Segmentation of coronal features to understand the solar EIV and UV irradiance variability

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In the first two papers of our series (Kumara et al., 2014; Zender et al., 2017), we have analysed periodicities, dependencies, and correlations of solar disk segmented features in the EUV wavelength as well as using magnetograms.

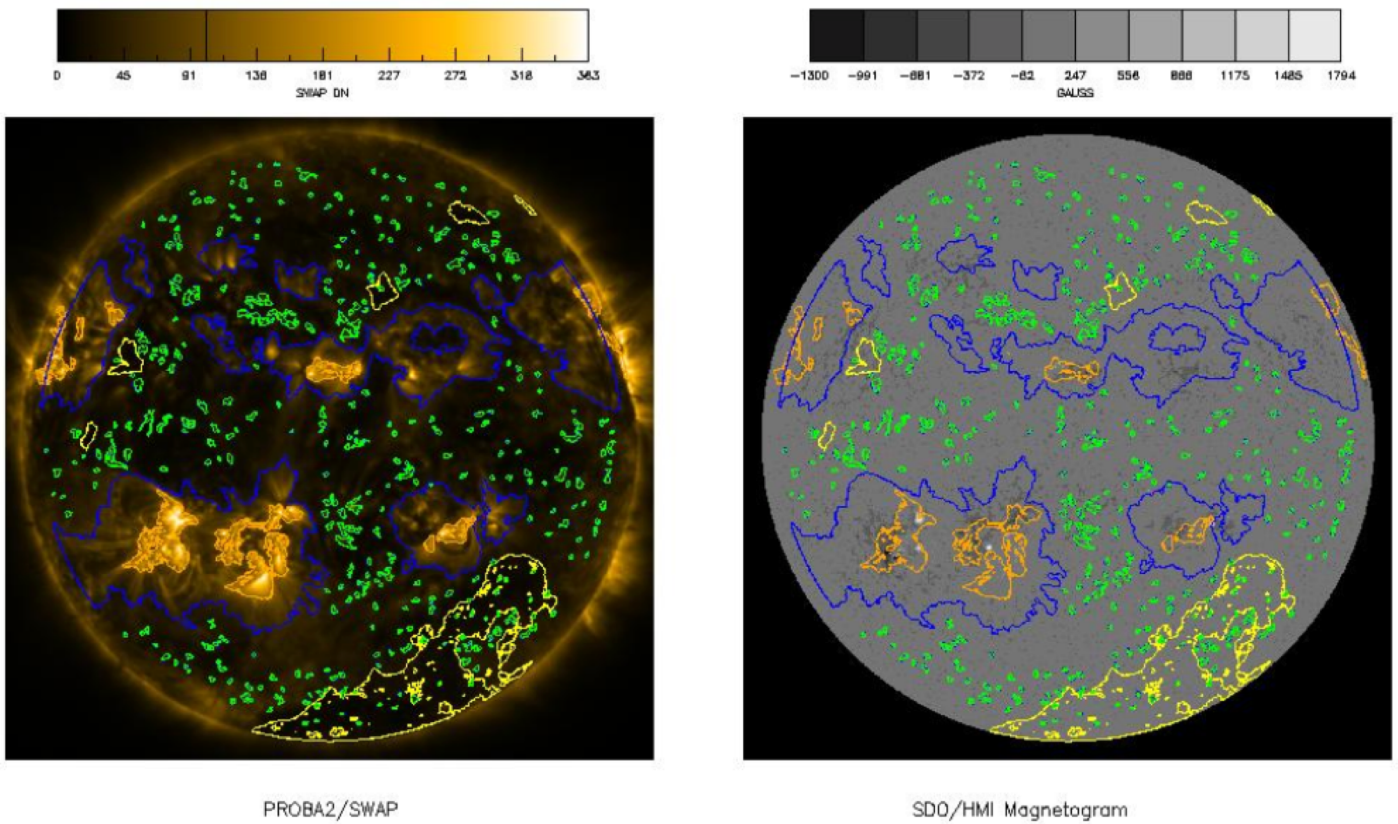
Segmented features analysed were: Active Regions (AR), Coronal Holes (CH), and the Quiet Sun (QS). Earlier results confirmed that the AR drive most of the energetical output of the Sun and correlate well with the energy received at Earth, e.g. by radiometers in Earth orbit.

The question we are addressing here is:

What is the role of Bright Points towards the solar irradiance variability entering the Earth atmosphere?

The study analyses data from Proba2-SWAP/LYRA and SDO-AIA/HMI from May 2010 until January 2020.

(a) Proba2/SWAP 17.4 nm and SDO/HMI LOS magnetogram



Left panel:
Segmentation features mapped onto a SWAP[1] 174A image.
Right panel:
Segmentation features mapped onto HMI[2] image.
In both maps, CH are colored in yellow, BPs in green, AR are in dark blue (morphological algorithm), and orange(SPoCA[3] algorithm).
Images are obtained on 1 January 2012.

