Derivation of the Solar Plage Index using the Flare Monitoring Telescope at the Hida Observatory

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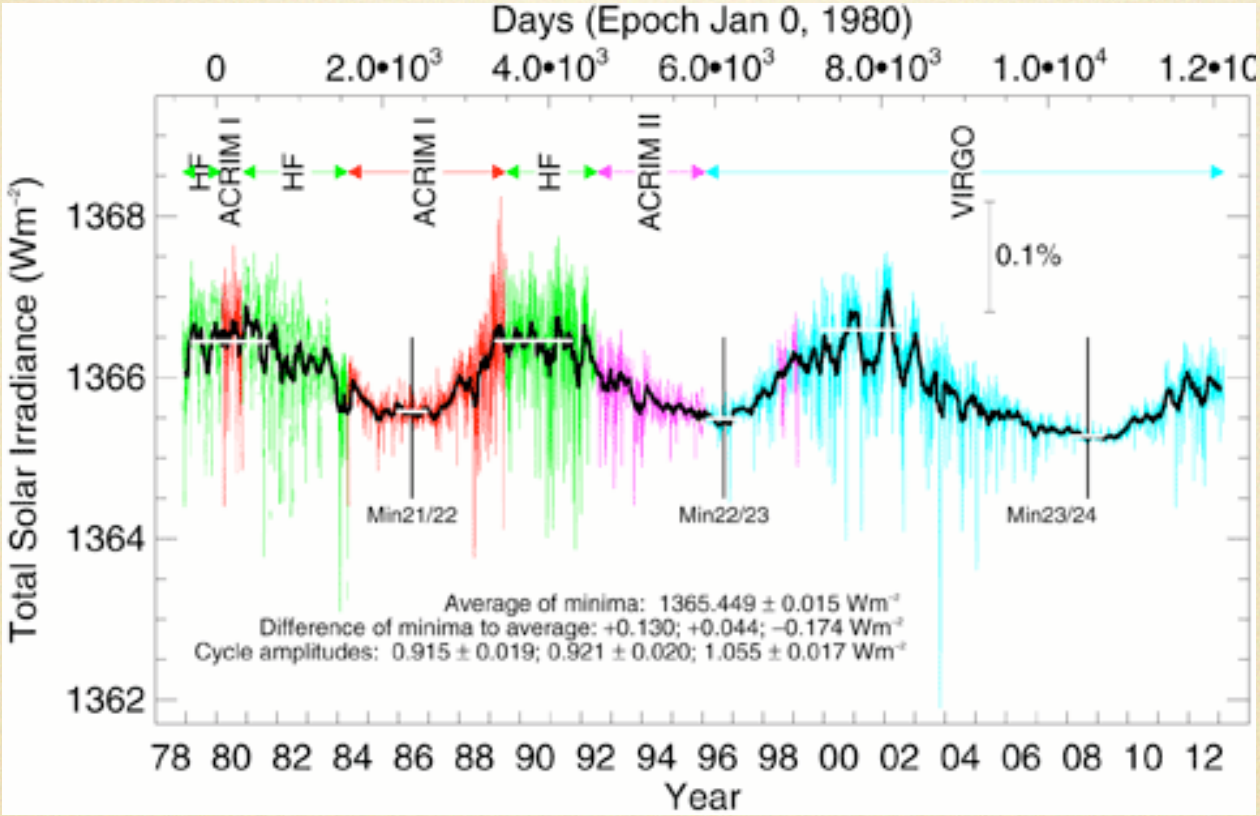
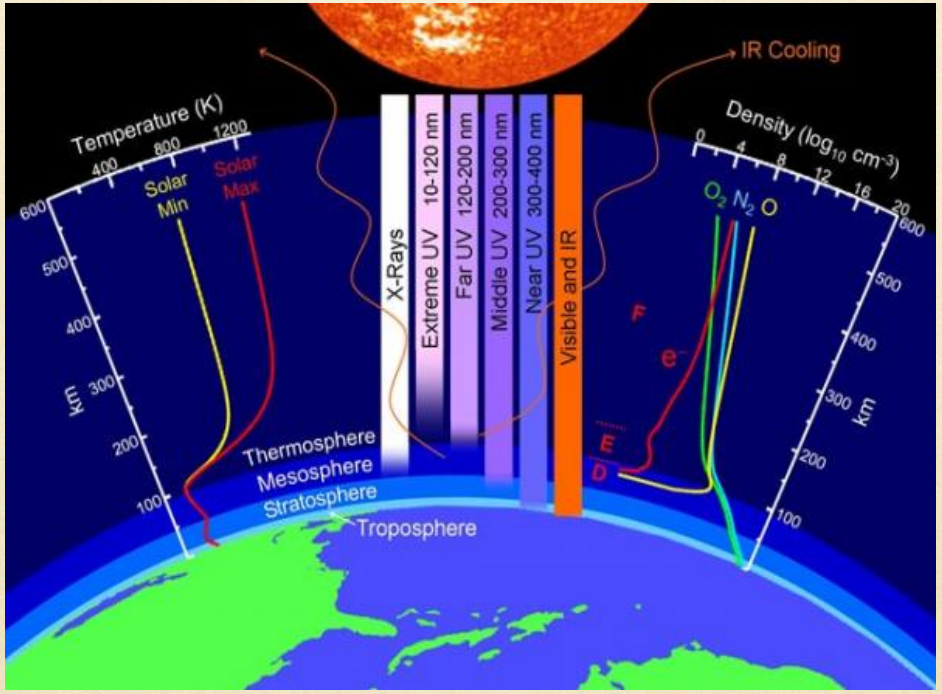
Solar cycle variation



