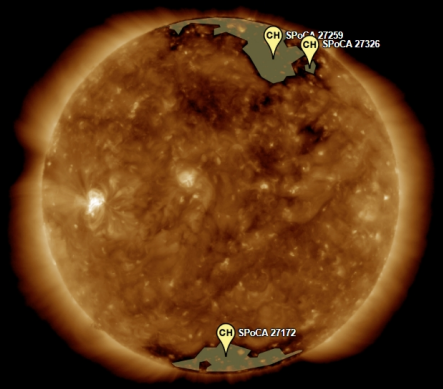
Segmentation of solar disk images with a convolutional neural network

Egor ILLARIONOV (Moscow State University)
Andrey TLATOV (Kislovodsk Mountain Solar Station)

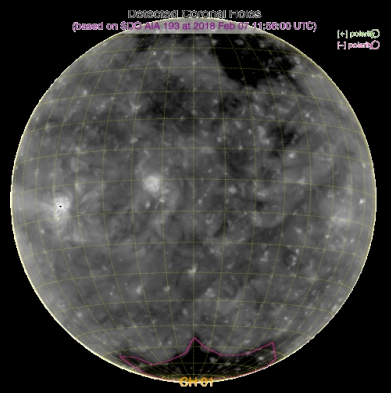
Examples of coronal holes segmentation for the same day

Helioviewer

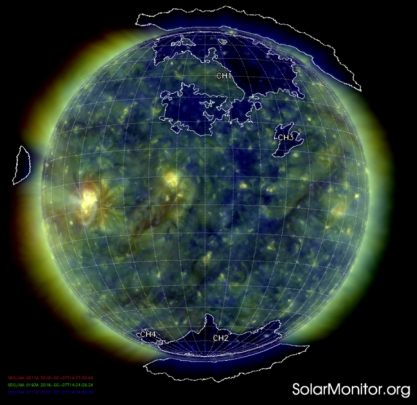


ObserveTheSun

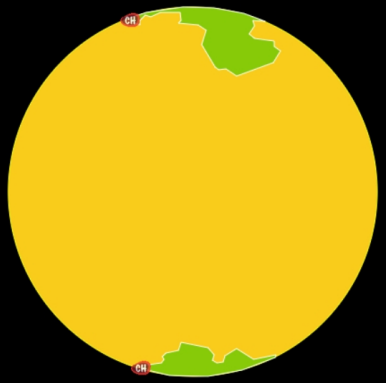
ASSA



SolarMonitor

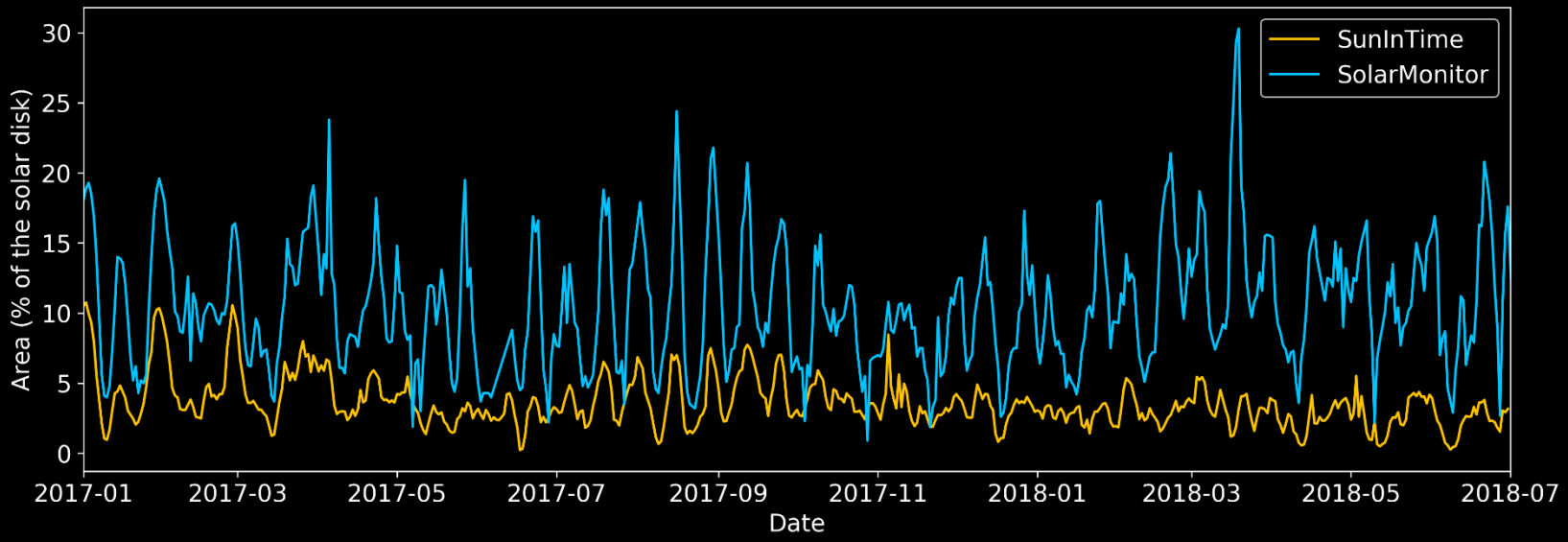


SunInTime



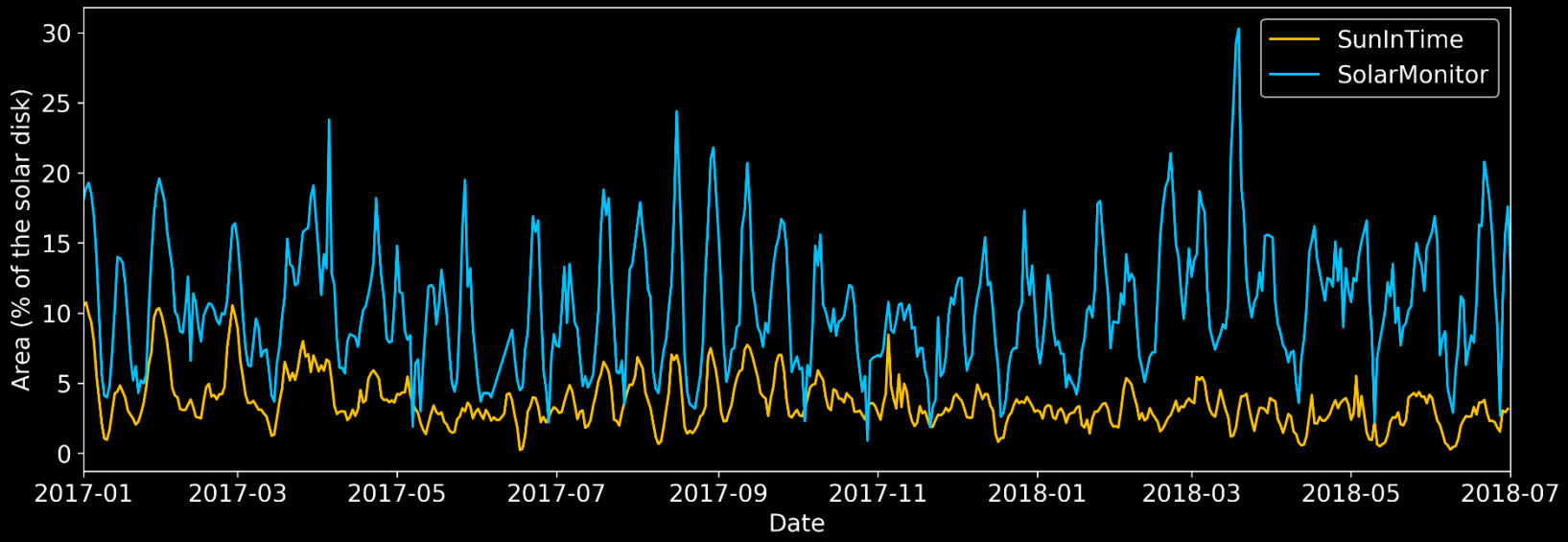
NOAA SWPC

Total area of CHs according to SunInTime (Spoca) and SolarMonitor (CHIMERA)



Yet another algorithm?

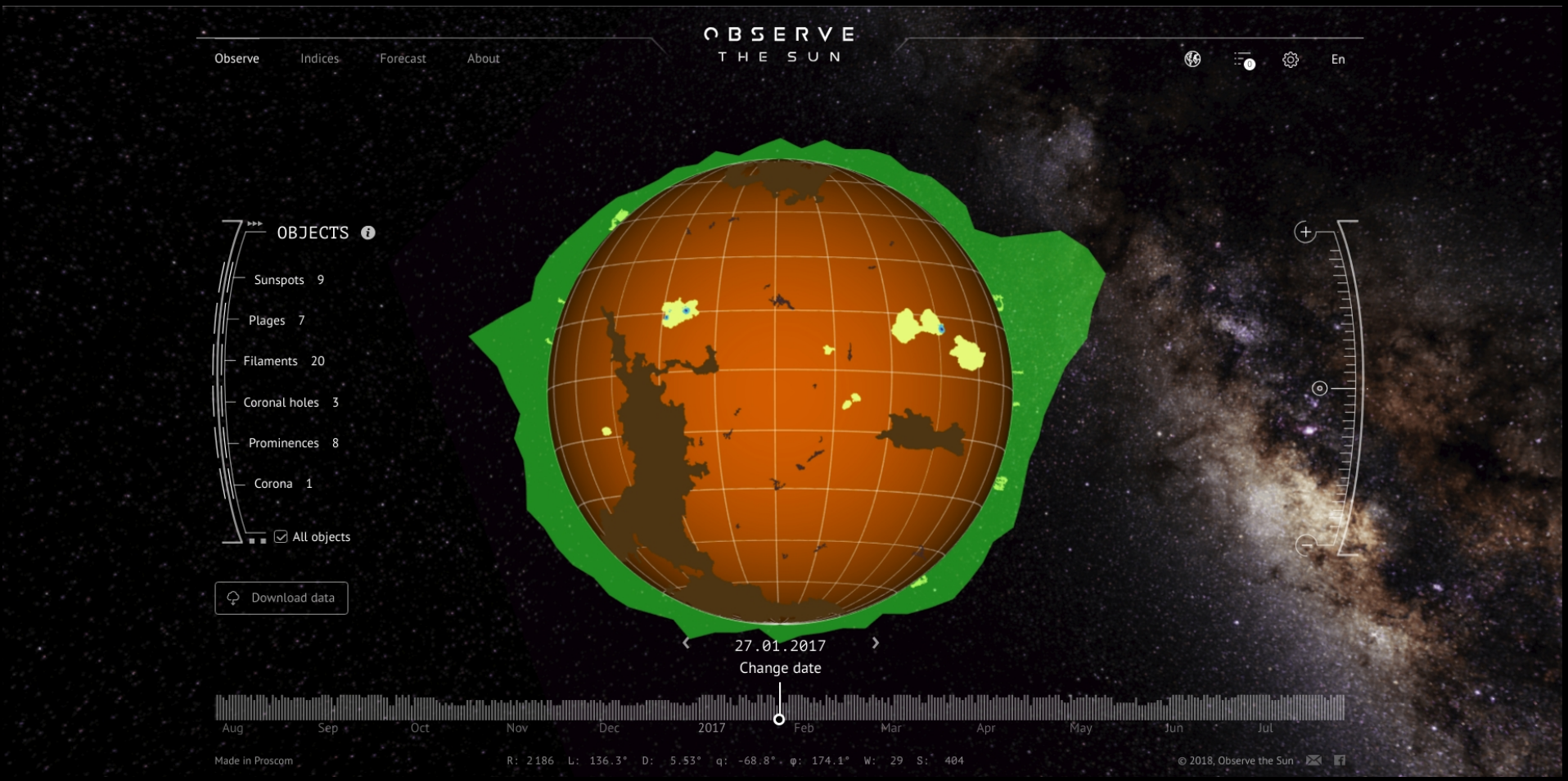
Total area of CHs according to SunInTime (Spoca) and SolarMonitor (CHIMERA)



