WHOLE HELIOSPHERE & PLANETARY INTERACTIONS

13 - 17 September, 2021
NCAR/HAO
Virtual Meeting

Comparative analysis of EUV solar radiation proxies during minimum activity levels

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Outline:

- Correlation between solar EUV proxies during different solar activity phases
- Some characteristics during minimum: time of occurrence, minimum proxy value, duration?
- Solar EUV proxies adequacy to determine foF2 long-term trends considering the role of minimum periods
- Discussion

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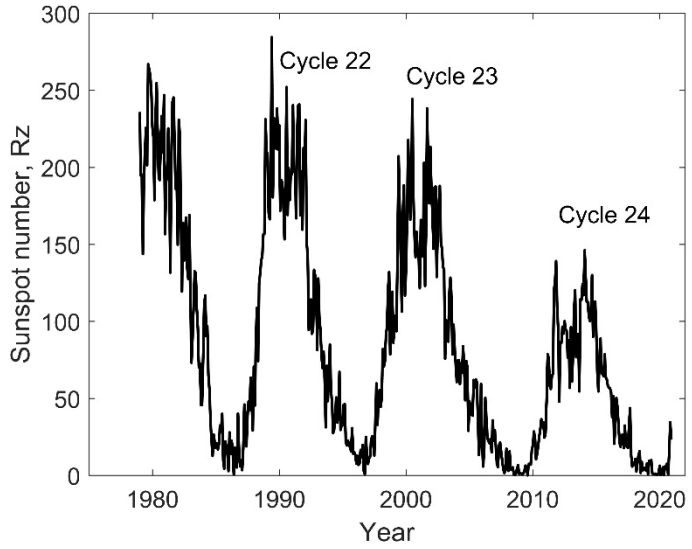
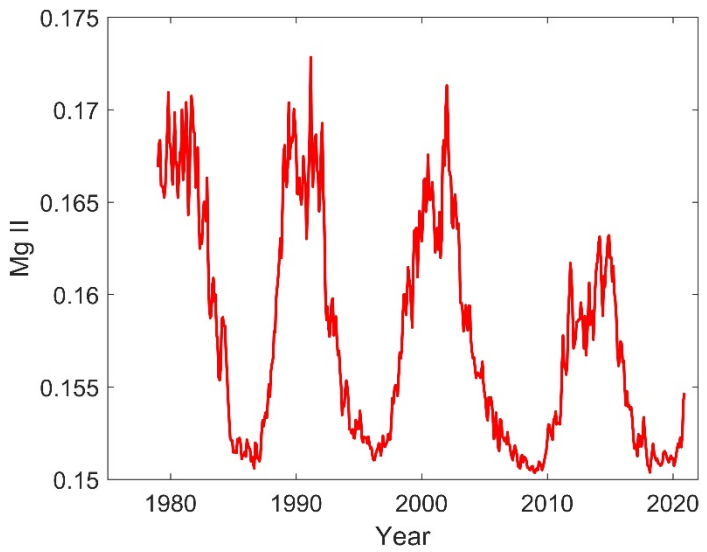
EUV solar proxies analyzed → **Rz, Mg II, Lyman α, and F10.7**

(monthly mean data, January 1979 – December 2020)

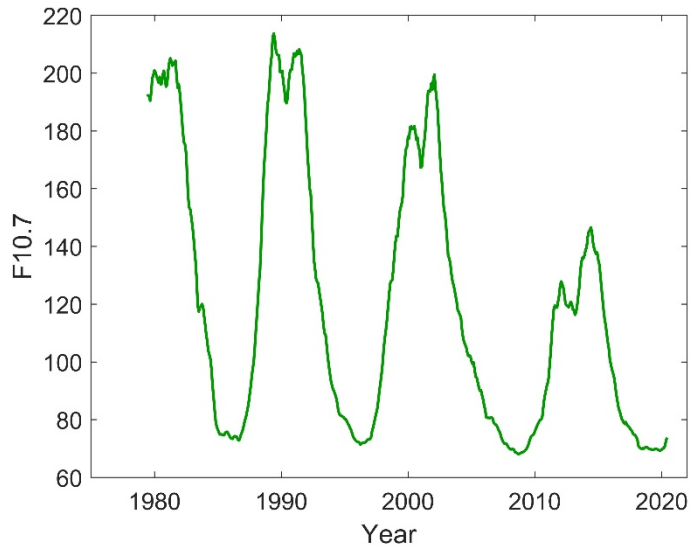
Timescale → Monthly means – 12-month running means

