How well do the Ca II K index time series correlate with the ISN?

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Outline

- Importance of Ca II K observations.
- Comparison of various Ca II K index time series:
  - Historical data: 1915 - 1985
  - Modern data: 1976 - Present
- Consistency of Ca II K index time series at different time scales:
  - Monthly averages
  - Annual averages
- Comparison of the Ca II K index time series with the International Sunspot Number (ISN) time series.

Conclusion: Both historical and modern Ca II K index time series correlate well with the ISN on time scales above one month.

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Importance of Ca II K observations

- They provide an important measure of solar magnetic activity. In particular, solar magnetic plages and network are easily observed in this strong chromospheric line, at 393.37 nm.
- Plages account for roughly one-half of the Sun's total magnetic flux and for most of the Sun's variability in UV flux.
- Ca II K observations started at the beginning of the 20th century at several observatories. These archives are of great importance for studies of the solar magnetism on time scales longer than the activity cycle.

Ca II K index time series

Historical Data

- MWO-UCLA: 8/1915 - 7/1985 (to present via proxy)
- MWO-Tlatov: 8/1915 - 7/1985
- MWO-Apn: 8/1915 - 7/1985 (to 4/1999 via proxy)
- Kodaikanal: 1907 - 1999

Modern Data - Integrated Sunlight

- KPO (Bill Livingston): 10/1974 - present
- SPO: 11/1976 - present
- SOLIS-ISS: 12/2006 - present

Note: Most of these data and related information are available on line from the UCLA, NSO, and NOAA websites.

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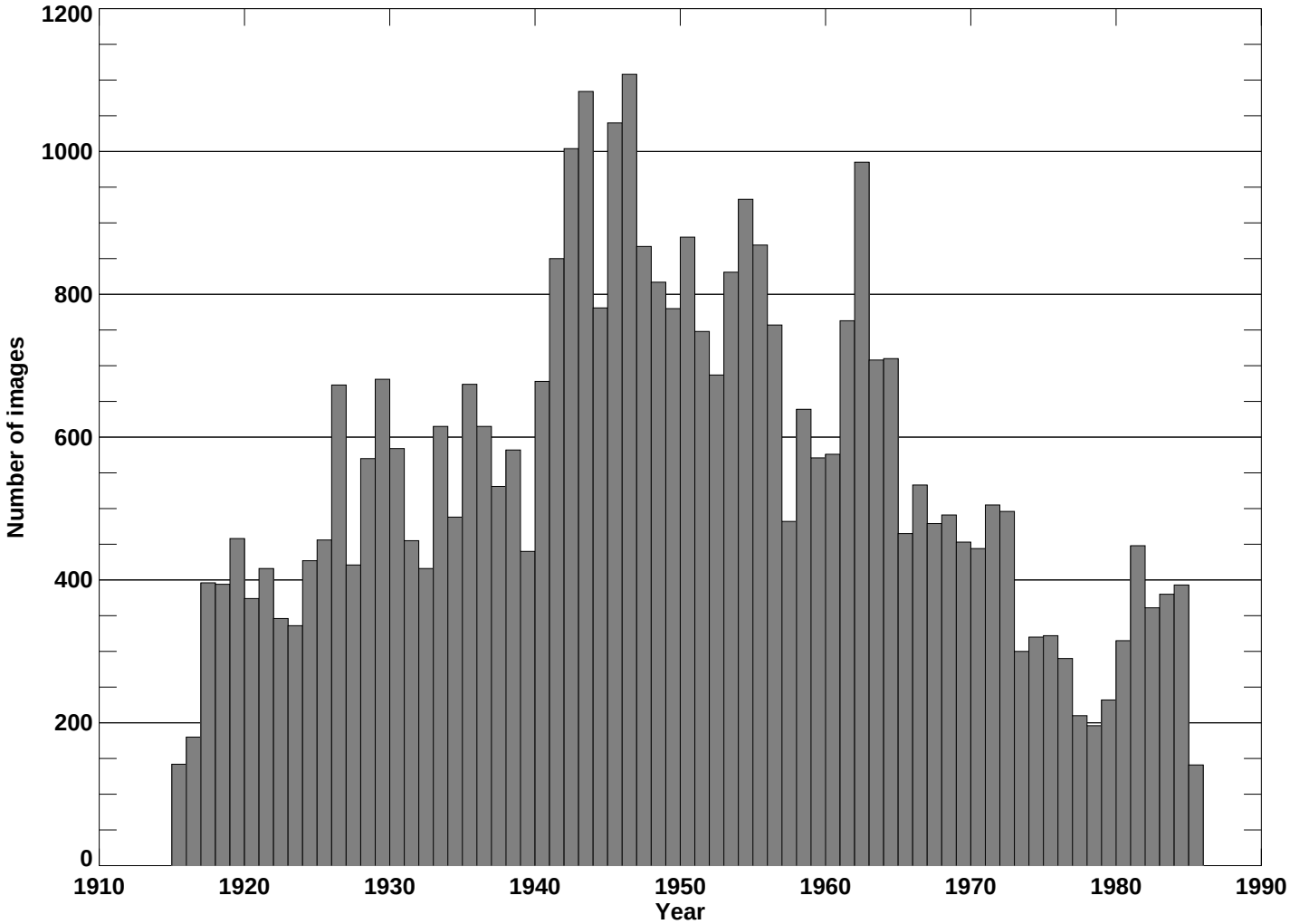
The historical MWO data set

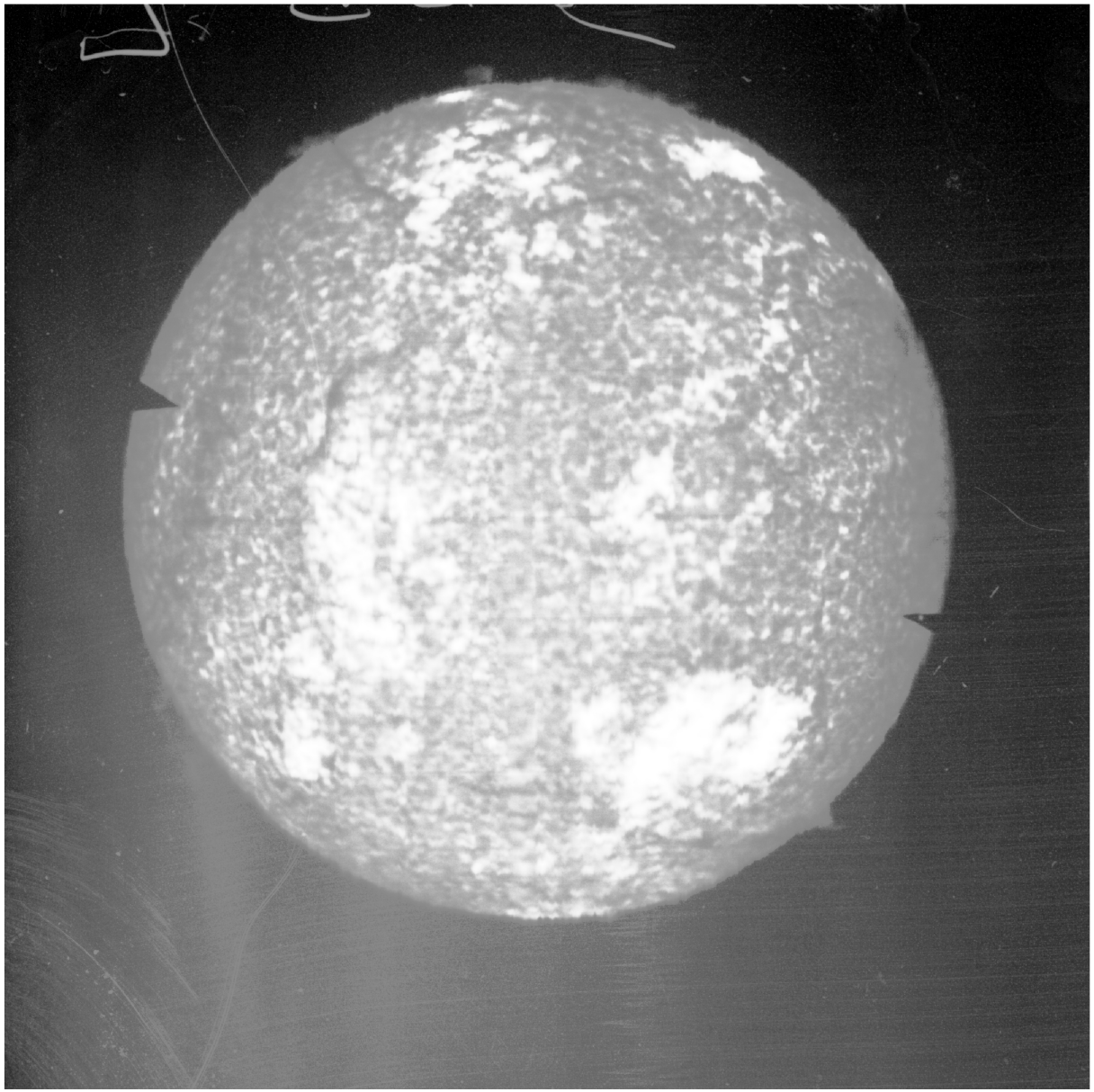
Starting in 1915 spectroheliograms in the light of the Ca II K line were taken twice per day at the Mount Wilson Solar Observatory. About the same time "white light" direct images were taken once per day.