~~Yet another algorithm?~~

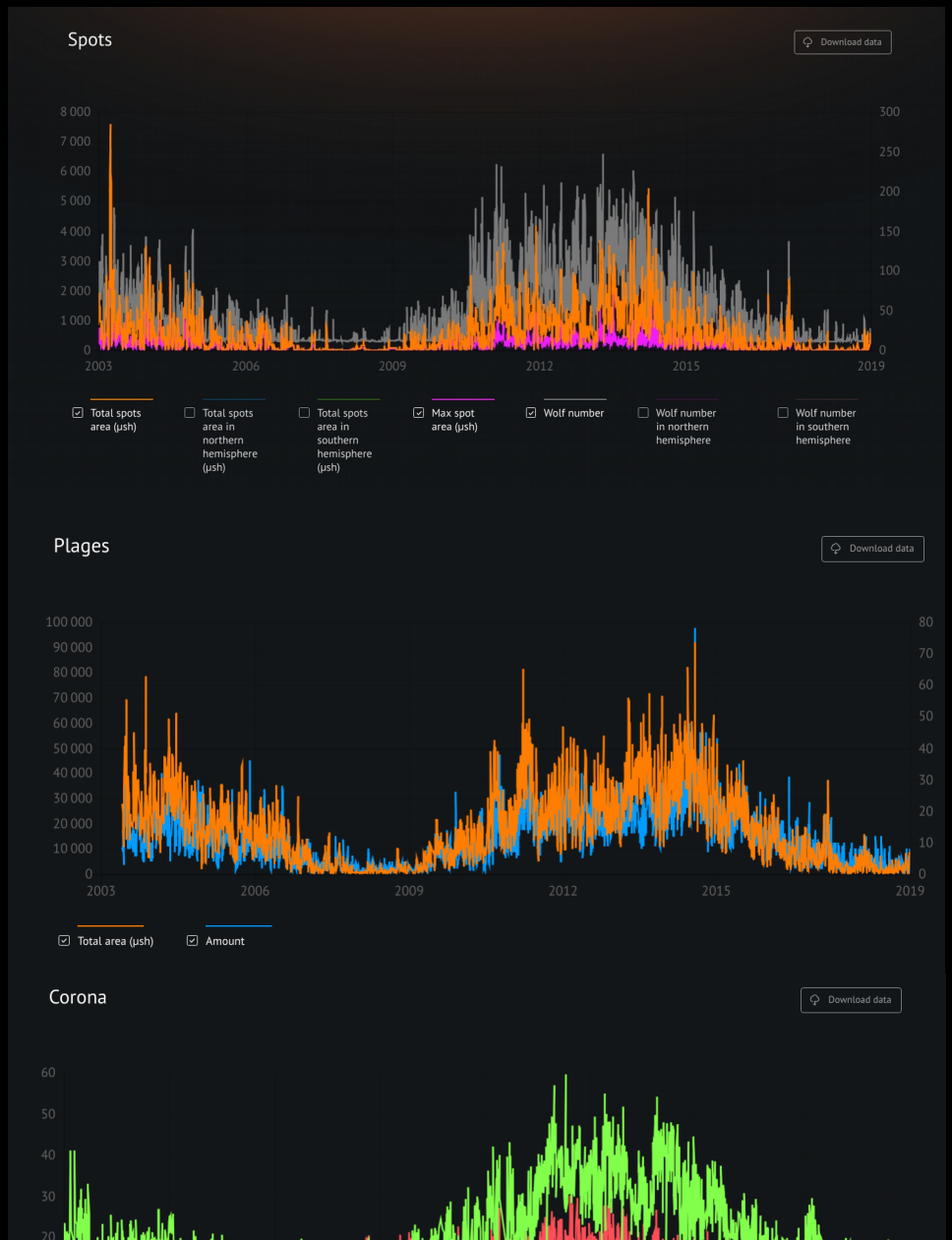
Reference dataset first!

Solar activity over 100 years is available in a new website



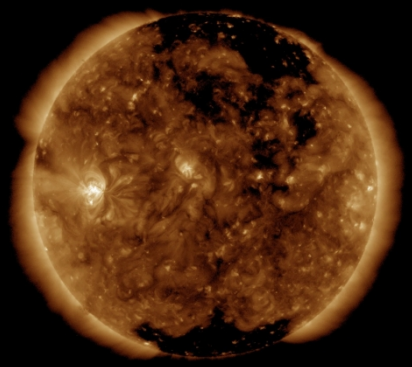
https://observethesun.com

Solar activity indices at observethesun.com

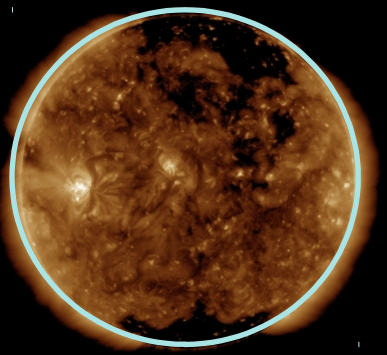


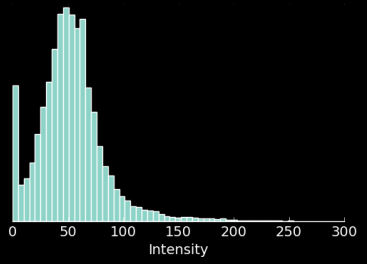
Actual forecasts of Kp and solar wind at observethesun.com

Semi-automatic segmentation procedure is applied on a daily basis for production of solar activity maps



