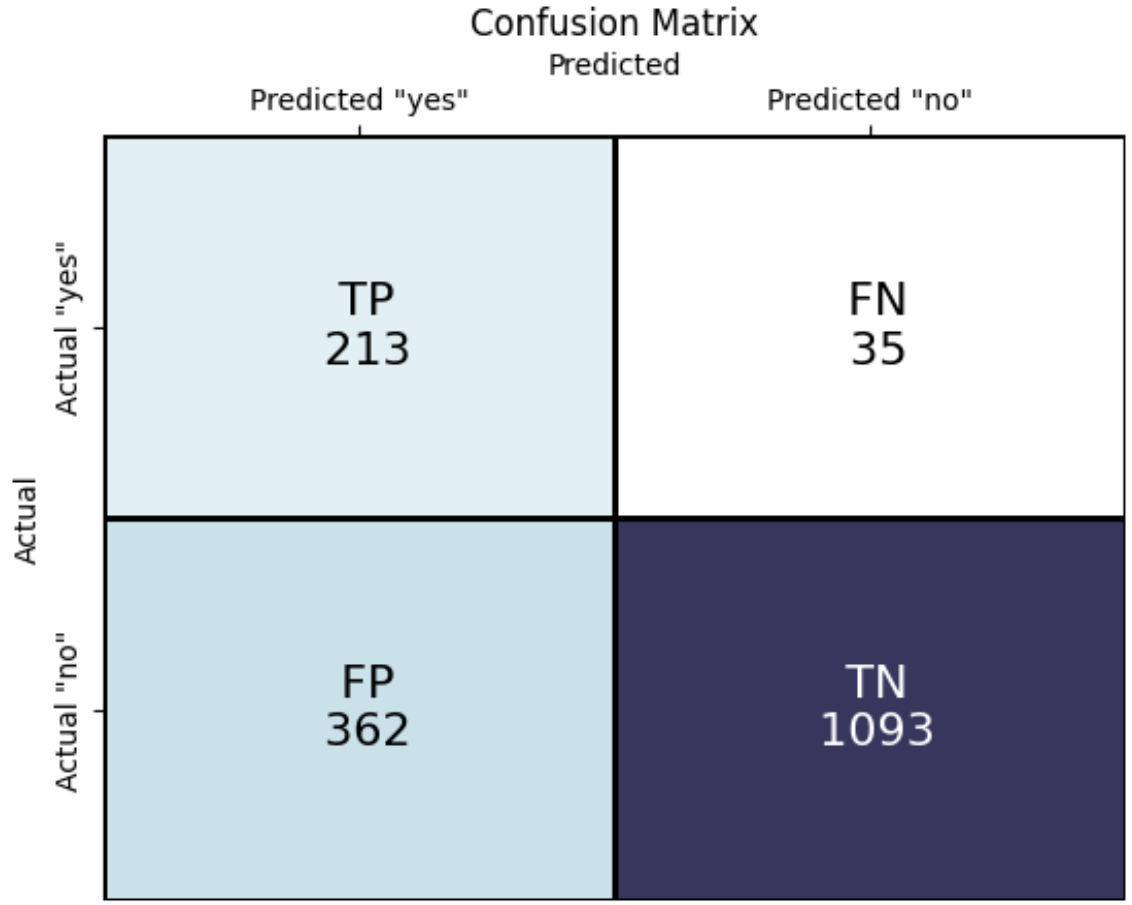
$$POD = \frac{TP}{TP+FN} = 0.86$$

- Probability of False Detection

$$POFD = \frac{FP}{FP+TN} = 0.25$$

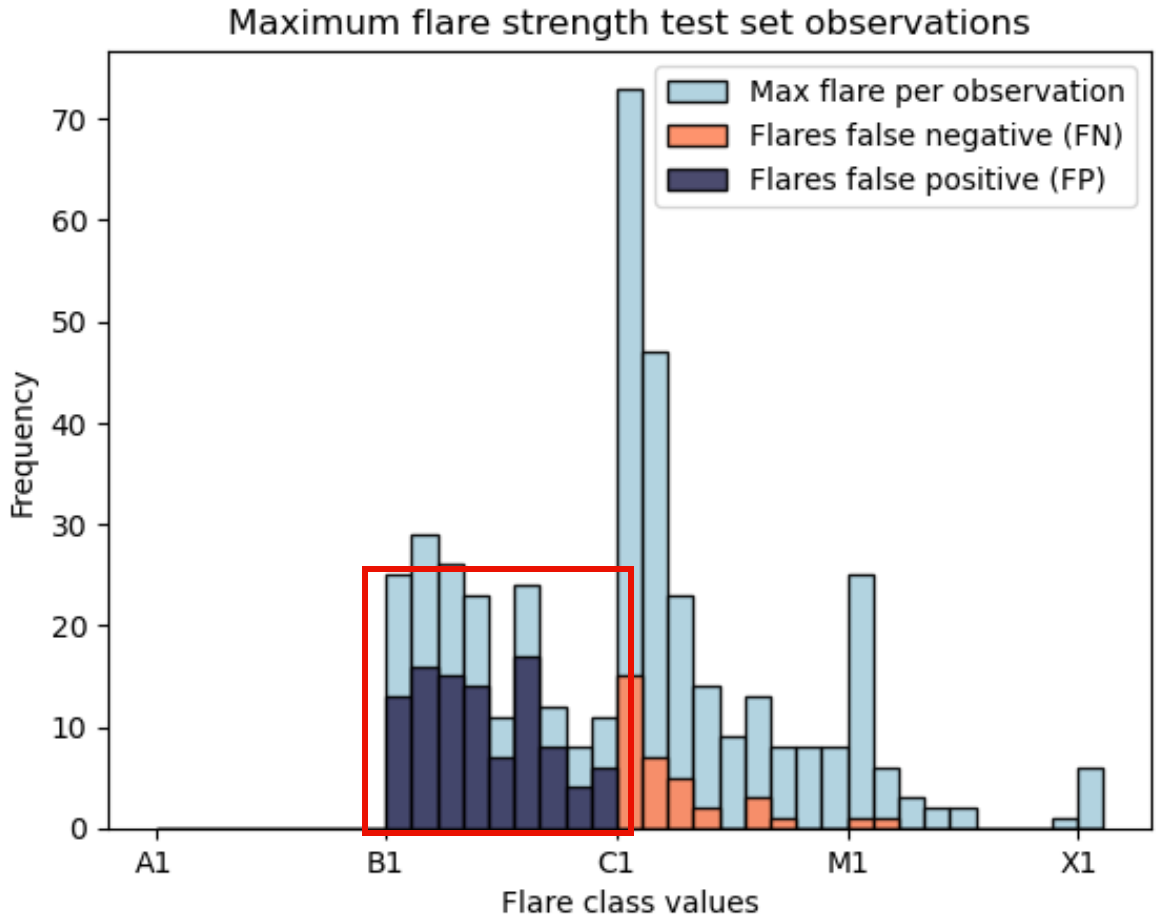
- Skill in separating yes/no events

$$TSS = POD - POFD = 0.61$$



Example results from fold 1

- About 27.5% of FP do have B-class flares, while they make up only 12% of “no-flare” samples