- Approximately 45,000 images in the light of the Ca II K line, acquired from August 1915 to July 1985.
- Approximately 30,000 broad-band images (white light) acquired over the same time period.
- The spectroheliograms were first digitized by Foukal (1996) using a 512-pixel format, 8-bit camera.
- The same images were re-digitized (starting in 2003) at UCLA using a higher resolution (3000×3000), 12-bit digitizer.

Distribution of MWO Ca II K images



The Sun on Ca II K: June 12, 1958



Historical Ca II K index time series

- MWO-UCLA: The index is derived from the properties of the intensity-ratio distribution of pixels across the image. The time series is extended using the MPSI as a proxy.
- MWO-Tlatov: The index is defined as the fraction of the solar hemisphere occupied by the chromospheric plages + active network at any given time.
- MWO-Apn: The index is defined as the percentage of the solar disk covered by plages + active network. The original time series was extended using NSO/SP data.
- Kodaikanal (KKL): Same as MWO-Tlatov.
- Spectral bandpass (centered on K3): $\sim$0.35 Å for MWO observations, and $\sim$0.5 Å for KKL and NSO/SP observations.

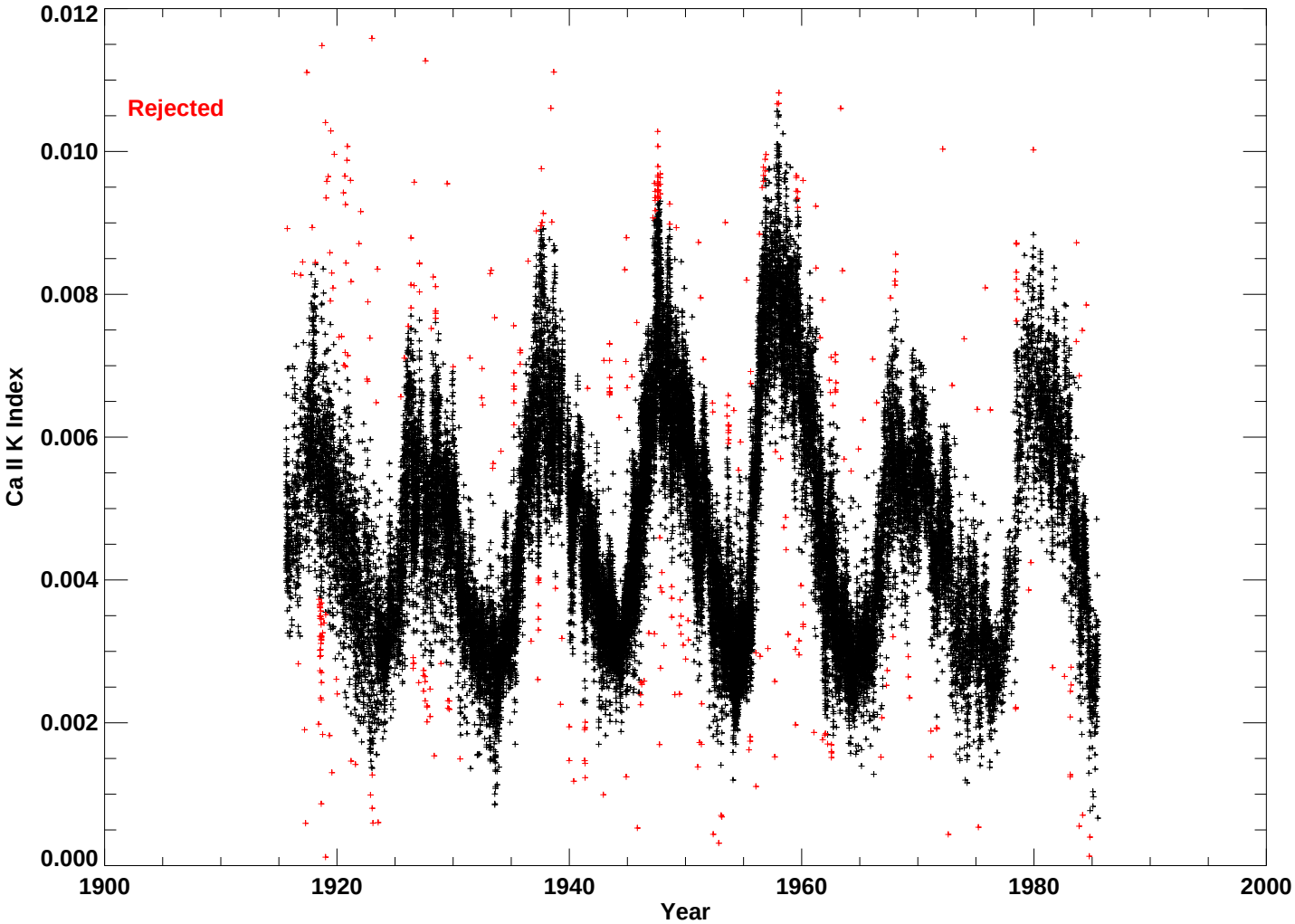
The MWO-UCLA Ca II K index

1. Each image is flat-fielded using a median filter.
2. A histogram is calculated using all pixels located within 0.99 solar radii from the center of the (flat-fielded) image.
3. A four-parameter Gaussian function is used to model this distribution:

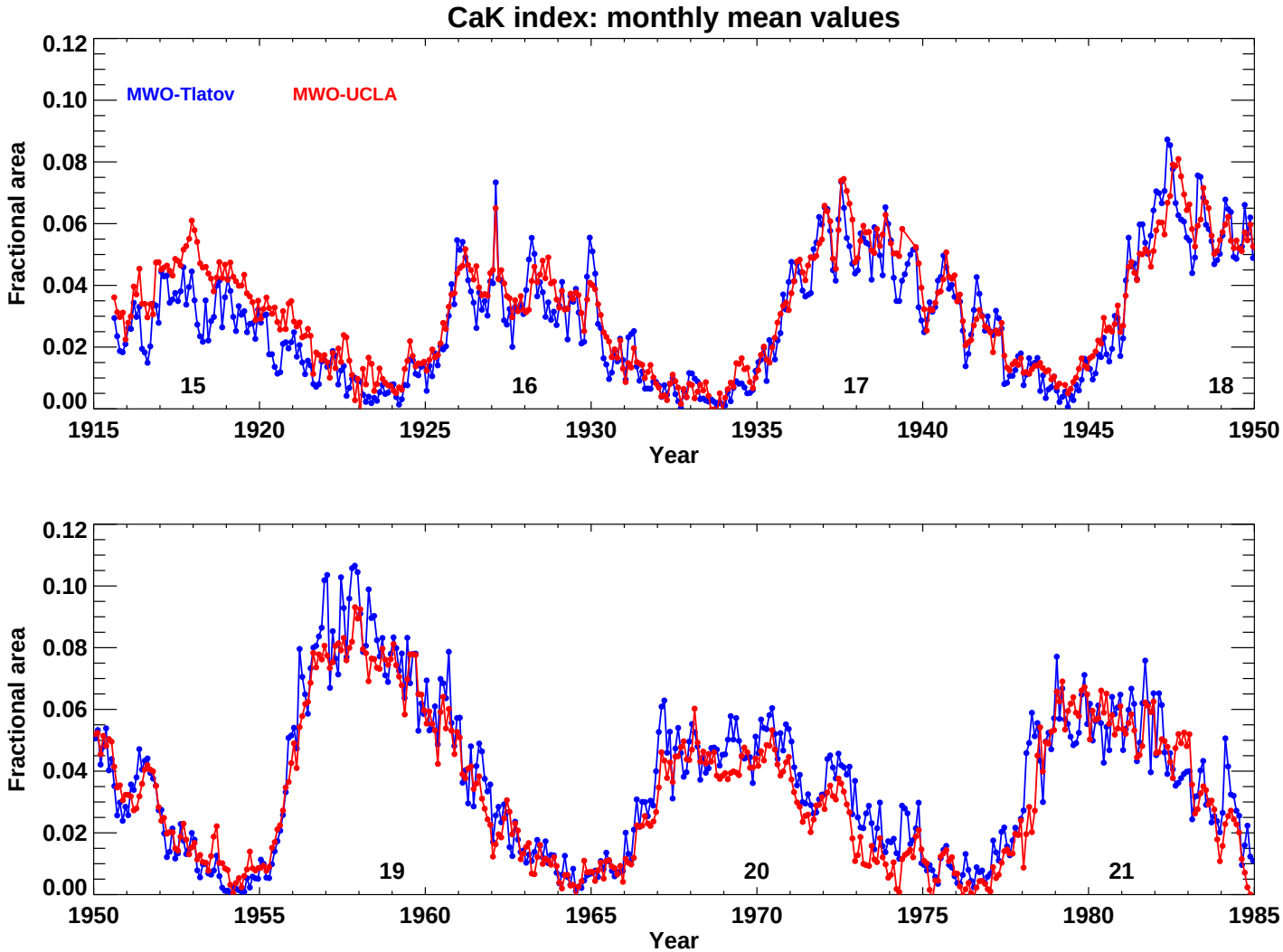
$$y(x) = A\exp(-u^2/2) + B,$$

   where $u = (x - x_c)/\sigma$, x is the bin value, y is the fractional number of pixels in the solar disk with value x, σ and x_c are the width and the center of the distribution, respectively ($x_c \approx 1$).
4. The constant baseline B is defined as the Ca II K index.
5. The parameter σ is related to the plage contrast.

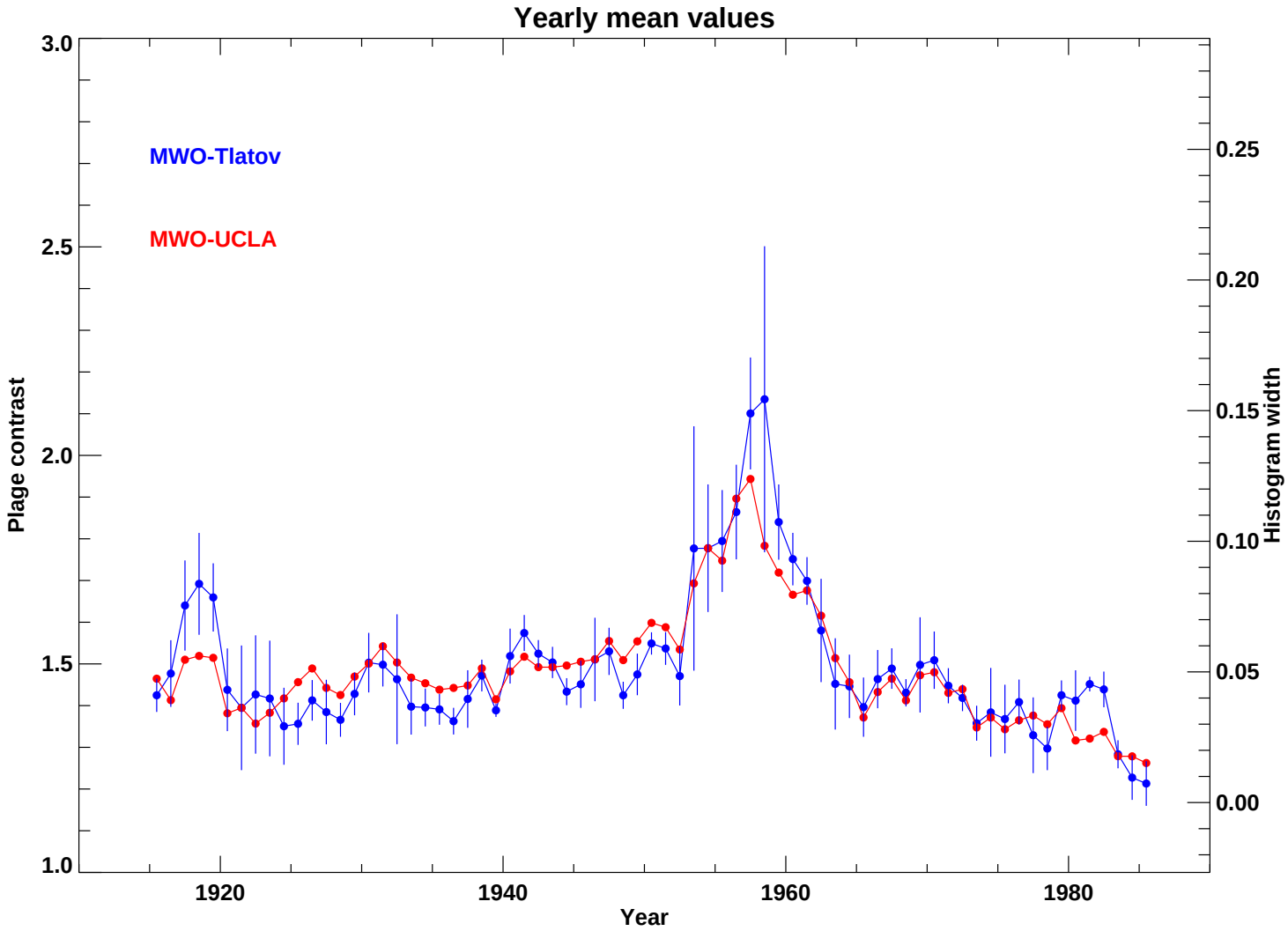
The MWO-UCLA Ca II K index (cont'd.)