SDO AIA 193A

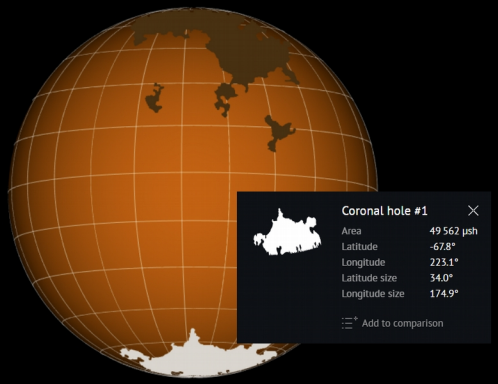




Solar disk detection and histogram analysis

Regions growing

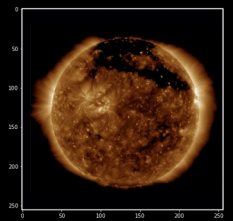
Manual post-processing

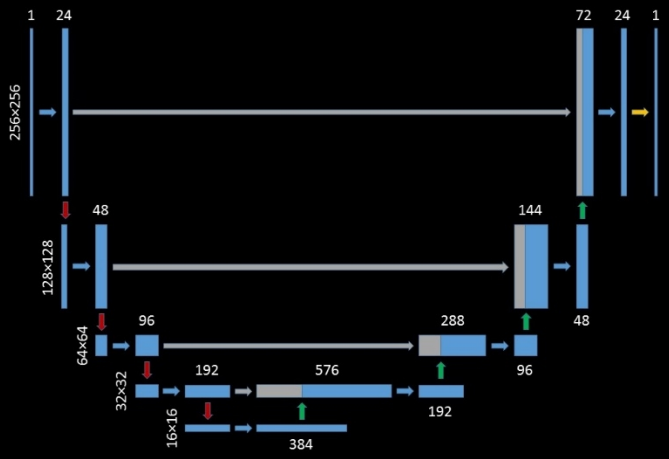


Boundaries and statistics of CHs

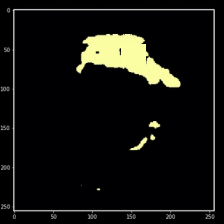
Neural network training

Input image





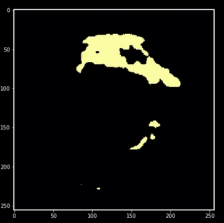
Predicted segmentation



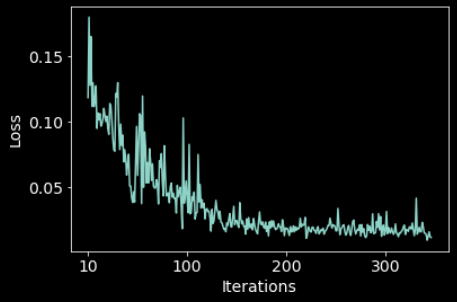
Loss function

$\ell(\theta, \hat{\theta})$

Target segmentation

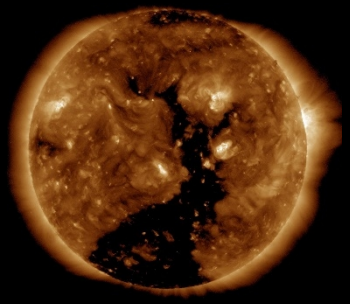


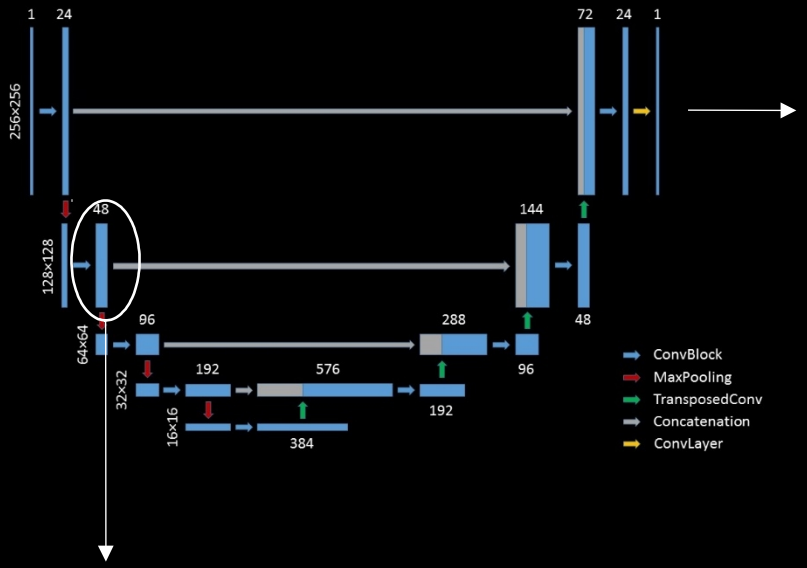
Update weights in hidden layers

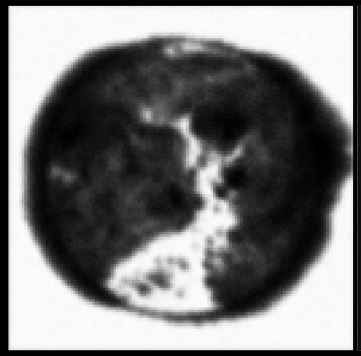


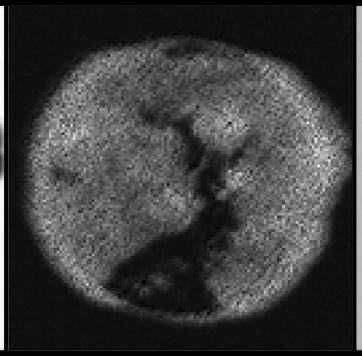
Plot of the loss function decay against iterations