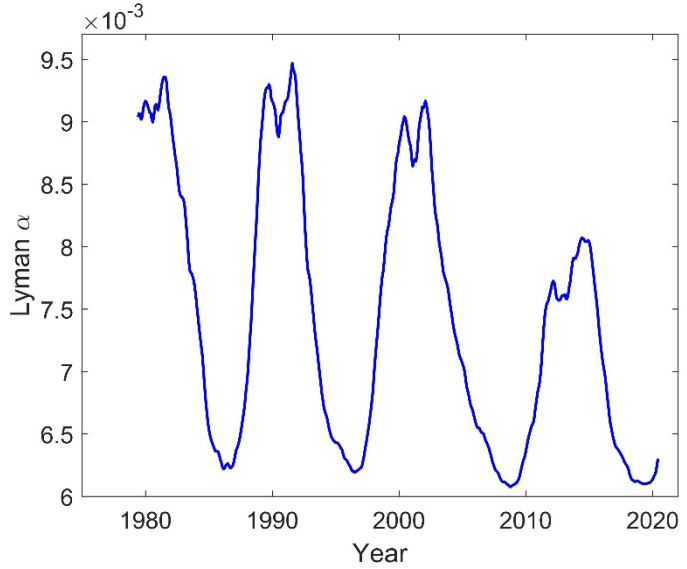
Example: monthly means





Example: 12-month running means





Many ways to do a “comparison” and to approach this analysis.

Here: Statistical !! (but ... many ways from the statistical point of view, as well !!)

Lets notice first that:

Source region in the Sun:

Rz → photosphere

Mg II → chromosphere

Lym α → transition region

F10.7 → corona

Sensitivity along solar activity cycle:

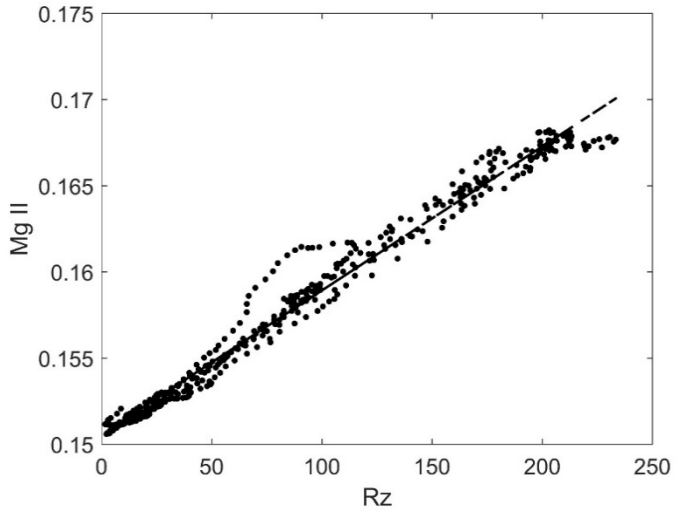
100 × [X(max)-X(min)] / mean(X)

Rz → ~ 250 %

Mg II → ~ 10 %

Lym α → ~ 45 %

F10.7 → ~ 120 %



12-month running means:

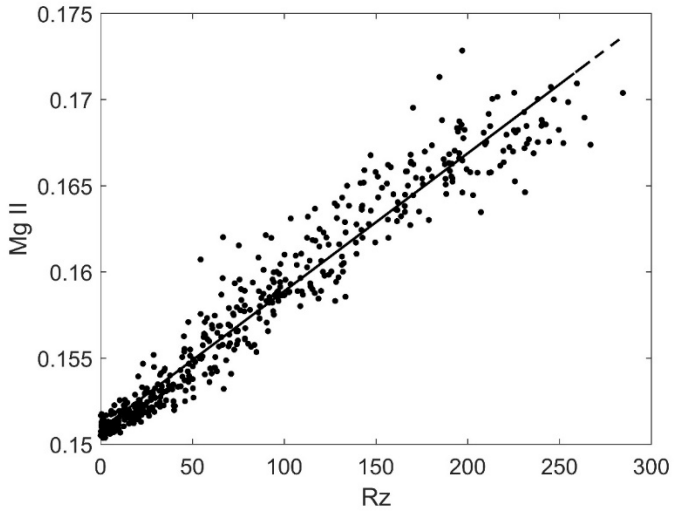
r(Rz, Mg II) = 0.99

r(Rz, Lyman α) = 0.98

r(Rz, F10.7) = 0.99

r(Mg II, Lyman α) = 0.98

...