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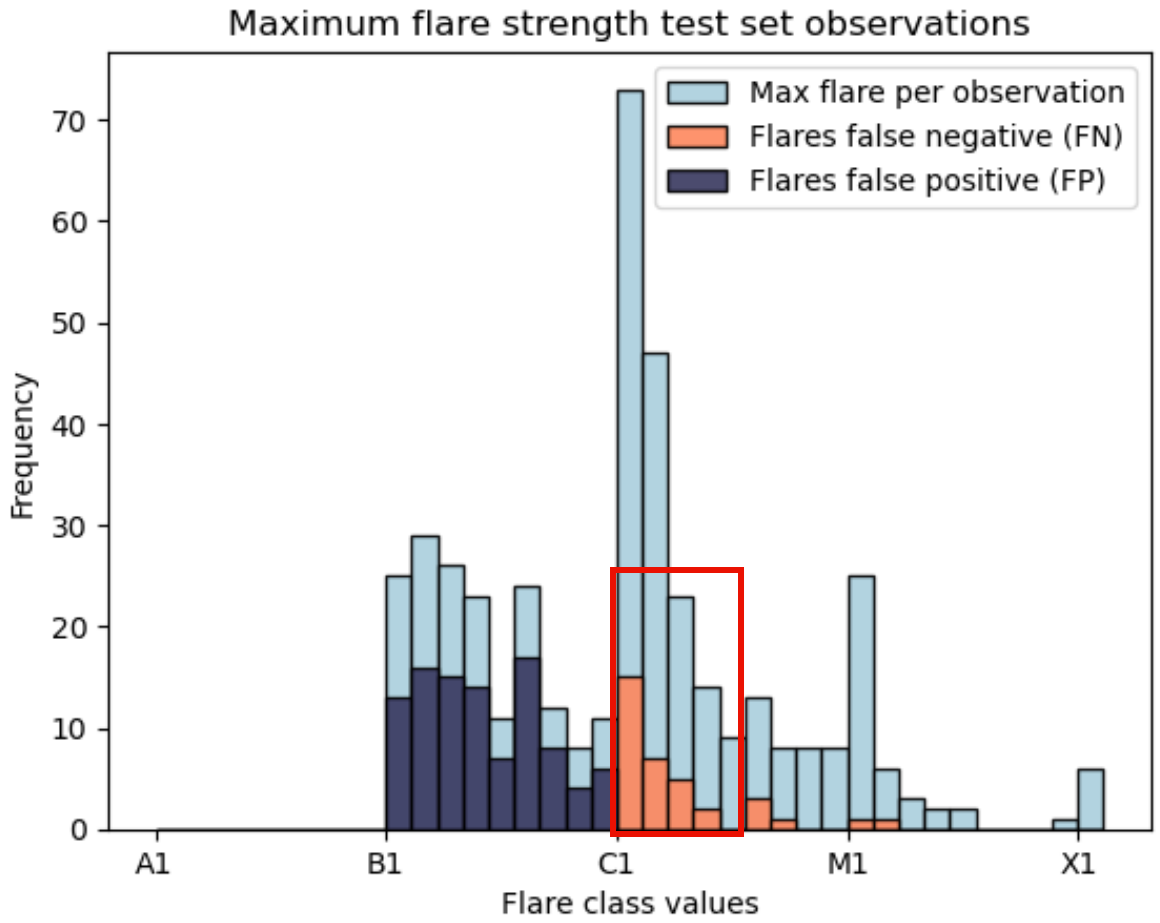
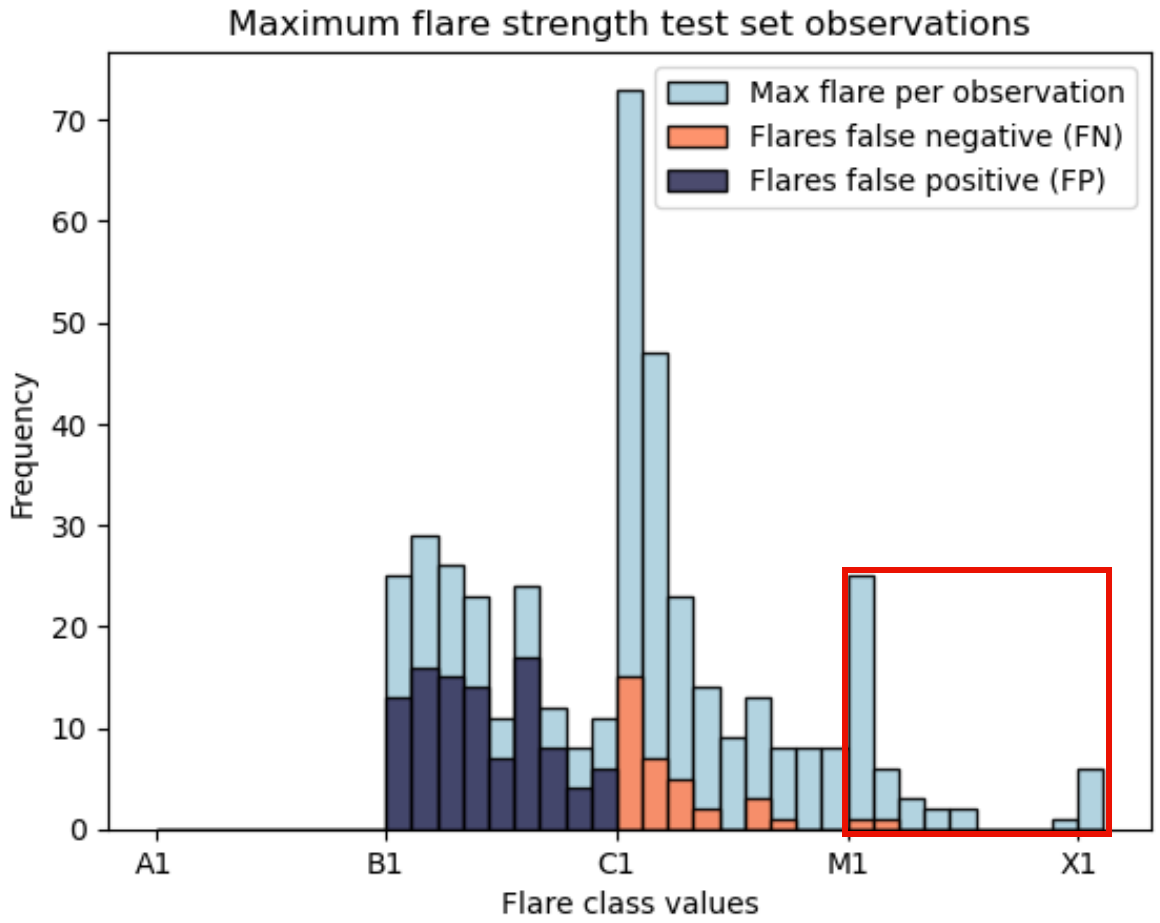
- Most FN in range C1-C4