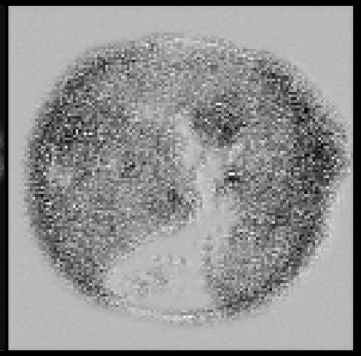
Hidden layers outputs

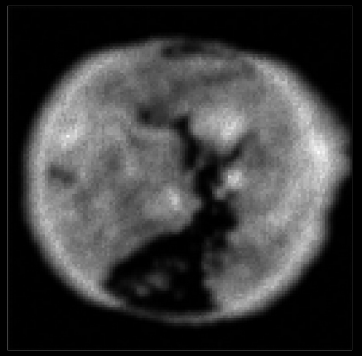


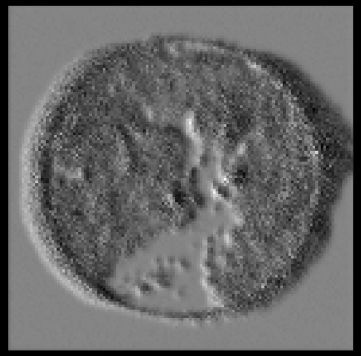




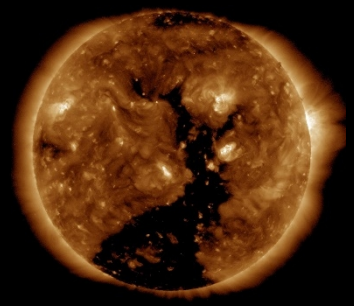


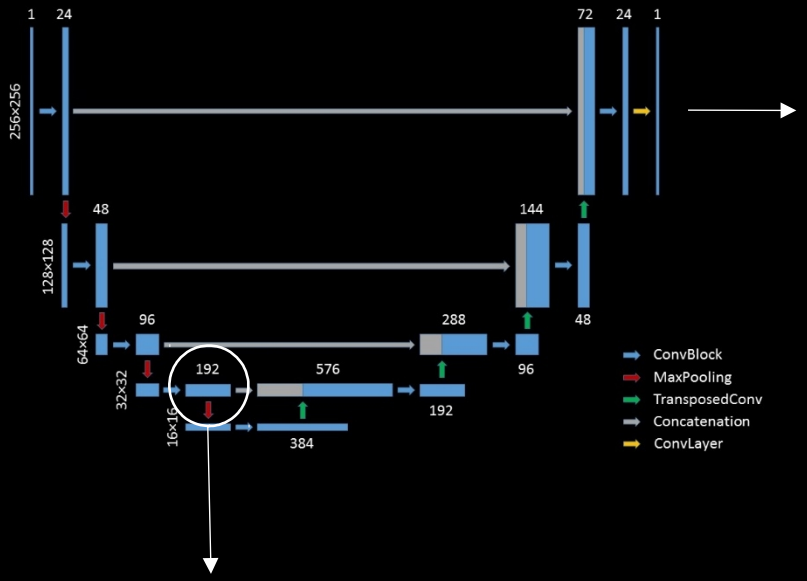


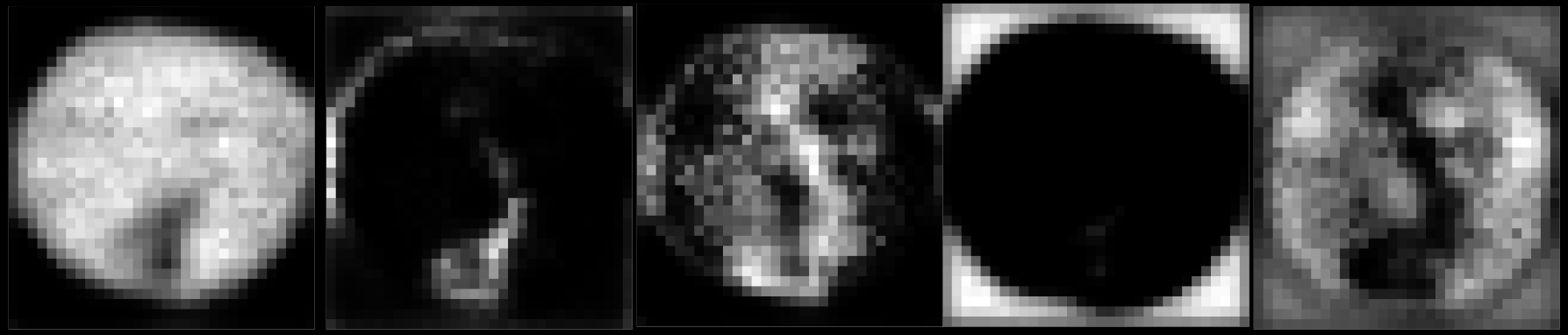




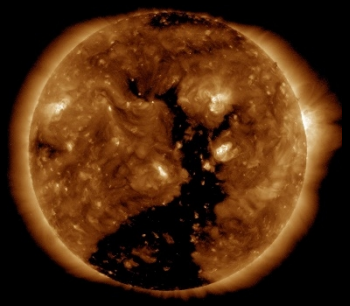
Hidden layers outputs

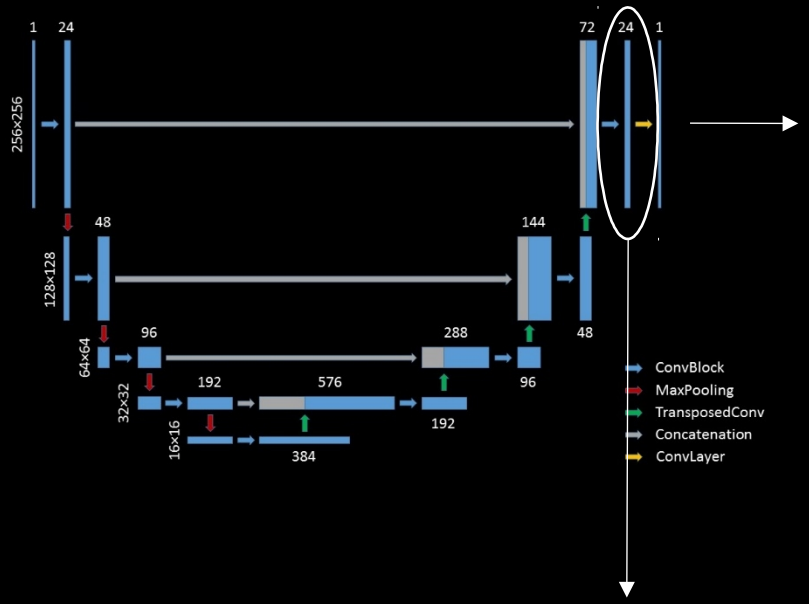


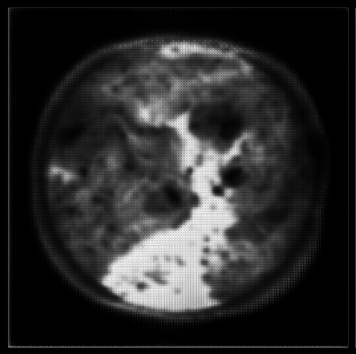


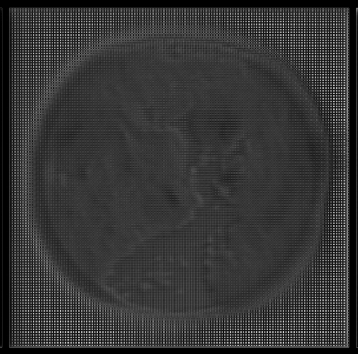


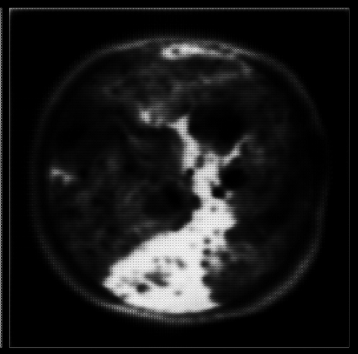
Hidden layers outputs

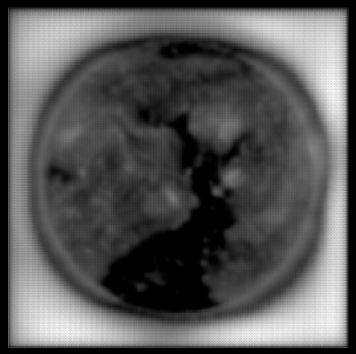


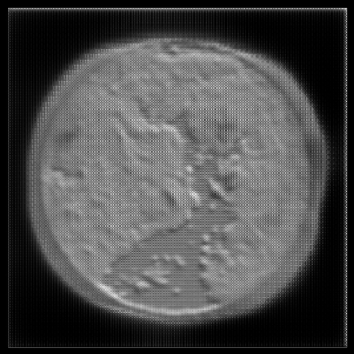




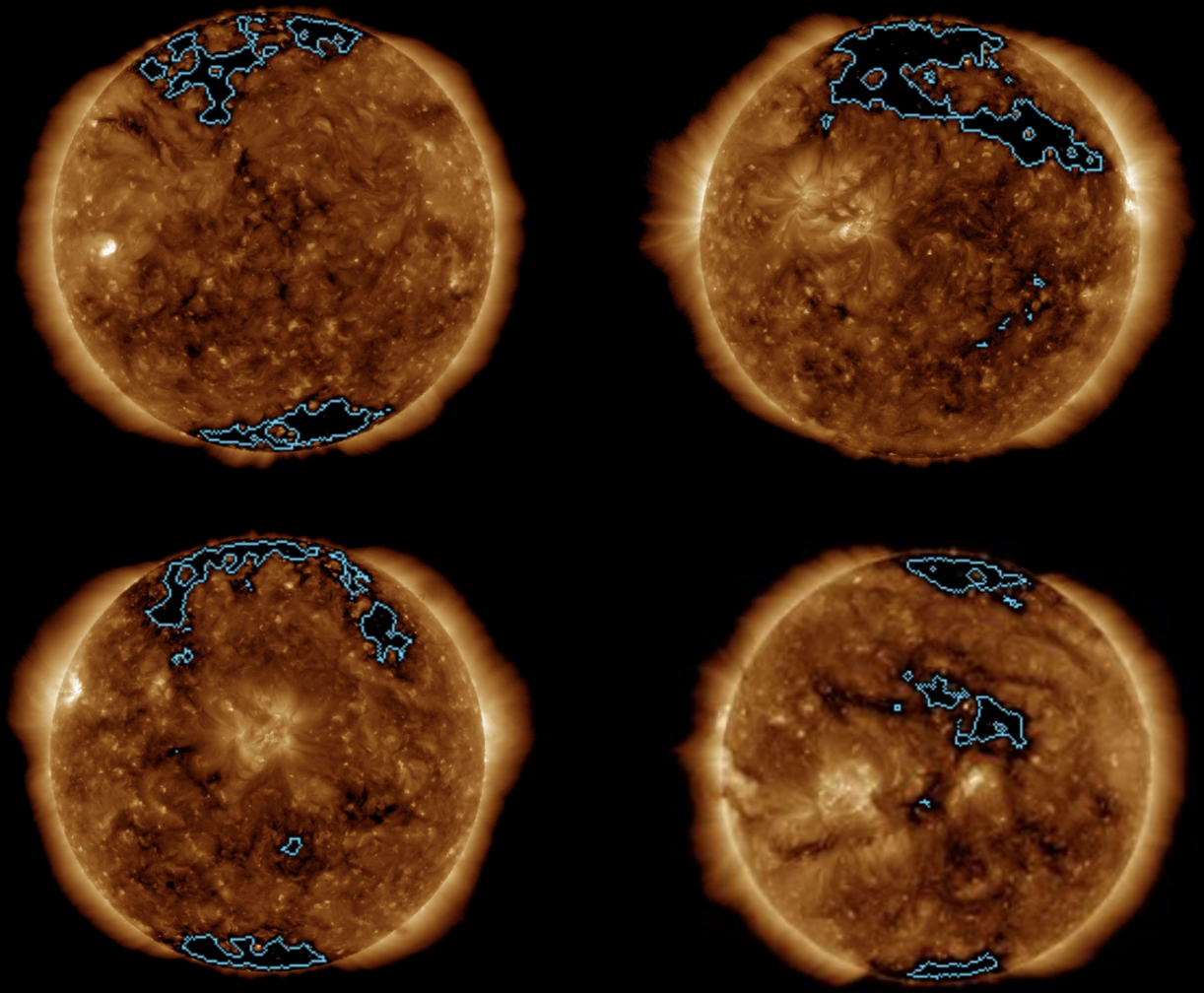








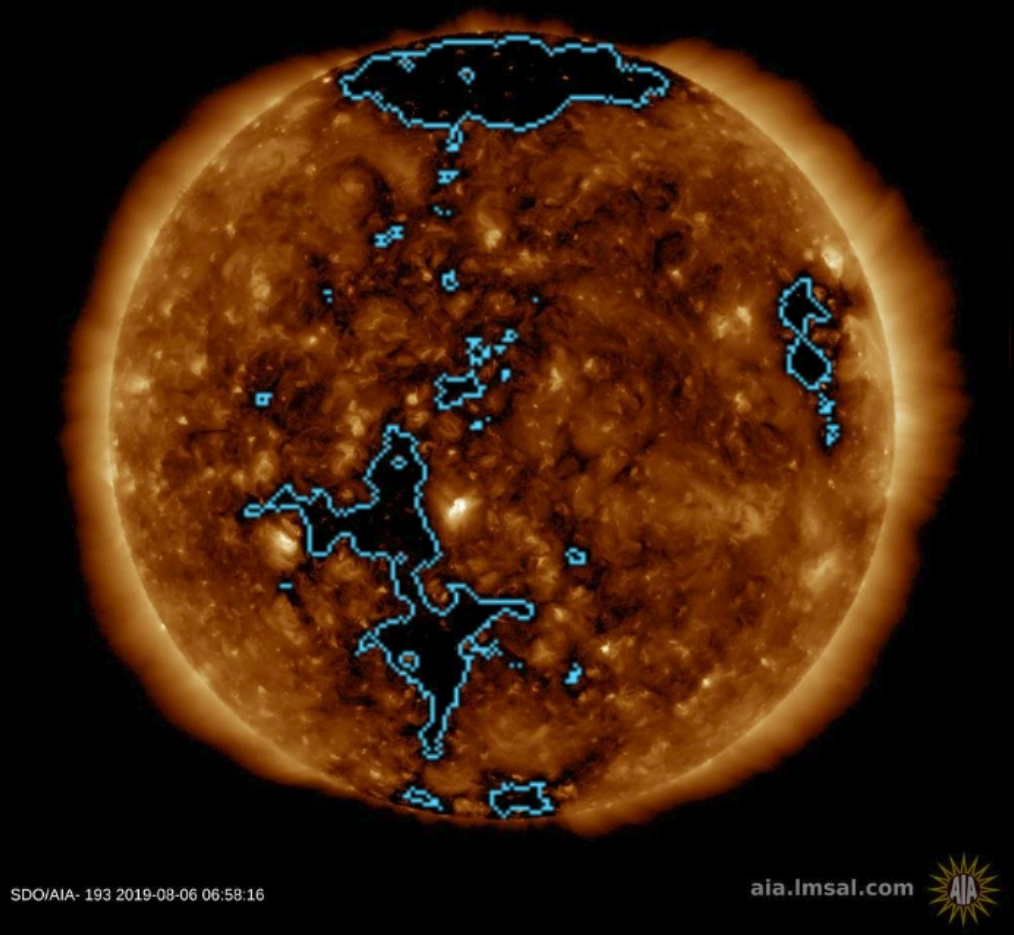
Coronal holes segmentation with a trained model