Monthly means:

r(Rz, Mg II) = 0.97

r(Rz, Lyman α) = 0.96

r(Rz, F10.7) = 0.98

r(Mg II, Lyman α) = 0.99

...

➢ Bruevich, E.A., Bruevich, V.V. & Yakunina, G.V. Changed Relation between Solar 10.7-cm Radio Flux and some Activity Indices which describe the Radiation at Different Altitudes of Atmosphere during Cycles 21–23. *J Astrophys Astron* **35,** 1–15 (2014).

Vertical dashed lines: solar minima – Vertical dotted lines: solar maxima

12-month running means

Correlation between:

Rz &Mg II

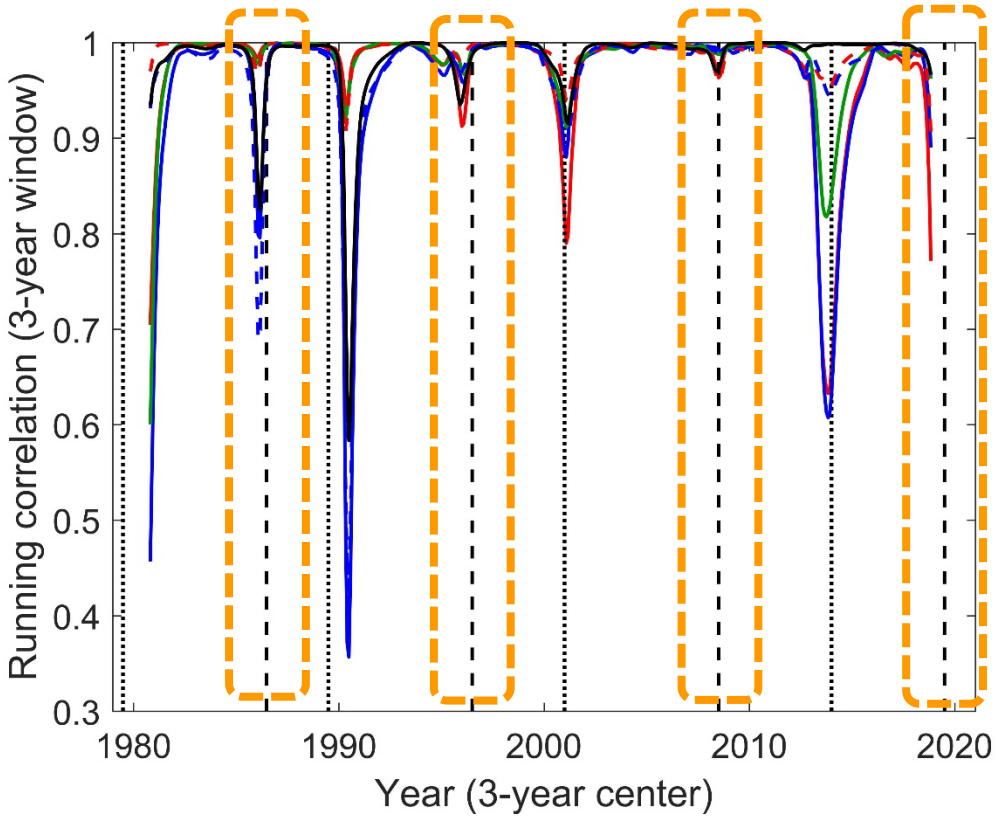
Rz & Lym α

Rz & F10.7

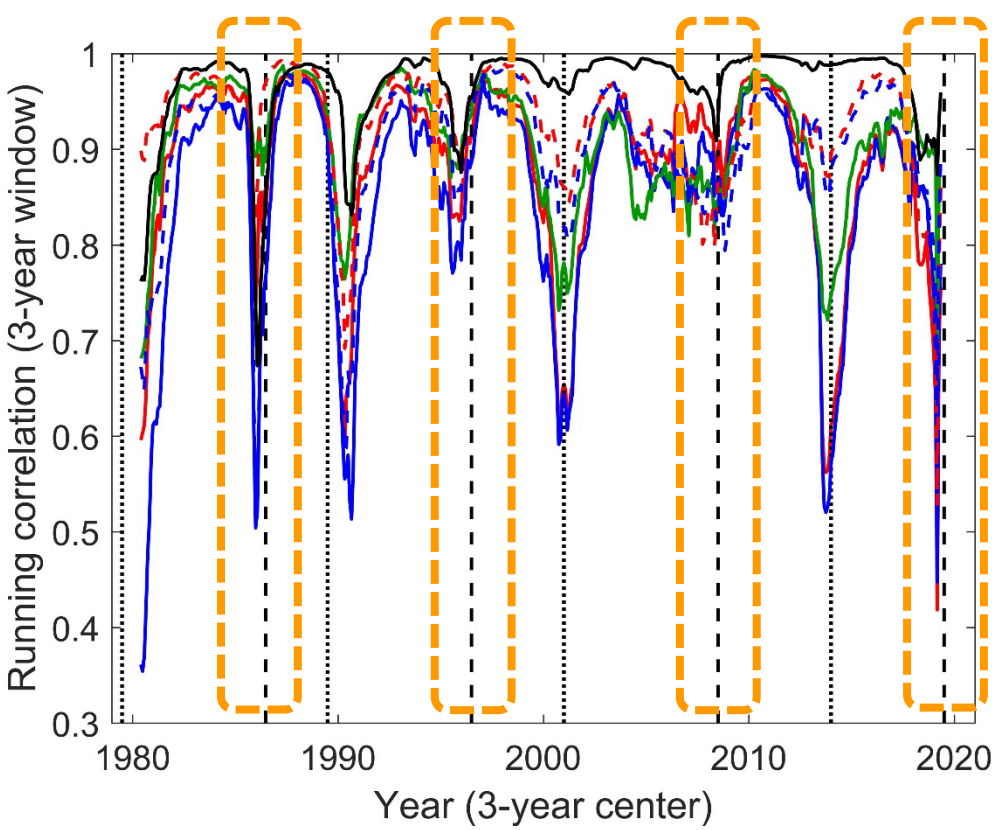
F10.7 & Mg II

F10.7 & Lym α

Lym α & Mg II



Monthly means



Rz & Lyman α ??

F10.7 & Lyman α ??

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Superposition:

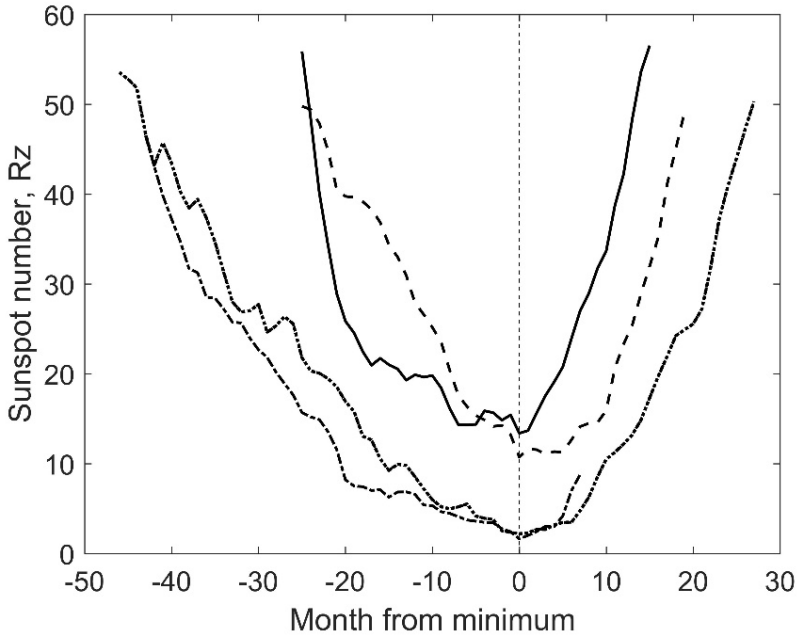
0: minimum considering 12-month running means