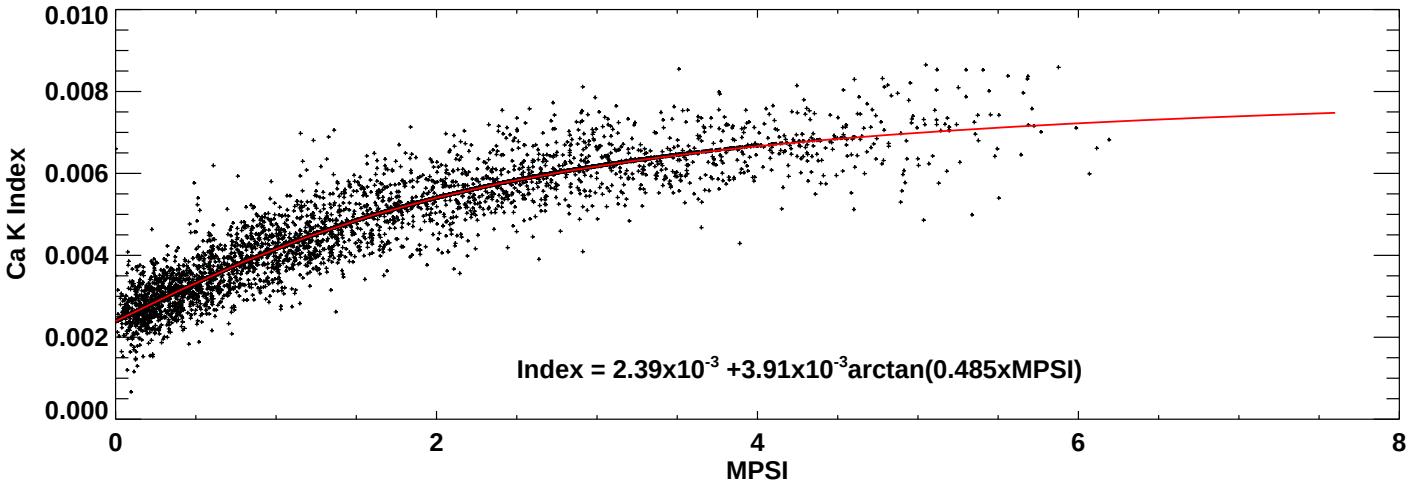
MWO-UCLA vs. MWO-Tlatov

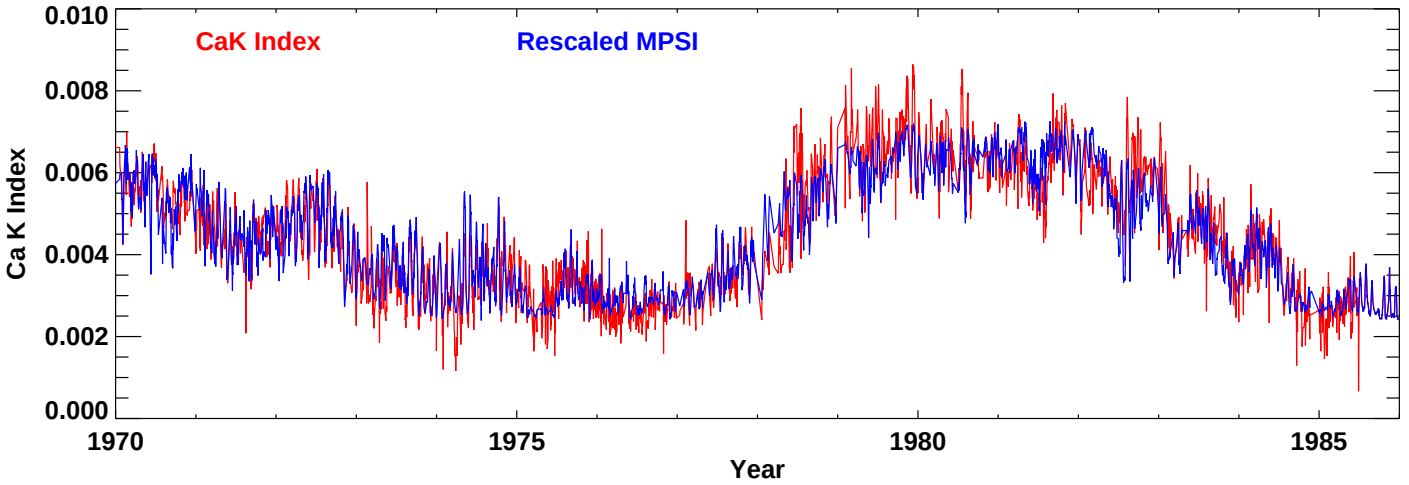


Plage contrast comparison

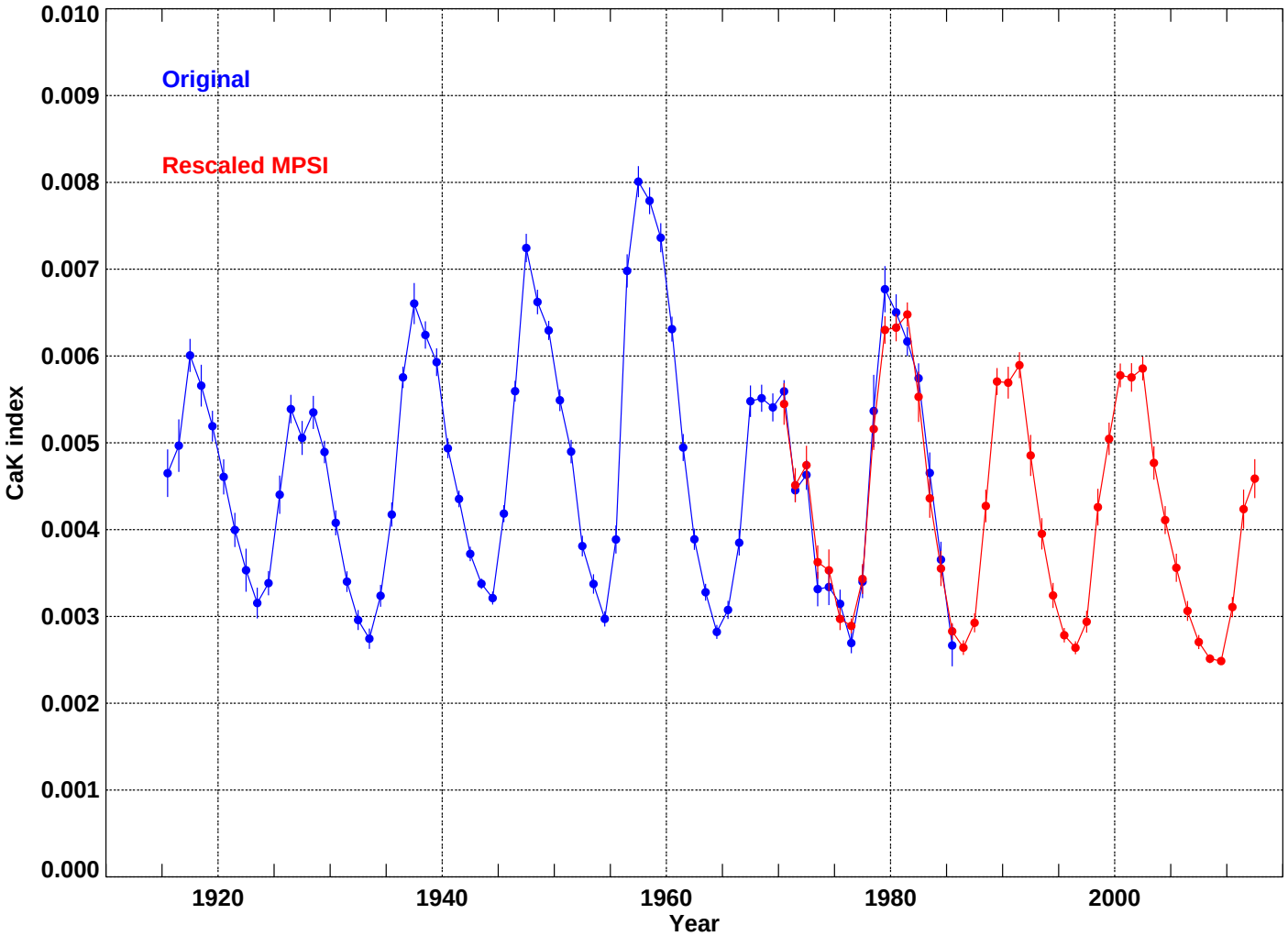


MWO-UCLA Ca II K index vs. MPSI

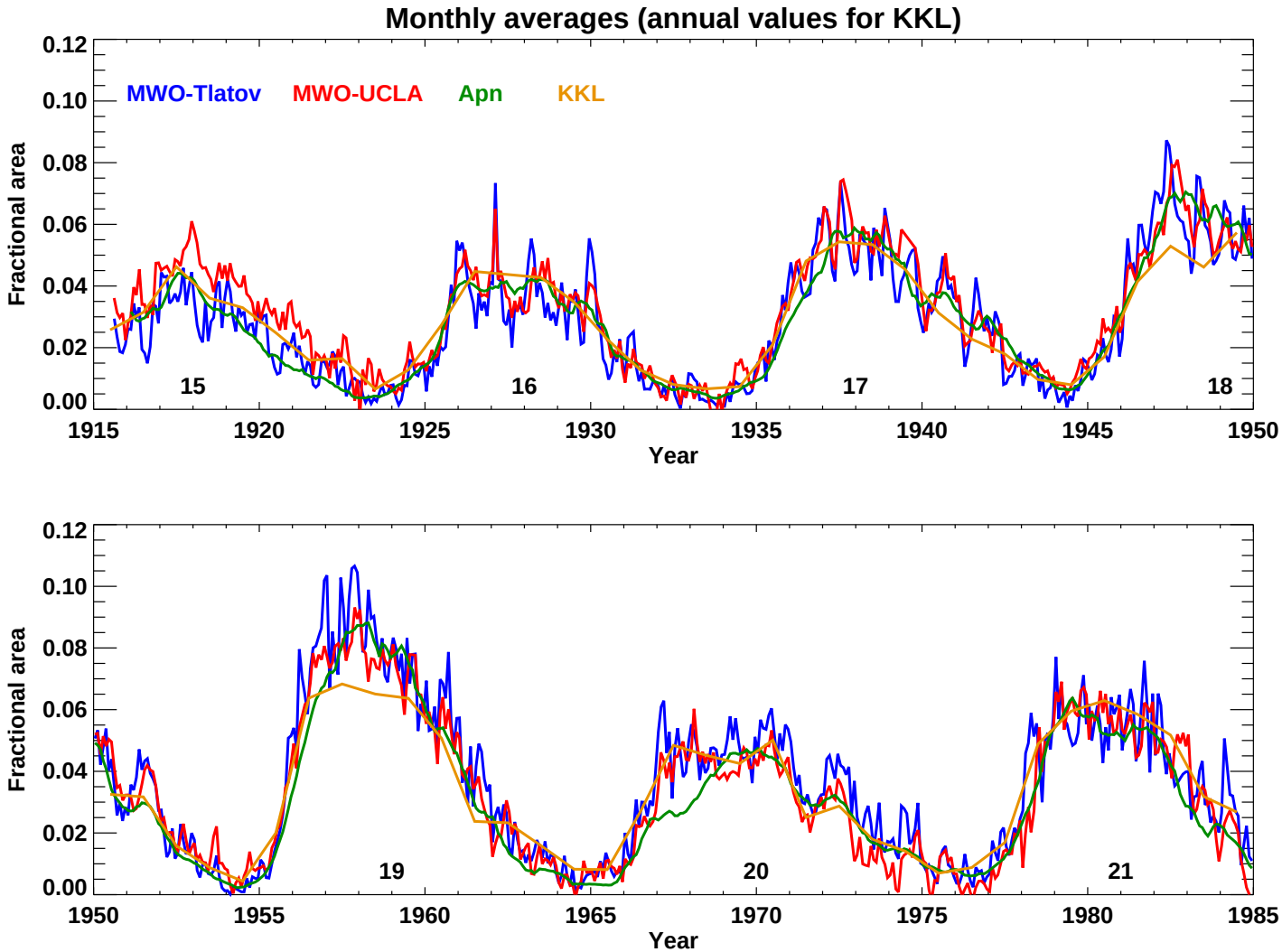