Online model for CH segmentation – https://illarionovea.github.io/

Coronal holes segmentation tool

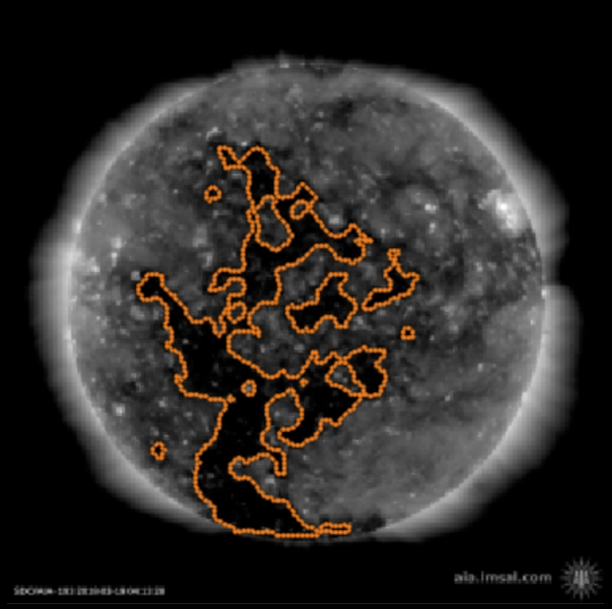
End-to-end neural network approach



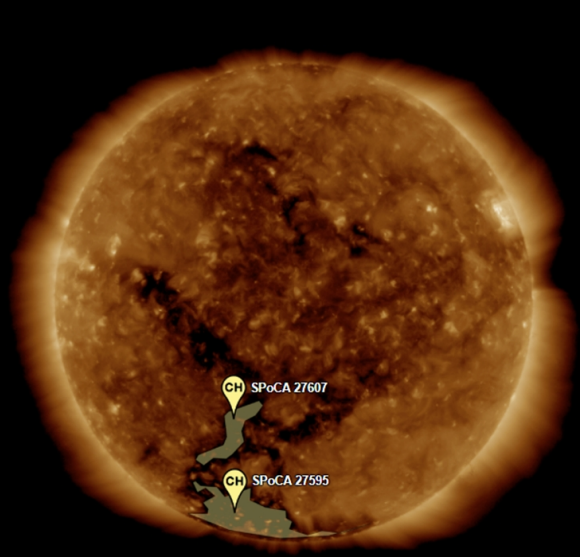
https://illarionovea.github.io/

Comparison of segmentation maps for the same day

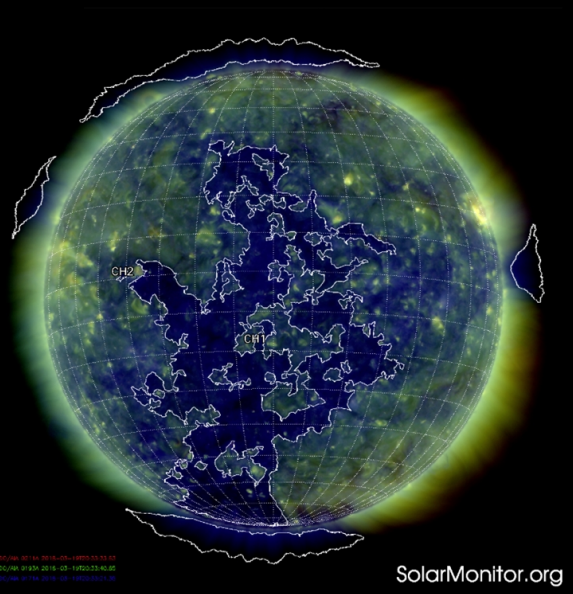
19 March 2018



U-Net

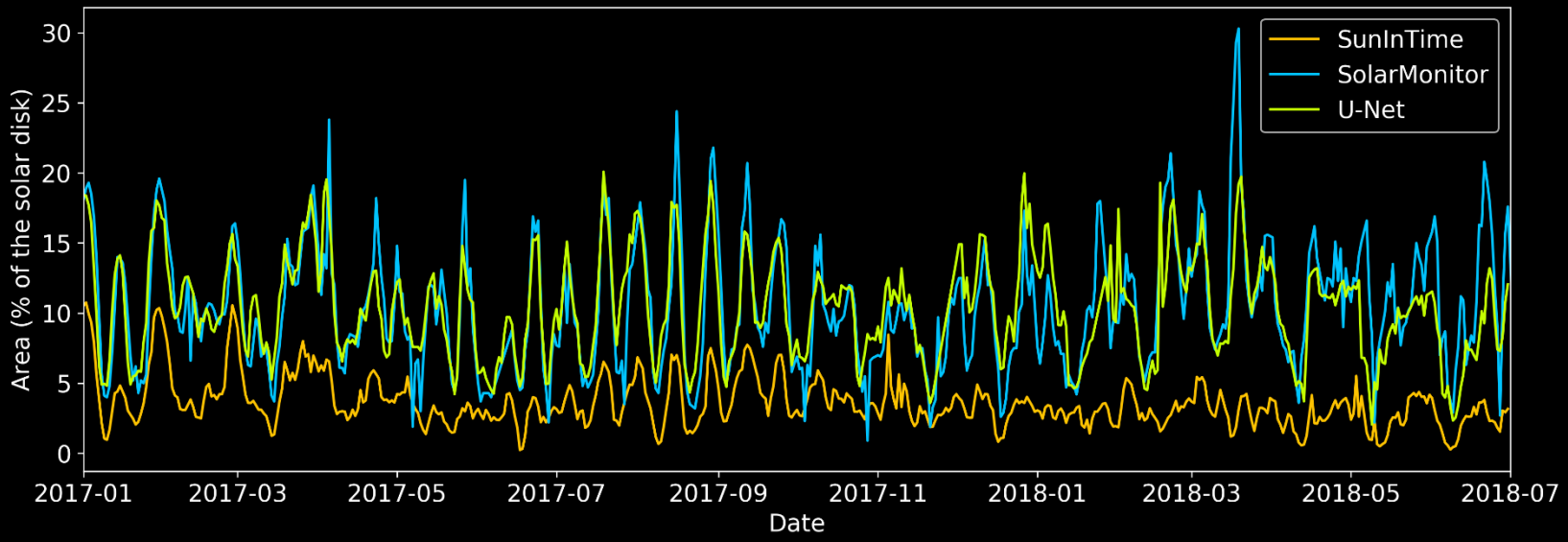


Helioviewer



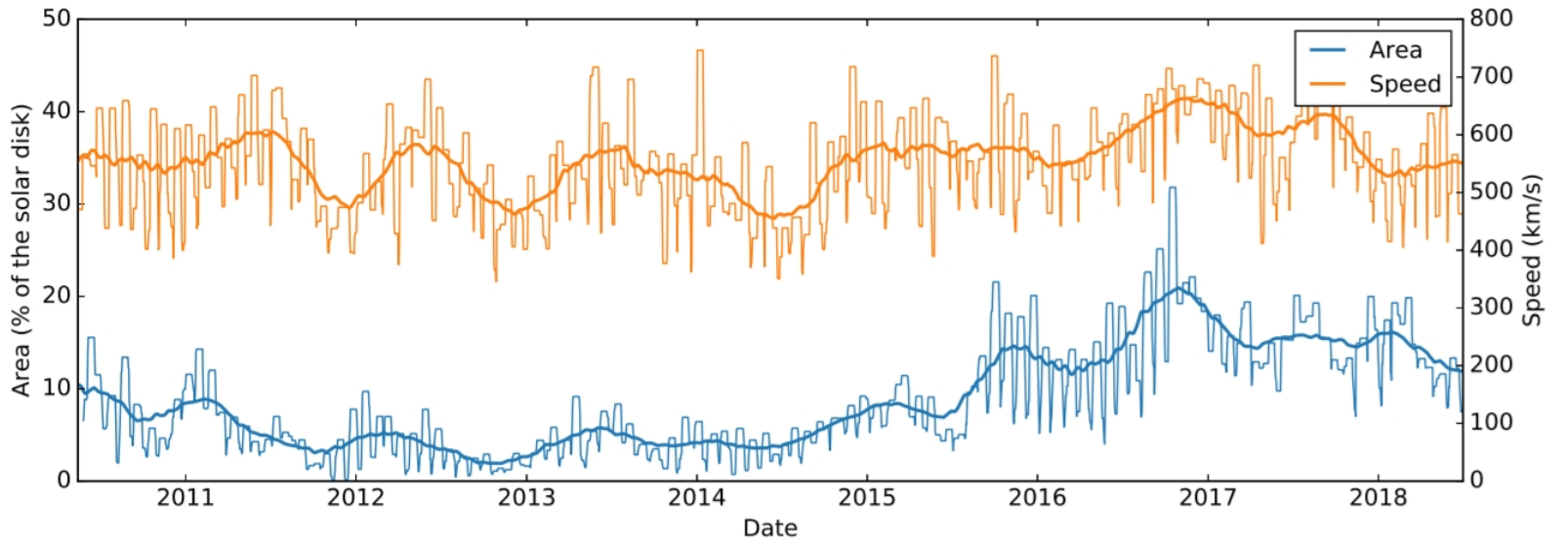
SolarMonitor

Total CH's area in comparison to the U-Net model



Correlation with SolarMonitor – 0.76

Long-term variations of the total CH's area



CHs area demonstrates yearly variations, increasing trend during the declining phase of the solar cycle and is minimal during the maximum of the solar cycle. We also note a correlation between CH areas and SW speeds (numerical value of this correlation is 0.7).

References to CHs segmentation model

E.A. Illarionov, A.G. Tlatov (2018). Segmentation of coronal holes in solar disk images with a convolutional neural network. MNRAS, 481, 4
https://doi.org/10.1093/mnras/sty2628

GitHub repository with source code and practical examples

https://github.com/observethesun/coronal_holes

```
def preprocess(batch):
    return (batch.load_images(fmt='blosc') #Load source images from blosc file format
              .load_objects() #load coronal holes
              .drop_empty_days() #Drop days without coronal holes
              .make_segmentation_masks((1024, 1024), ohe=False) #Make binary target images
              .downsize_image(['images', 'masks'], 256) #Resize images to 256 x 256
              .random_rot90(['images', 'masks']) #Augmentation
              .random_flip(['images', 'masks'], axis=0) #Augmentation
              .random_flip(['images', 'masks'], axis=1) #Augmentation
              .apply(lambda x: x / 255, ['images']) #Change pixel intensity range to [0, 1]
            )
```