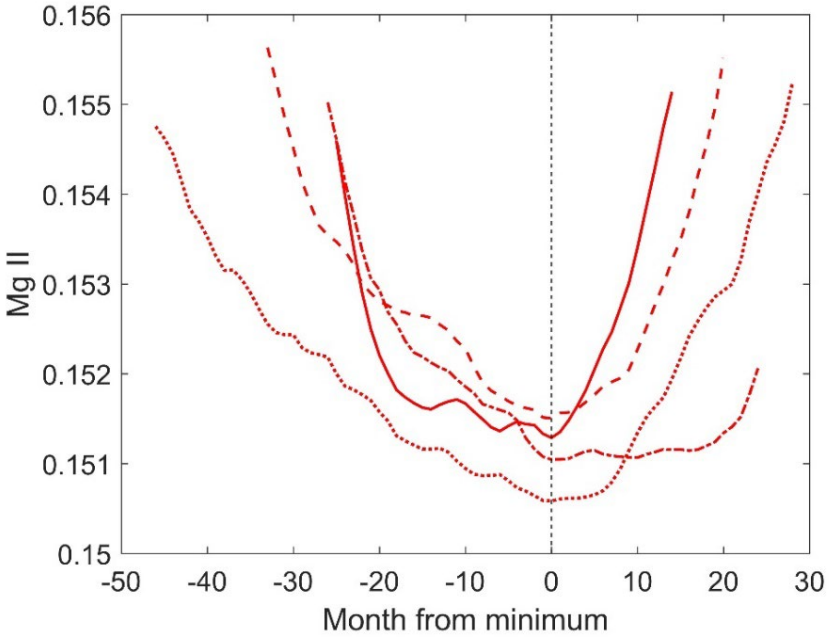
Rz < 50 Mg II < 0.155

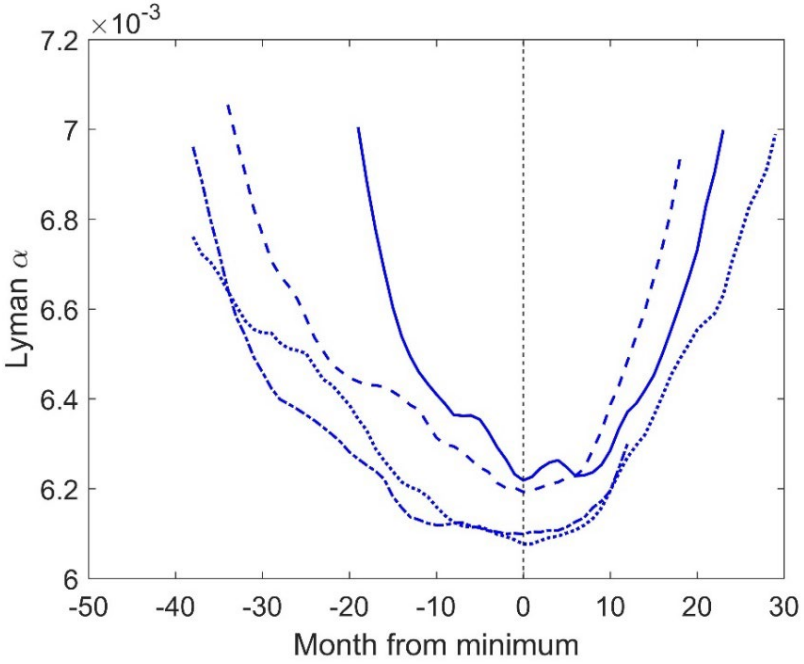
Lyman α < 0.0069 F10.7 < 97

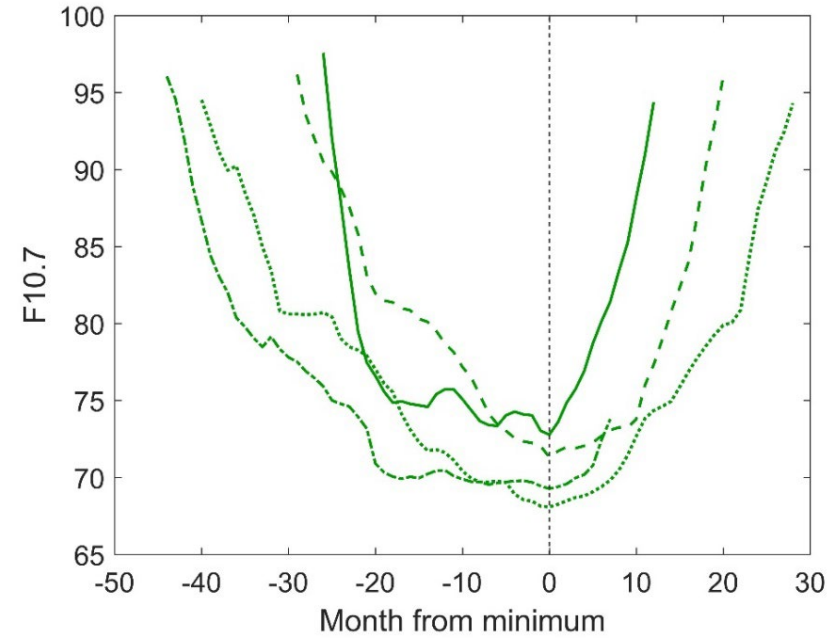
(1) min 21-22: solid
(2) min 22-23: dashed
(3) min 23-24: dotted
(4) min 24-25: dot-dashed

- Minimum values order: (1) & (2) clearly higher than (4)&(3), in Rz, F10.7 and Lyman α
- Less pronounced in Mg II. Due to the lowest sensitivity?
- lowest minima [(4) & (3)] → longer duration









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Ionosphere parameters forced by EUV solar radiation: foF2 [MHz] (at noon) !!