- Solar cycle variations have a great impact on the earth's and space weather
- Arguments on the long solar minimum around 2009 and the strength of the solar maximum in the cycle 24

Importance of UV

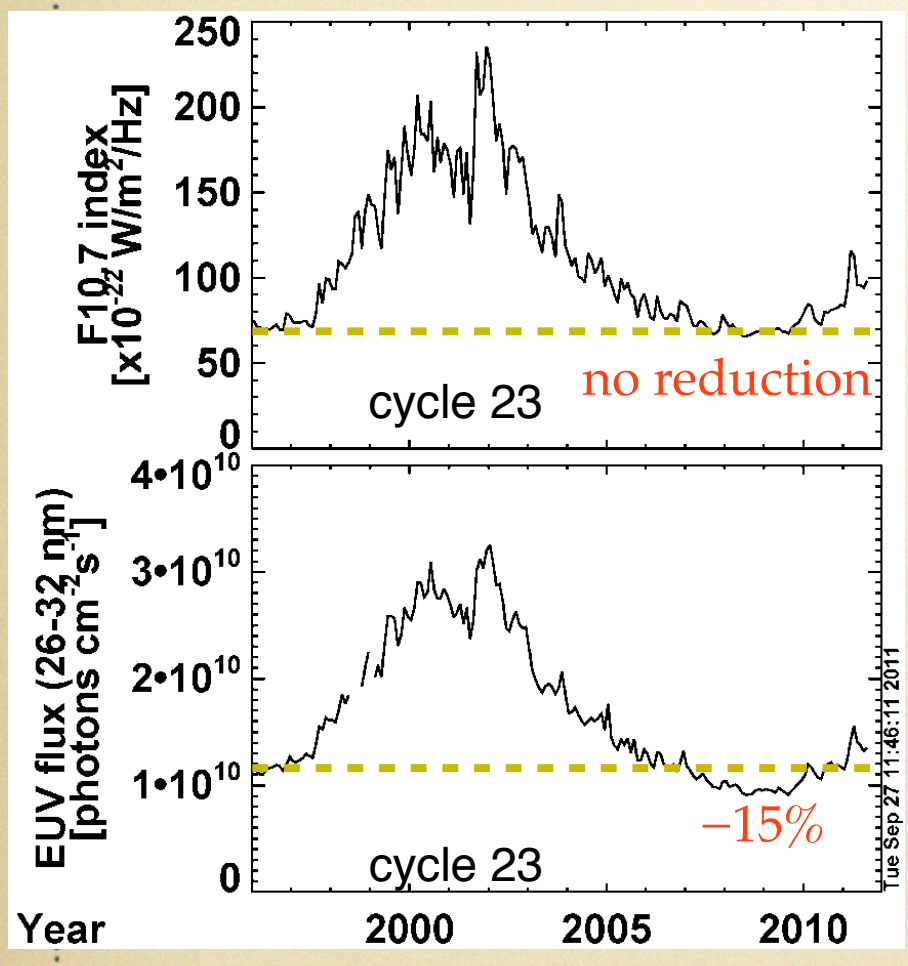
geomagnetic activity originates from the magnetospphere (thermosphere and mesosphere)