Extended MWO-UCLA Ca II K series



Historical Ca II K time series

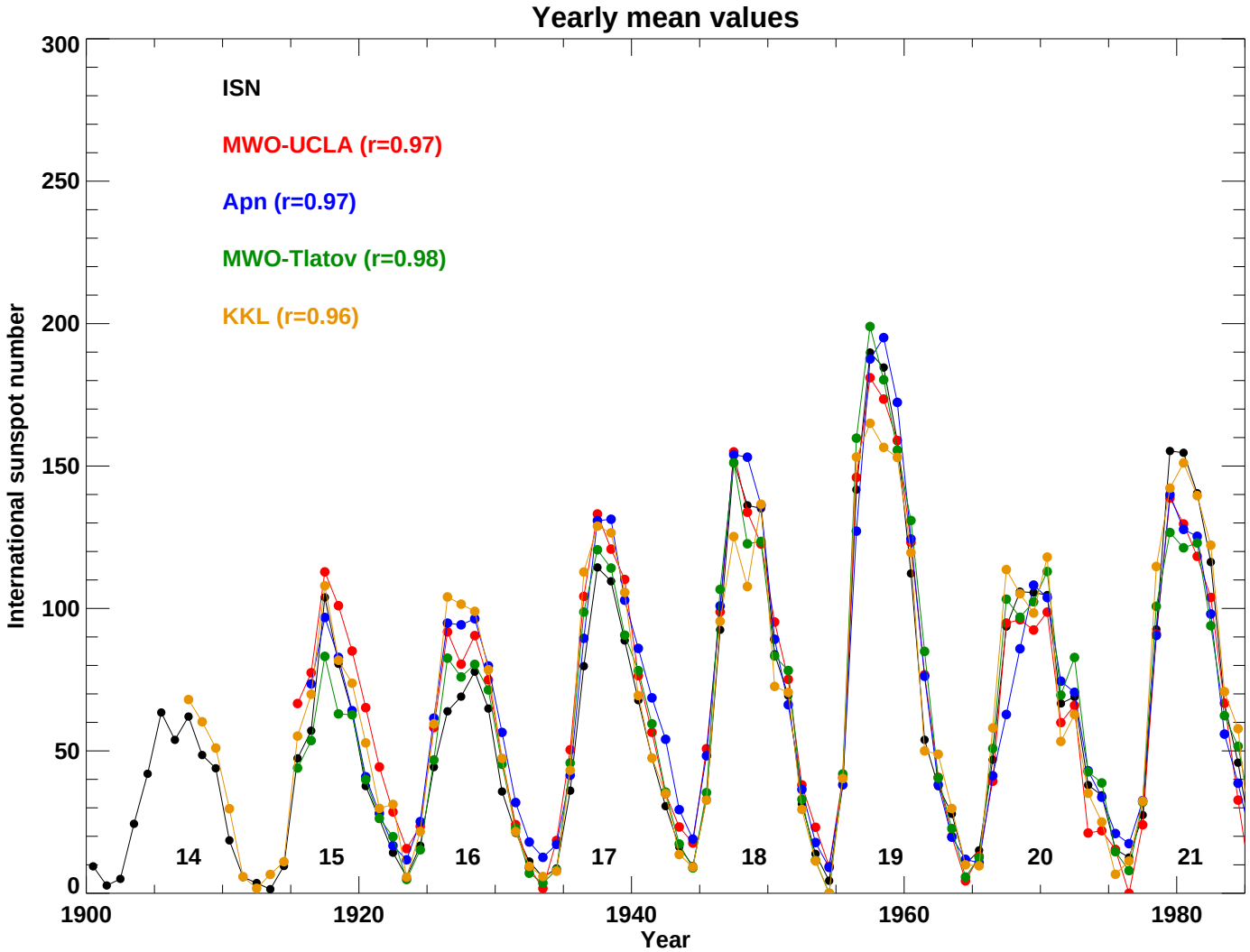


Historical Ca II K index: Correlation matrix

The correlation matrix has been computed using the yearly mean values of each time series from 1916 to 1985.