Kokubunji station (35.7°N, 139.5°E), Wakkanai station (45.4°N, 141.7°E), Syowa station (69.0°S, 39.6°E)

Trend estimation considering foF2 “experimental” data:

1st step: Filtering of solar activity effect (solar EUV effect):

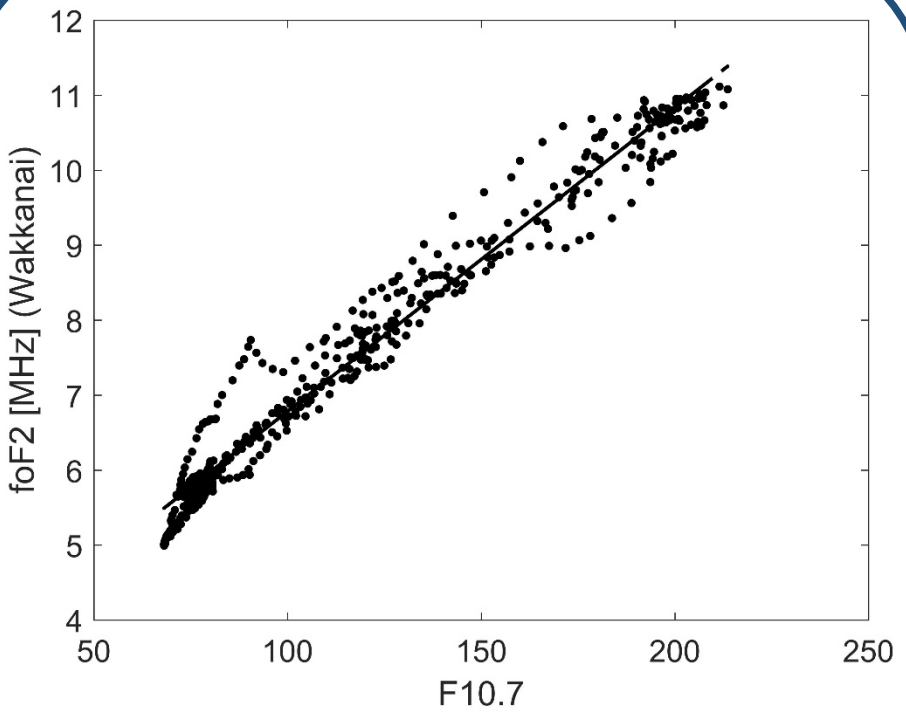
$foF2_{residual} = foF2 - (a\,Rz + b)$

foF2: “experimental” foF2 value
a & b coefficients of foF2 vs. Rz linear regression (least square)

2nd step: Linear trend “α” estimation:

$foF2_{residual} = \alpha\, t + \beta$

t: time in year
α t & β coefficients of $foF2_{residual}$ vs. t linear regression (least square)



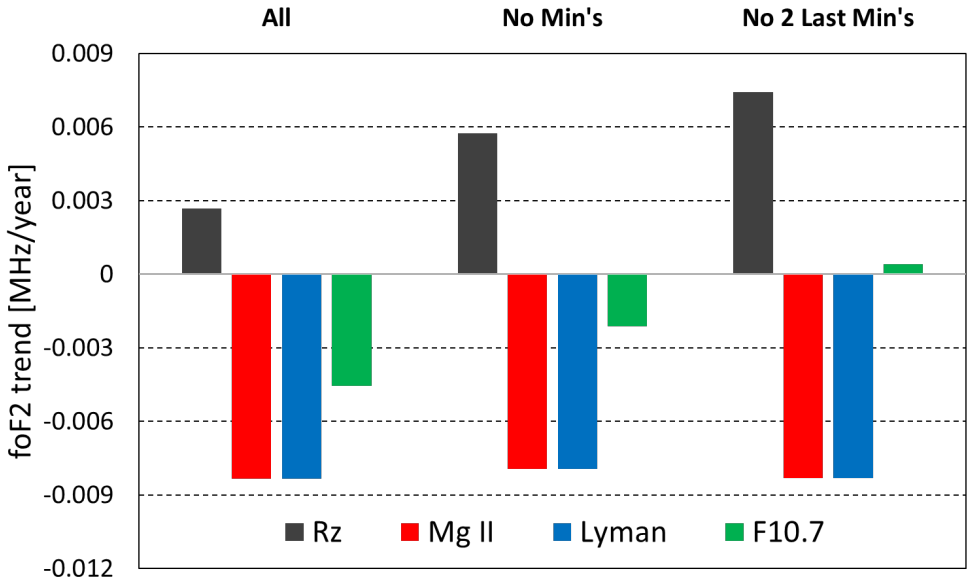
In general:
r^2 (foF2, Rz) and r^2 (foF2, F10.7) > 0.95