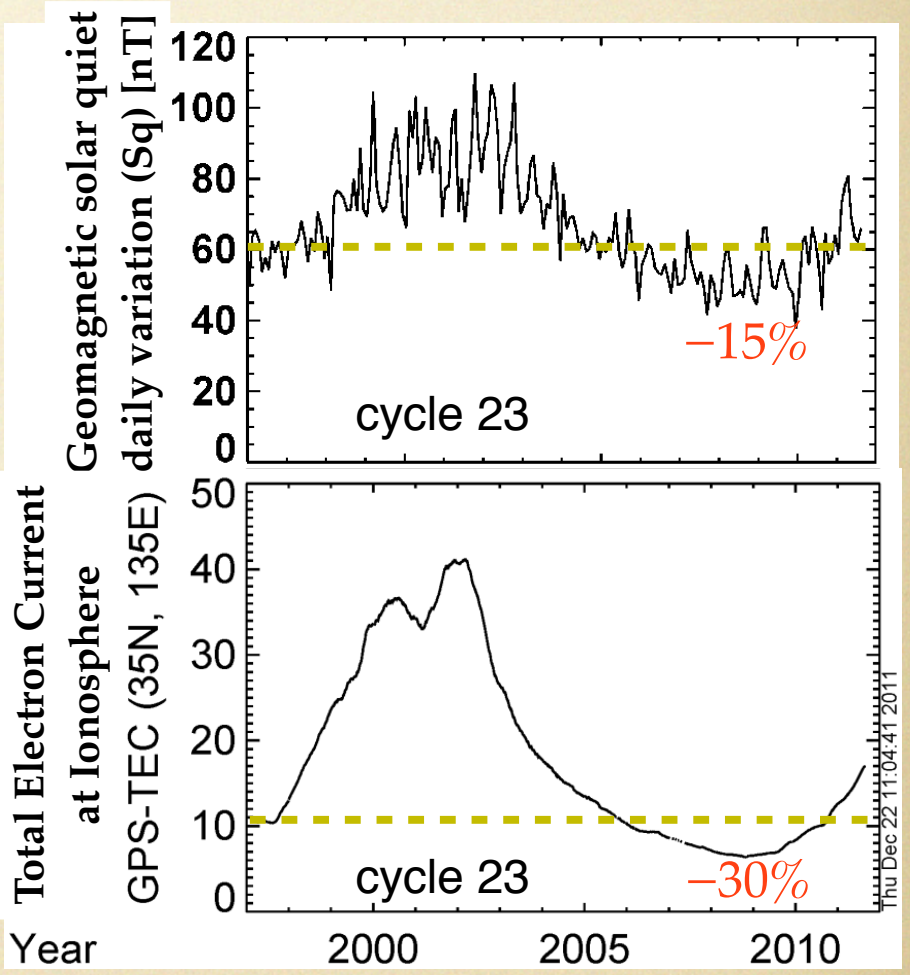


- Solar UV (10-400nm) is absorbed in the earth's atmosphere
- UV influences the earth's climate and geomagnetic condition

⇨ Important to estimate solar UV radiation

Issue raised by Recent Analysis





Courtesy to A. Shinbori

F10.7 index may not represent the solar UV variation properly.