Sunspot segmentation

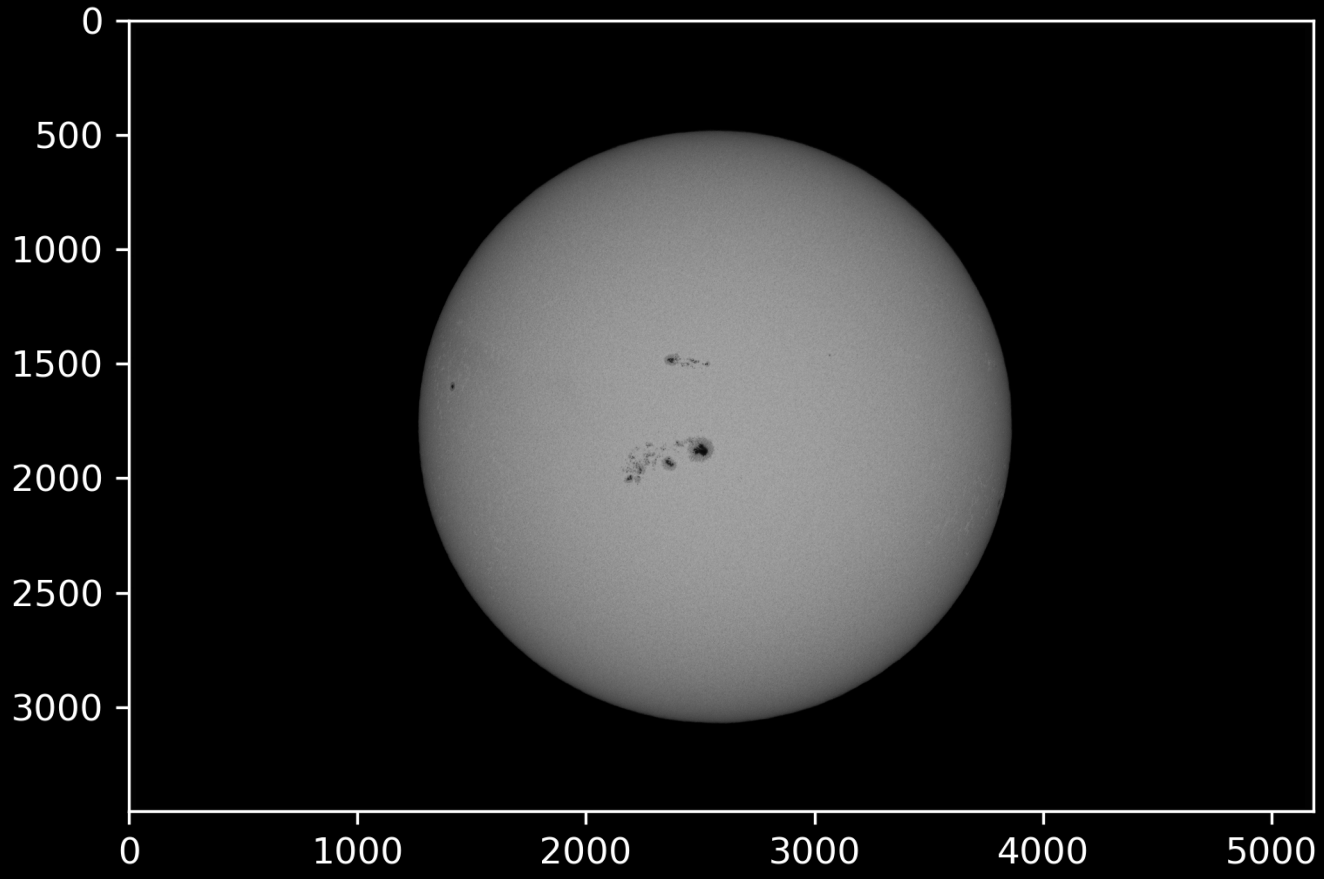
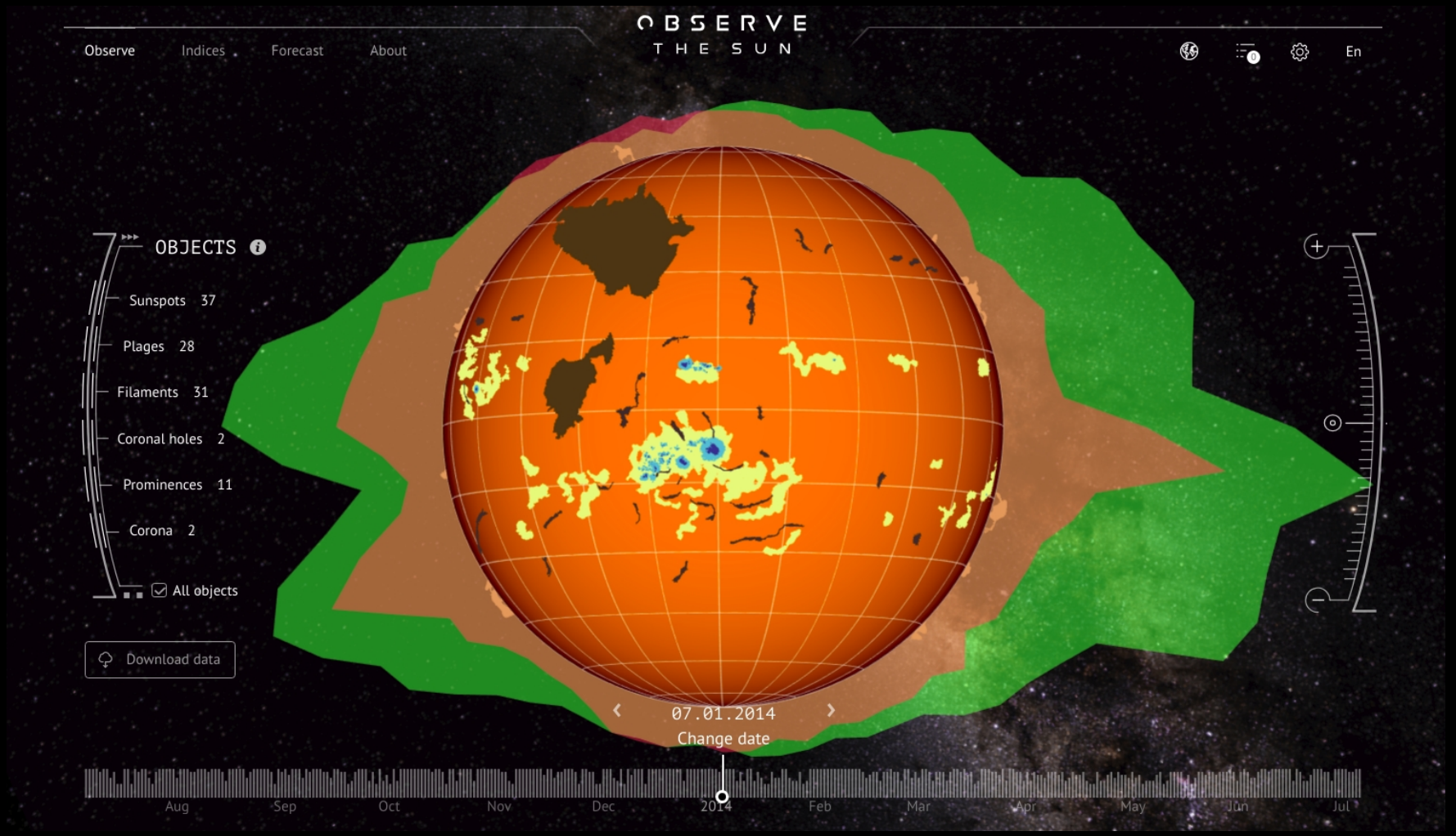


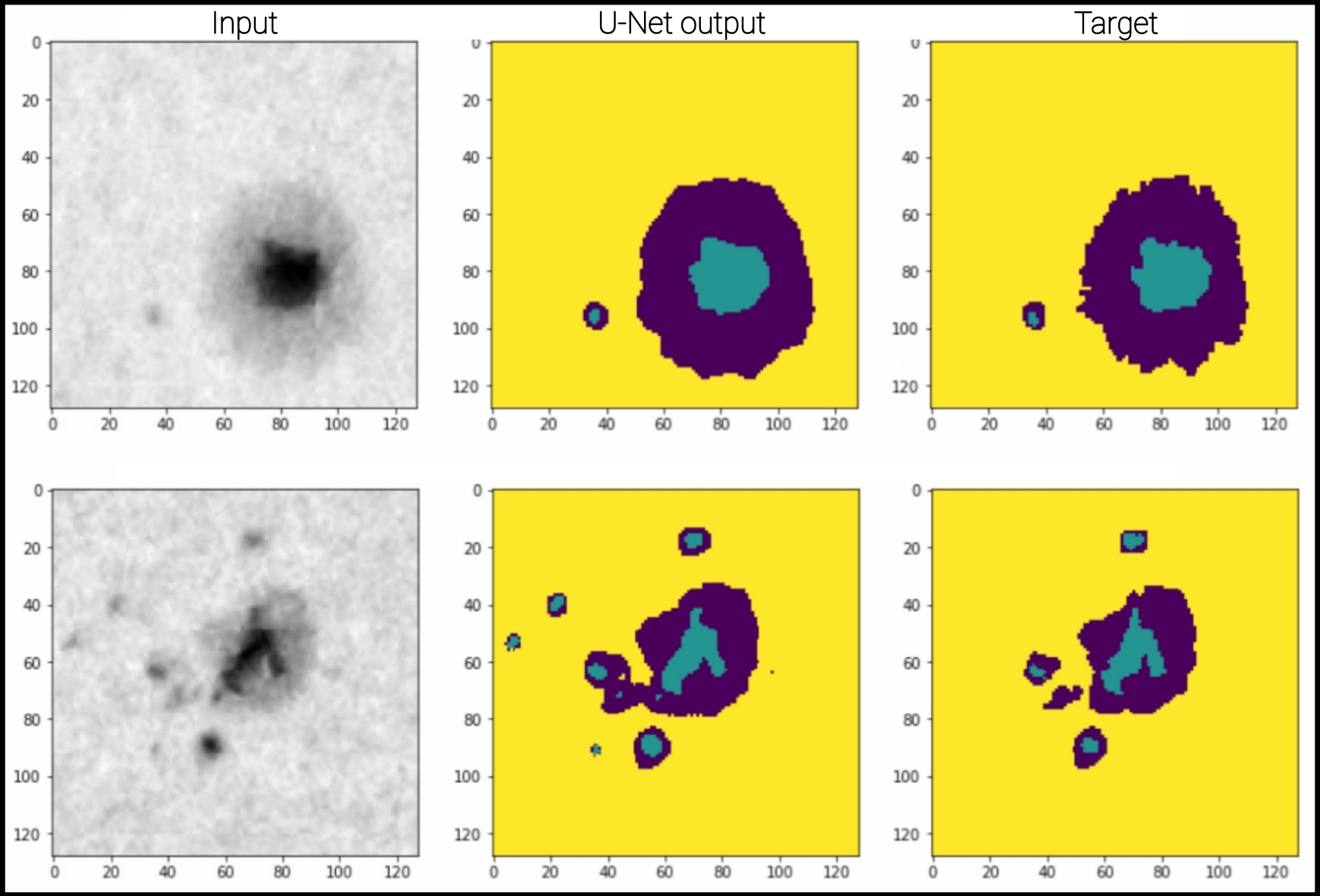
Image of the solar disk taken at Kislovodsk station
2014-07-01 06:46