$\Rightarrow$ more than 95% of foF2 variance explained by Rz or F10.7

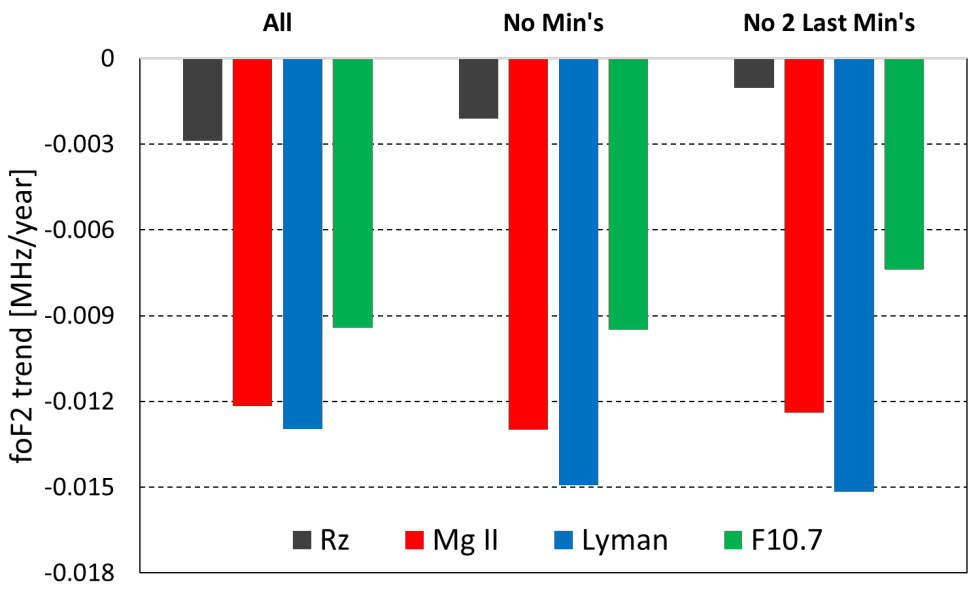
What we expect regarding foF2 trends:

- residuals to decrease steadily due to increasing CO2
- If EUV is higher than the level indicated by solar proxies during the last two minima ⇒ (+) trend
- If EUV is lower than the level indicated by solar proxies during the last two minima ⇒ (-) trend
- If EUV behaves like solar proxies, then everything fine !!! No trend !! or same trend as before !!

Kokubunji



Wakkanai



Mg II: trend values more stable for different periods
Rz: least stable trend values
What does this mean about their EUV “proxy” role ??