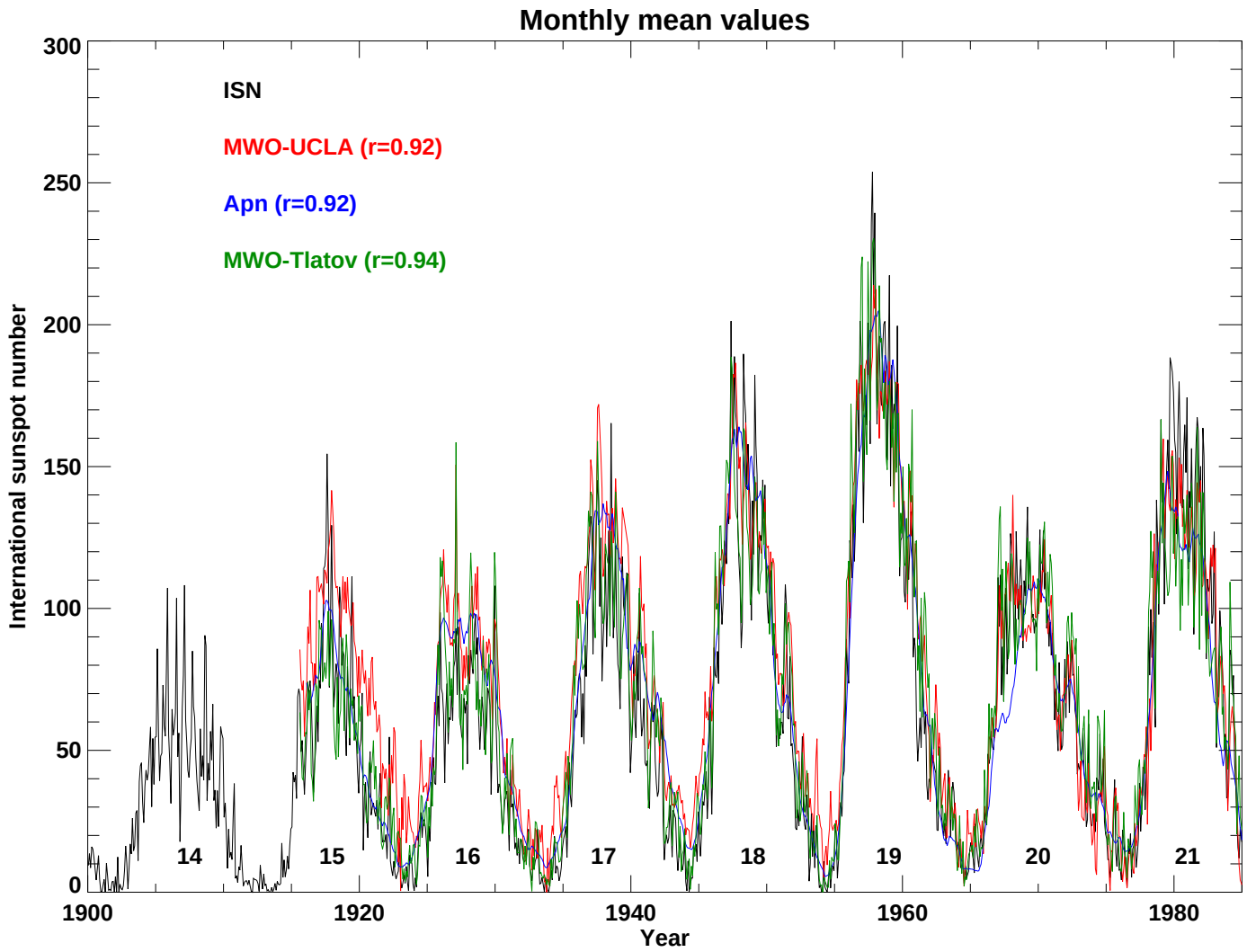
	Tlatov	UCLA	Apn	KKL
Tlatov	1	0.966	0.969	0.959
UCLA	0.966	1	0.972	0.964
Apn	0.969	0.972	1	0.943
KKL	0.959	0.964	0.943	1

Historical Ca II K data vs. ISN

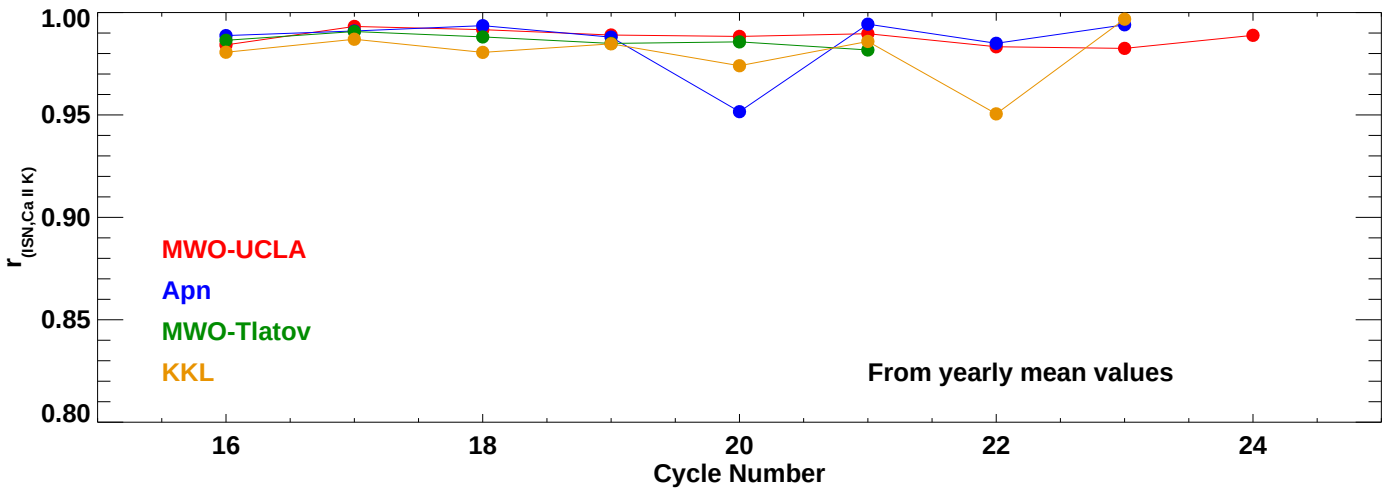


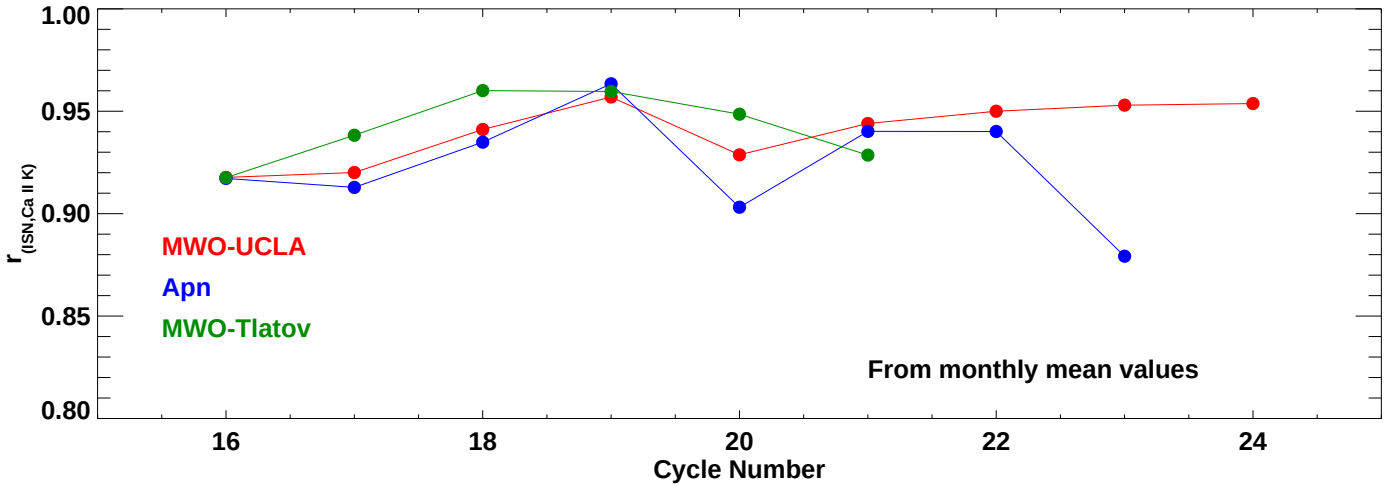
Note: During cycles 16 and 17 ISN underestimates the Ca II K by ∼30%!

Historical Ca II K data vs. ISN (cont'd.)