Sunspot segmentation

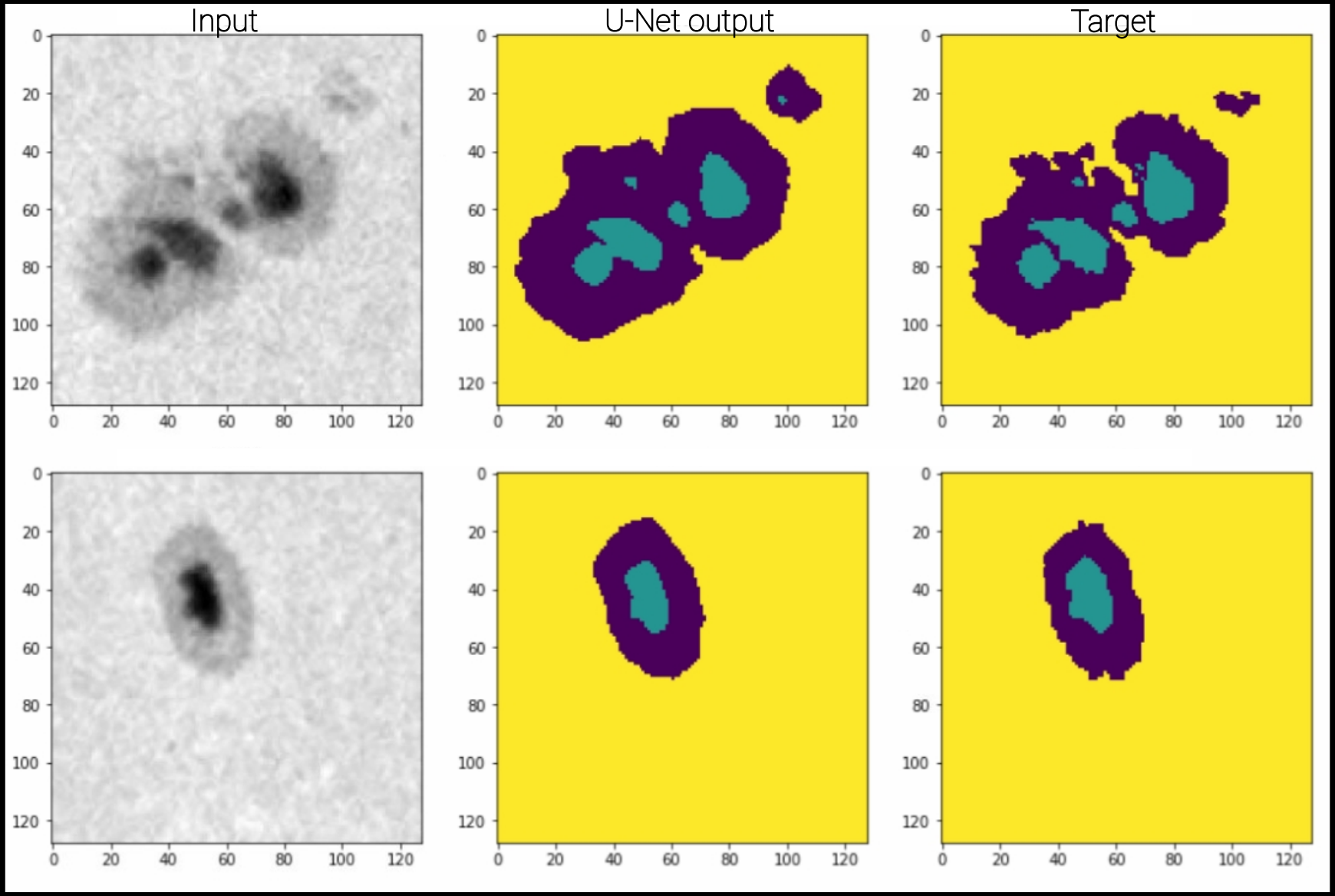


Target segmentation at observethesun.com
2014-07-01

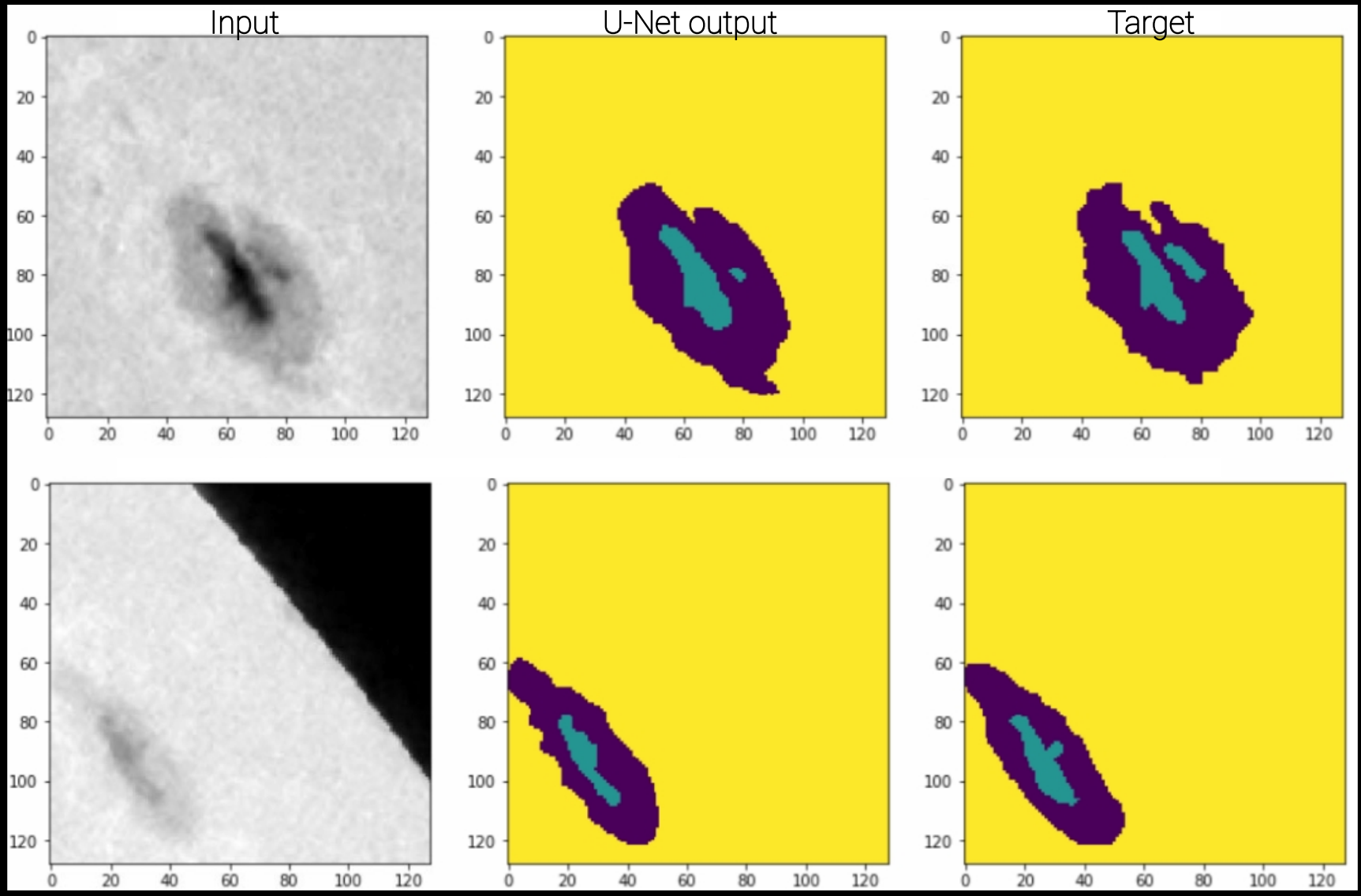
Examples of umbra and penumbra segmentation



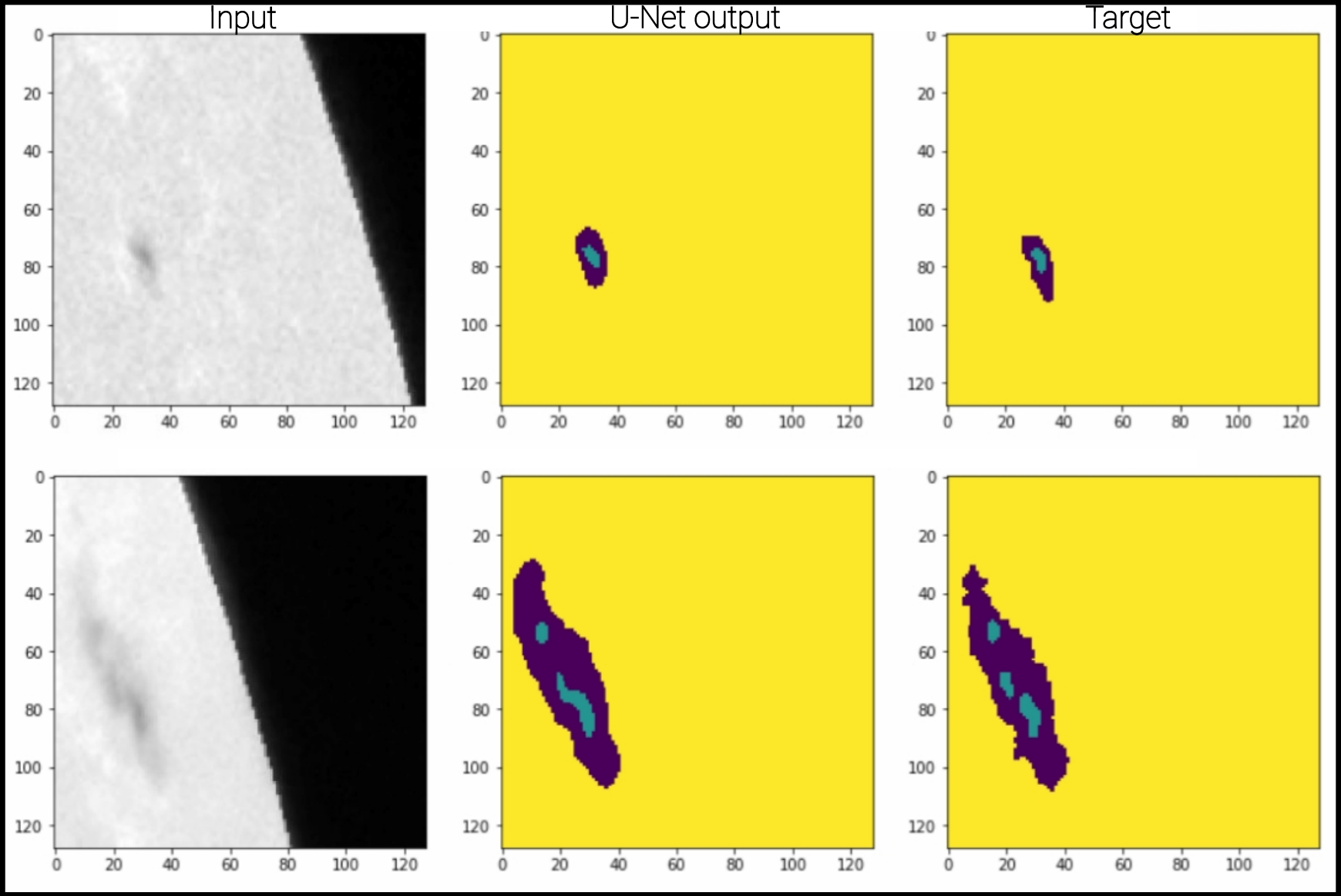
Examples of umbra and penumbra segmentation