Example results from fold 1

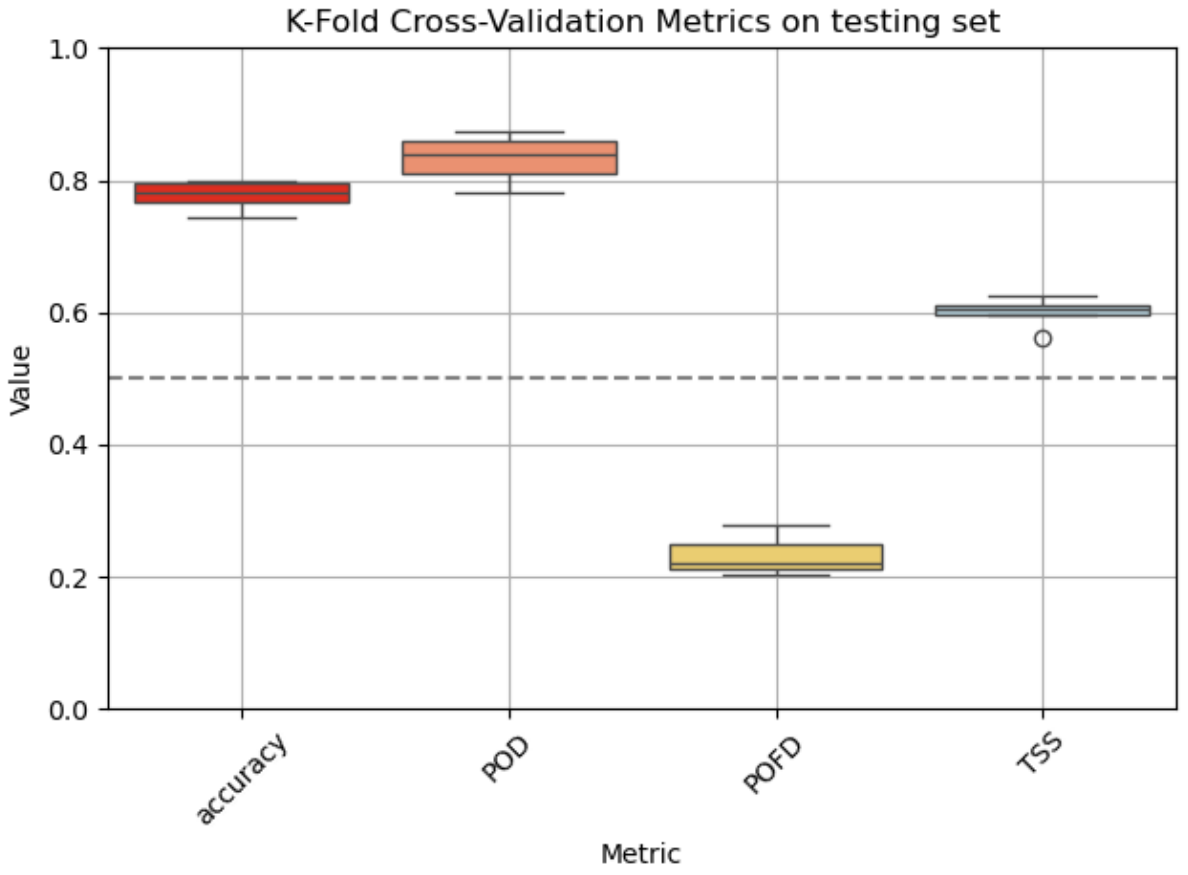
- About 27.5% of FP do have B-class flares, while they make up only 12% of “no-flare” samples
- Most FN in range C1-C4
- Most M-class flares correctly predicted (43), with two misclassifications a M1.1 and M2.0



Aggregated results across folds

- Using same independent test set for 5 trained models

Metric	Mean	σ
Accuracy	0.78	0.02
POD	0.83	0.04
POFD	0.23	0.03
TSS	0.60	0.02



Conclusion

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Northumbria University NEWCASTLE
NUdata CDT

Approach
- Predicting solar flares ≥C1-class in next 24 hour from magnetogram data
- Trained an FCN using variable-size full HMI resolution images (2013-2023)

Results
- Event days are correctly forecast 83±4 % of the time with 23±3% false detection and a TSS of 0.60±0.02
- Magnetograms that lead to no more than B-class flaring activity are overrepresented in the False Positive forecasts
- Very few ≥M1 flares missed (only 2 out of 43; M1.1 and M2.0)

Future work
- Future work to interpret the model's decisions is still pending, which could provide insights into the achieved metrics

References

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