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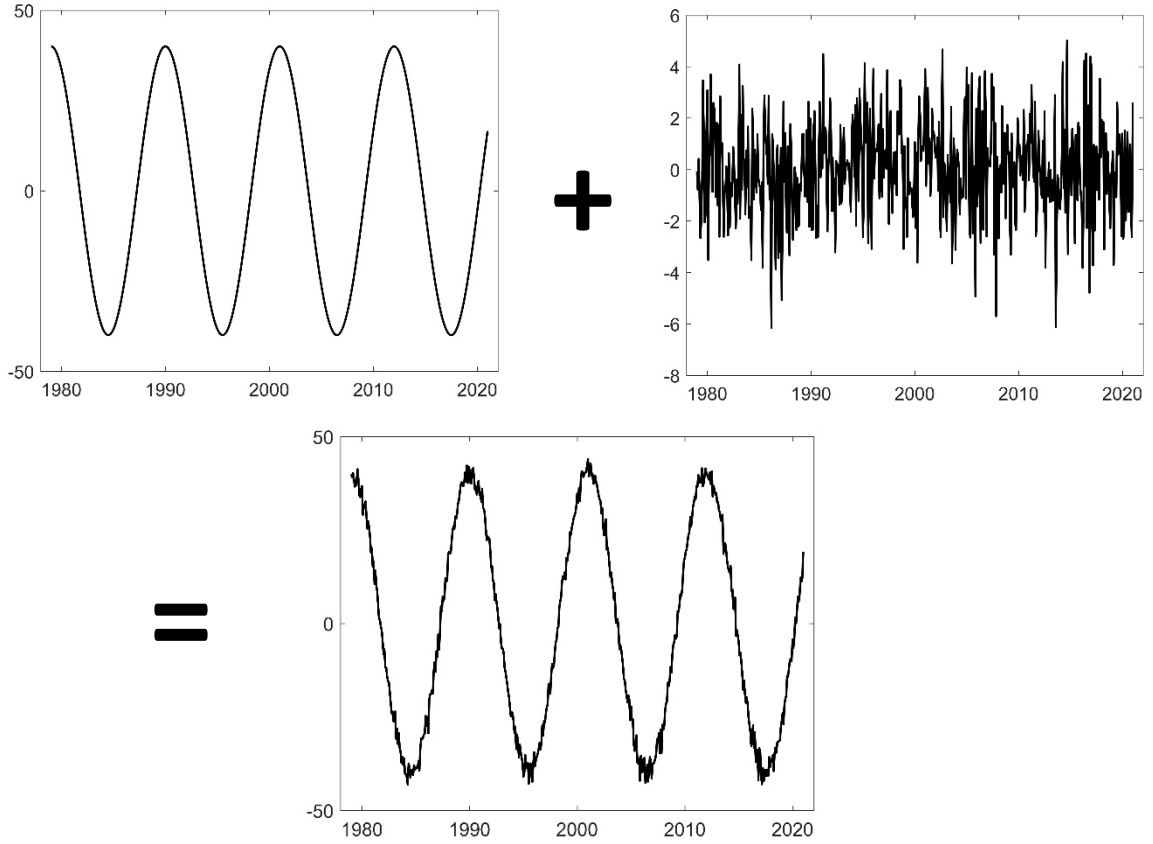
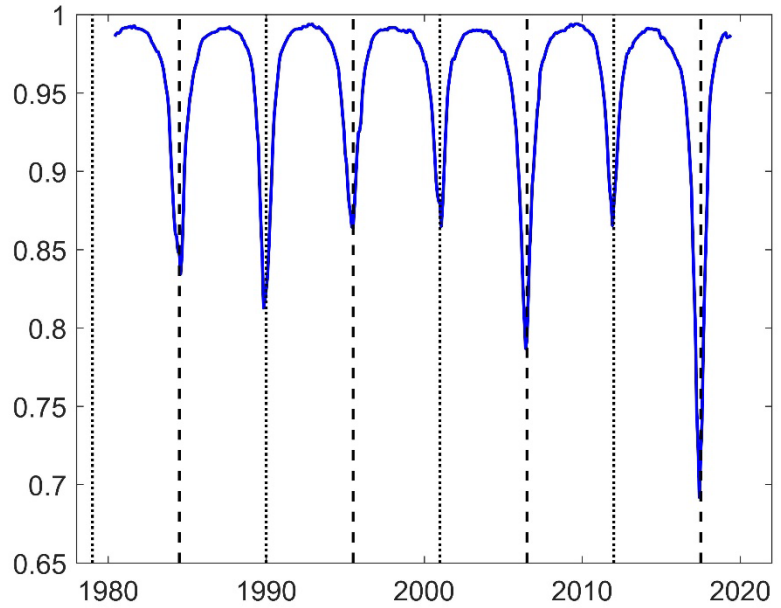
About correlations:

- Correlation coefficients between any pair of solar EUV proxies (Rz, Mg II, Lyman α, F10.7), for the entire period 1979-2020 is greater than 0.96 and, when we focus on shorter periods, it decreases specifically during maximum and minimum periods.
- A reason for this could be purely statistical:



Running correlation:



About foF2 trend analysis:

- Mg II $\rightarrow$ “produce” the most stable foF2 trend values.
- Rz $\rightarrow$ trend values are the most unstable
- Does this indicate that Mg II plays the best role as EUV solar measure and Rz the worst?
- Analysis of more stations data and other parameters affected by EUV !!!
- Another possibility: the association between foF2 and solar EUV, through its dependence with proxies, should be revised during minima.

About comparison with superposed epoch analysis:

- The first two minima were clearly higher and shorter than the last two, particularly for Rz and F10.7.
- In terms of percentage difference (relative to the solar cycle amplitude) they are all similar, being greater for Rz.
- In contradiction to what we just deduced from foF2 trend analysis?

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Thank you !!

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