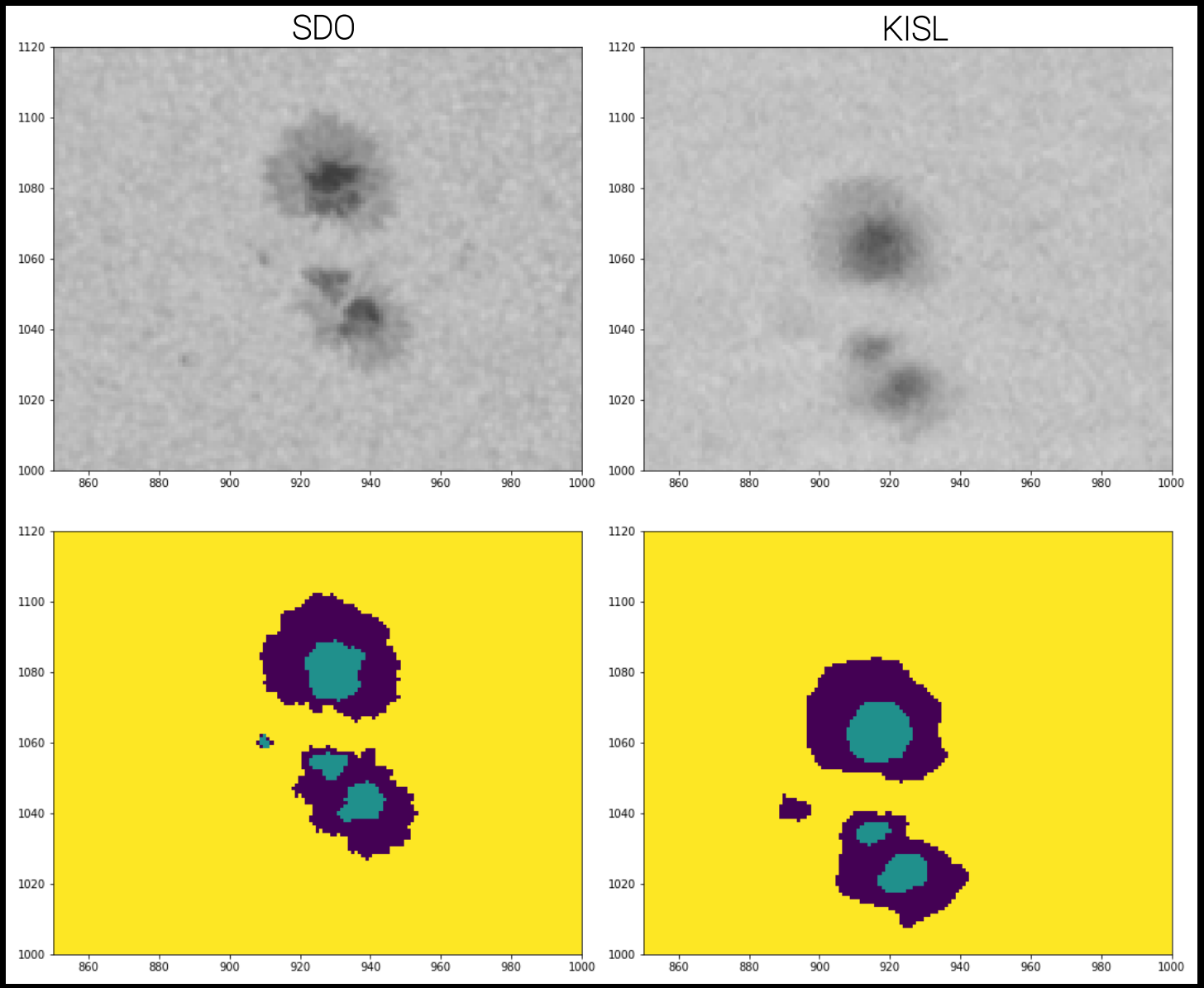
Examples of umbra and penumbra segmentation



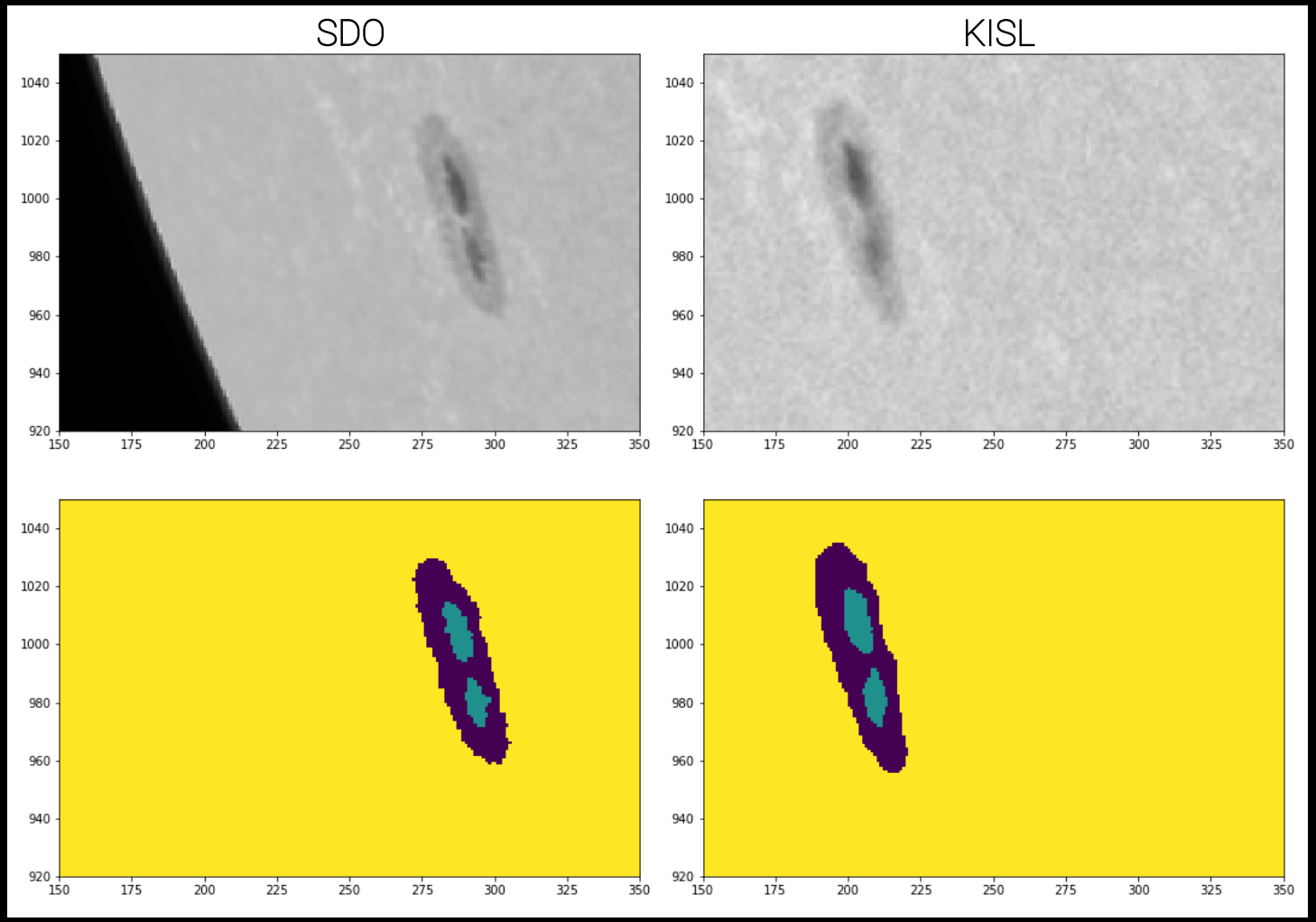
Examples of umbra and penumbra segmentation

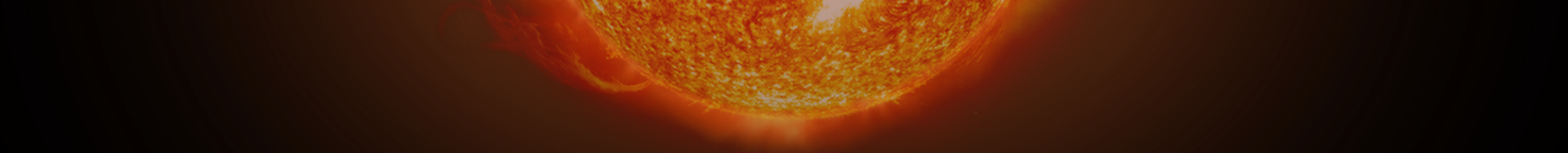


Application to SDO data



Application to SDO data



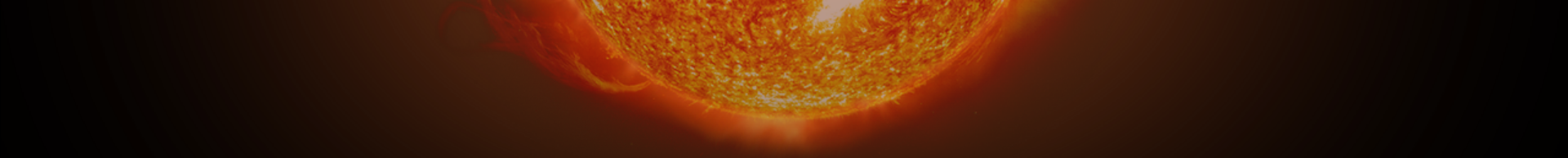


Conclusions

Conventional automatic image processing tools produce weakly consistent results.

Neural network models are able to produce segmentation similar to manual image interpretation.

Reference datasets are required to compare models and measure progress. Datasets produced by Kislovodsk solar station and available at observethesun.com may be a starting point in this way.



Thank you for attention!

E. A. Illarionov, A. G. Tlatov (2018). Segmentation of coronal holes in solar disk images with a convolutional neural network.
https://doi.org/10.1093/mnras/sty2628

Source code https://github.com/observethesun/coronal_holes

Online demo https://illarionovea.github.io/

K. Tlatova et al (2018) Reconstruction of Centennial Series of Solar Activity.
https://doi.org/10.1134/S0016793218080182

Tlatov,A. G. et al (2016). Forecast of solar wind parameters according to STOP magnetograph observations.
https://doi.org/10.1134/S0016793216080223