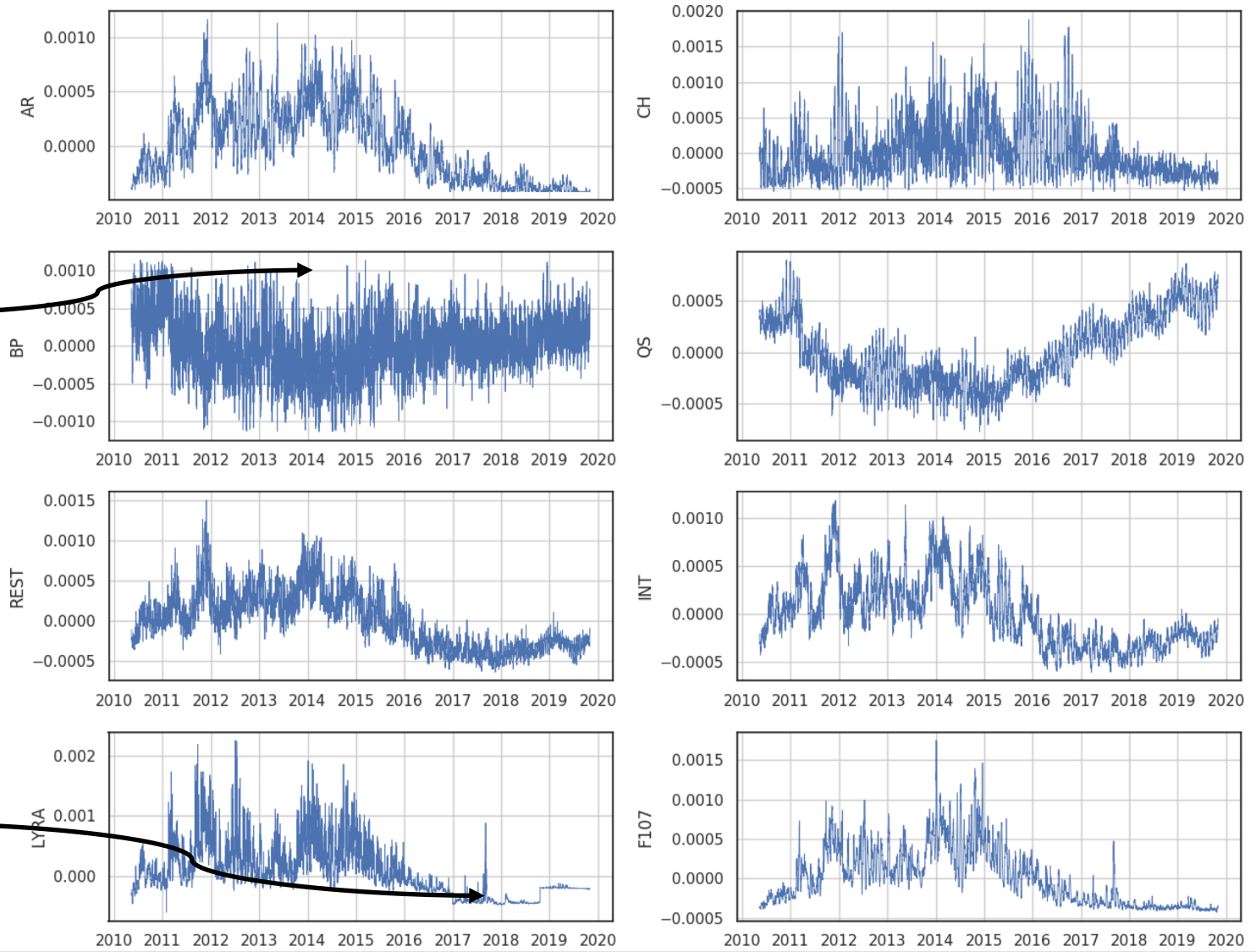
SPoCA algorithm is based on SWAP image (174A). The AR detected by SPoCA ”seemed to” be too small, and we implemented a morphological algorithm for AR detection.
BP detection is also based on morphological algorithm, with underlying AIA[4] 193A images.

1) Seaton et al., 2013; 2) Hoeksema et al., 2014; Barra et al., 2009; Boerner et al., 2012

Normalised time series of the AIA171 segments integrated intensity, LYRA irradiance and F10.7 flux

BP show reverse AR behavior[1]

LYRA re-calibrated data was received in the mean-time. Needs to be updated.