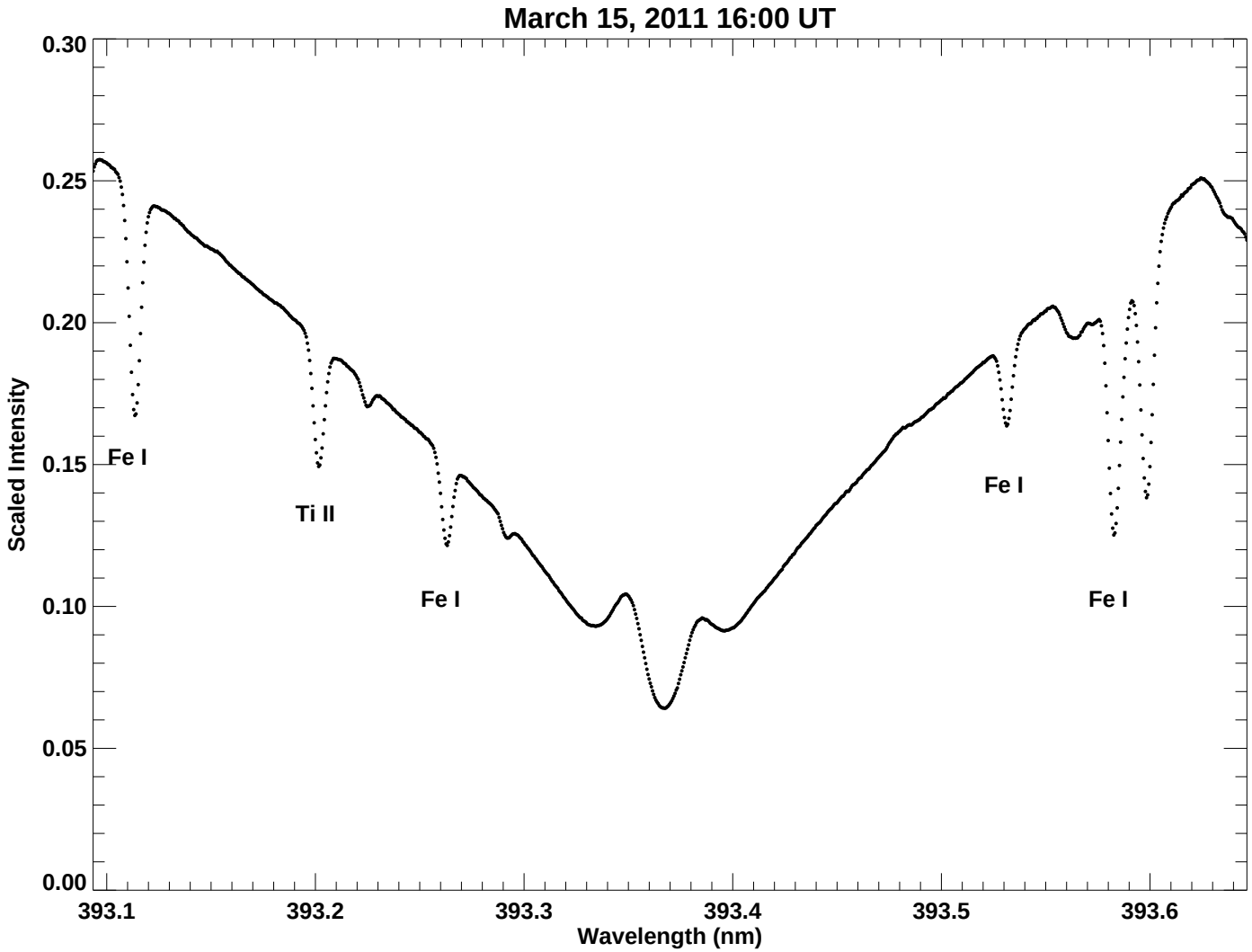


Historical Ca II K data vs. ISN: Correlation by cycle



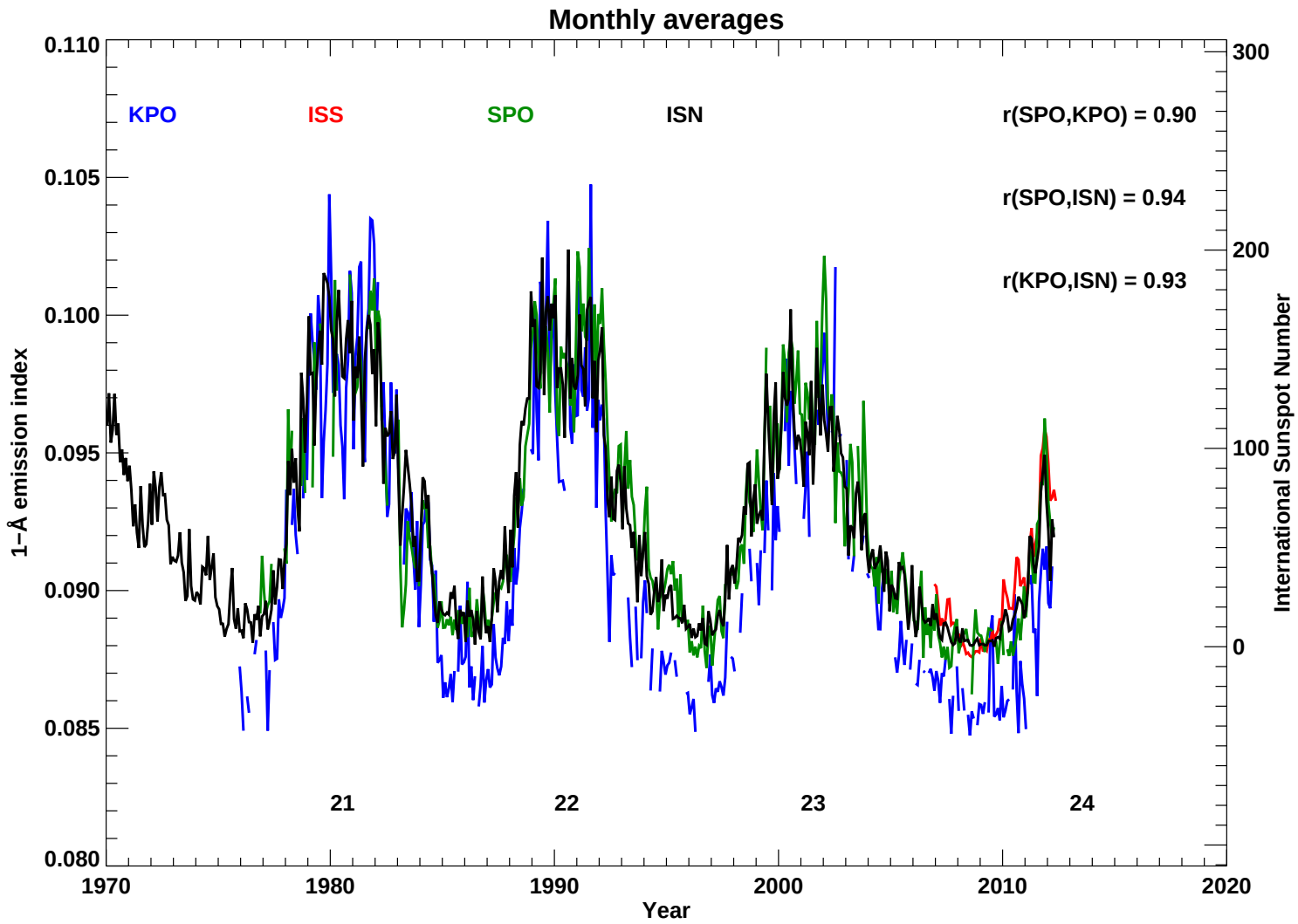


ISS Ca II K spectral line profile

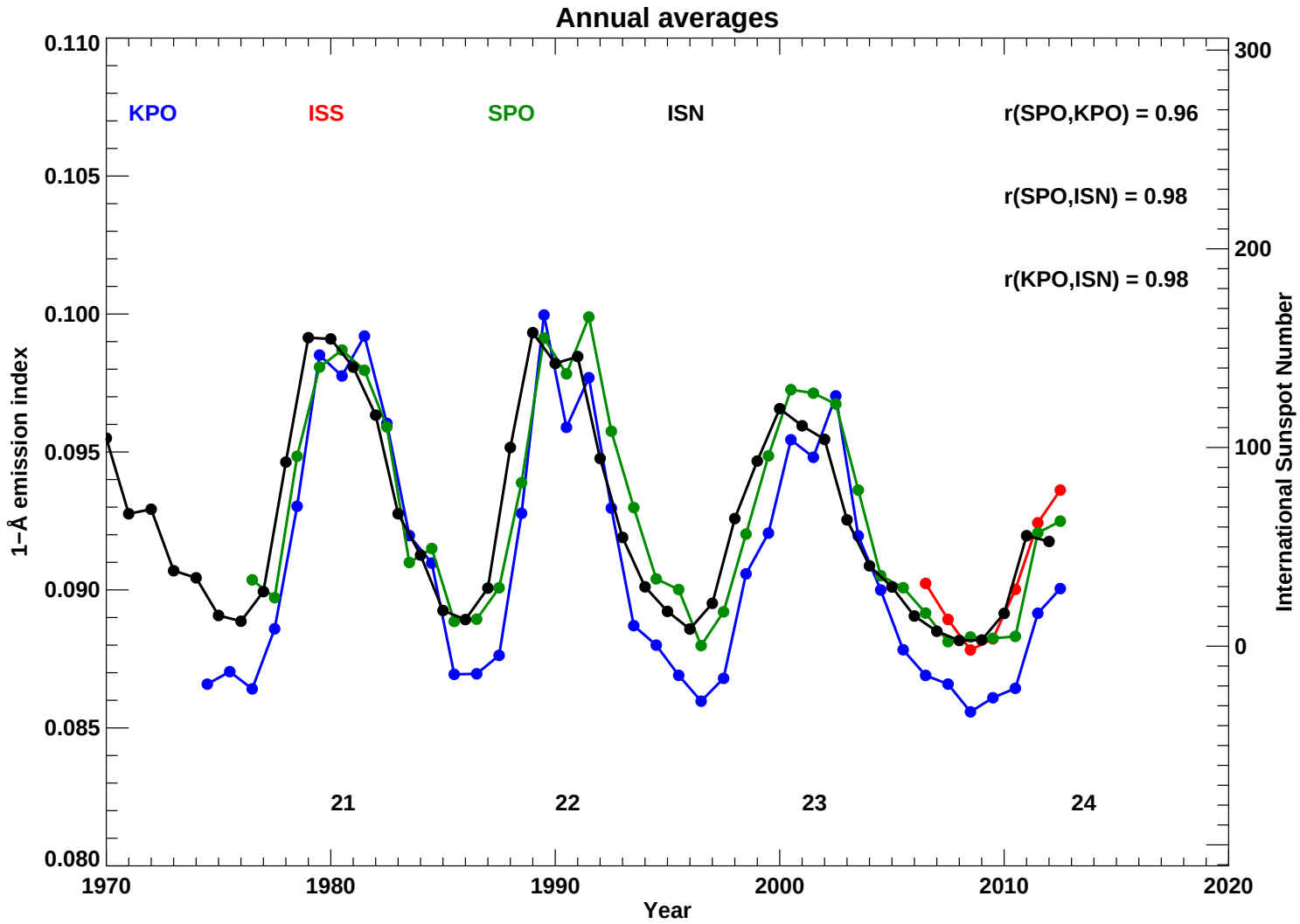


SOLIS-ISS high spectral resolution (R = 300,000) observation of the K line. ISS data are available from: http://solis.nso.edu/iss/

Ca II K integrated sunlight vs. ISN



Ca II K integrated sunlight vs. ISN (cont'd.)



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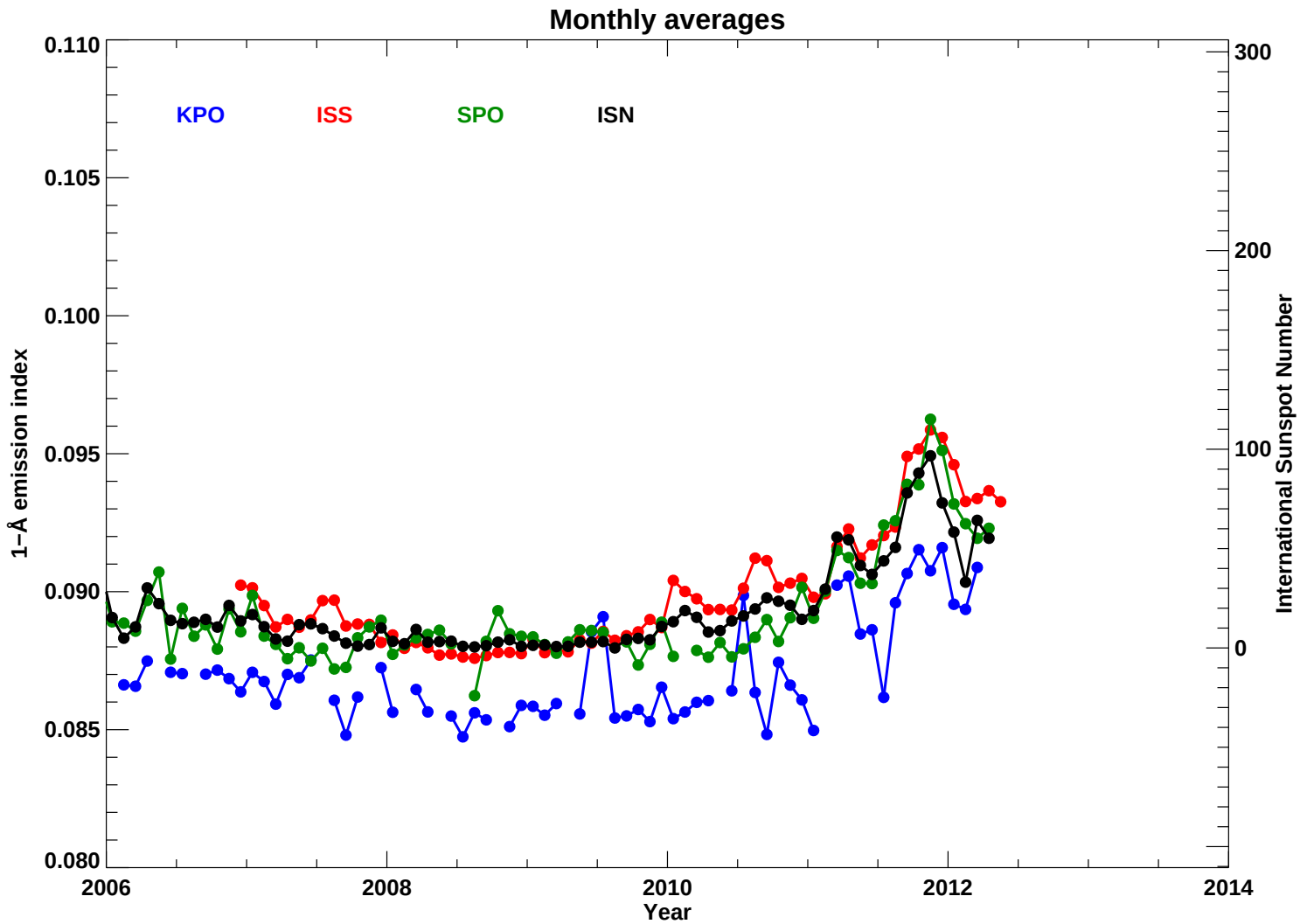

Conclusions

- Overall there is a very good agreement among the different Ca II K index time series on time scales above one month. Some discrepancies are noticeable between the MWO and KKL data, particularly during cycle 18 and 19.
- The KPO and SPO 1-Å emission index time series show significant differences during the last three solar minima. Is data calibration a factor?
- Correlations between the Ca II K index time series and the ISN exceed 0.96 for all the yearly mean indices, and 0.92 for the monthly mean values. These correlations are slightly higher for modern data.
- During cycles 16 and 17 ISN underestimates the Ca II K by $\sim$30%.

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