QS show reverse AR behavior[1]

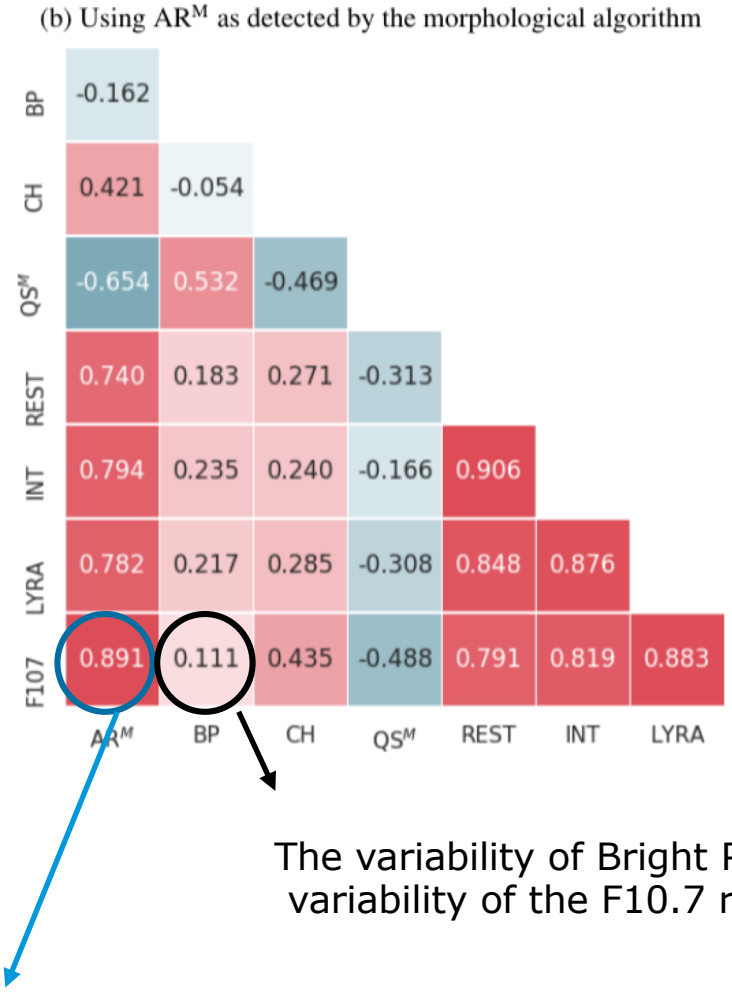
1) Sattarov et al, 2010;

Spearman correlation coefficients between the integrated intensity of segments using AIA171 images, the LYRA irradiance and F10.7 cm radio flux.

INT stands for the integrated intensity of the entire image, and is the sum of the integrated intensity of the segments.

A heat map is used such that the relative differences in values can easily be observed: red stands for a positive coefficient, blue stands for a negative coefficient, a darker colour indicates a stronger absolute value

|r| > 0.6 indicates a correlation



The variability of Bright Points is not correlated with the variability of the F10.7 radio flux.

The variability of AR is correlated with the variability of the F10.7 radio flux.

Reconstruction of the 10-year data from the segmented features:

$$Y = a \cdot AR + b \cdot BP + c \cdot CH + q \cdot QS + l \cdot LC$$

Coefficients a,b,c,q, and l represent the contribution of the corresponding feature to the reconstruction.

Y	a	b	c	q	l	R^2
INT	0.5191	0.0236	0.0538	0.309	0.4537	0.999
w.r.t. a	100.0%	4.6%	10.4%	59.5%	87.4%	
LYRA	0.3819	0.1487	0.0069	0.1888	0.4457	0.652
w.r.t. a	100.0%	38.9%	1.8%	49.4%	116.7%	
F107	0.5804	0.1384	0.1239	0.2429	0.2293	0.813
w.r.t. a	100.0%	23.8%	21.3%	41.9%	39.5%	

R^2 is the coefficient of determination and represents a measure how well the reconstruction of the original signal worked, R_2=1 represents a perfect reconstruction.

Interpretation 1:
The integrated intensity of the full solar disk, INT, can be reconstructed perfectly (R^2=1).
That is an expected outcome and hints that the linear model used is useful.

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Interpretation 2:

The reconstruction of the F10.7 flux over a 10 year period is reasonably good (R^2=0.81), with

a) One main contributor: AR with a=0.58
b) Two medium contributors: QS with q=0.24, and LimbCorona with l=0.23
c) Two small contributors: BP with b=0.14 and CH with c=0.12

Wrap-up / Conclusion

- (nearly) automated data pipeline to retrieve, feature segmentation, and data analysis works reliable for 10+ years of data.
- Data Analysis covers Active Regions, Coronal Holes, Bright Points, Quiet Sun, and the Limb-corona region.
- This analysis concentrated on the question, if the variance in Bright Point intensity data acquired in the EUV correlates with proxies of irradiances (LYRA) or fluxes (F10.7) measured at Earth (orbit).