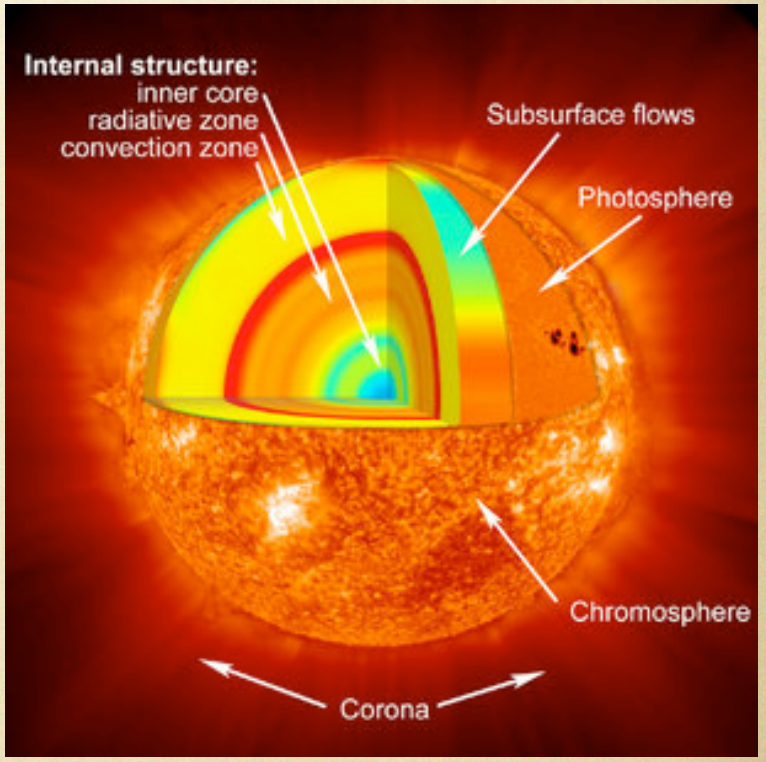
UV radiation from the Sun

- Photosphere ... ~6000K
  source of visible light

- Chromosphere ... ~10,000K
  source of UV (100-300nm)

Intense lines are Hα, Ca II K, ...

- Corona ... >1 million K
  source of EUV and X-rays

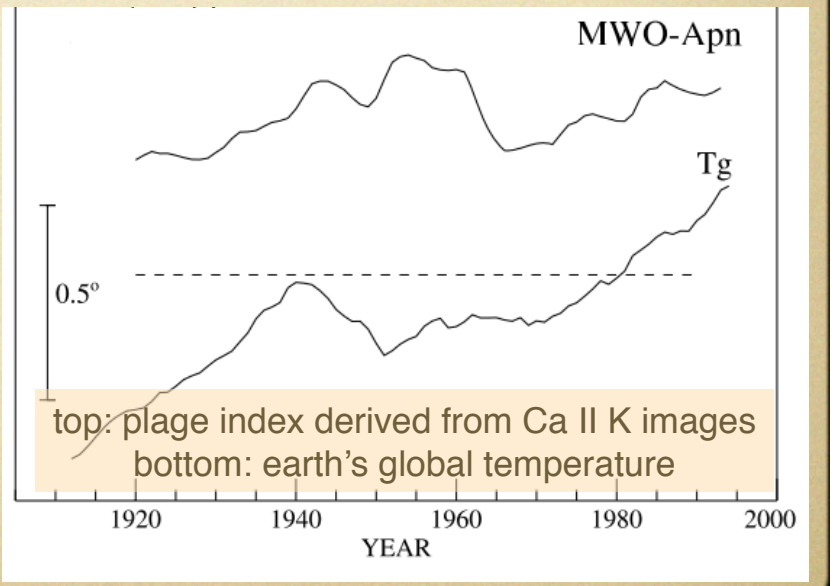


Pioneering work on Ca II K imaging

- Archives of Ca II K (*chromospheric* line) full-sun images spans about a century.
- Measure the area of bright region (*plage*) in Ca II K images → **Ca II K Plage index**

Foukal et al. (2009) right figure →

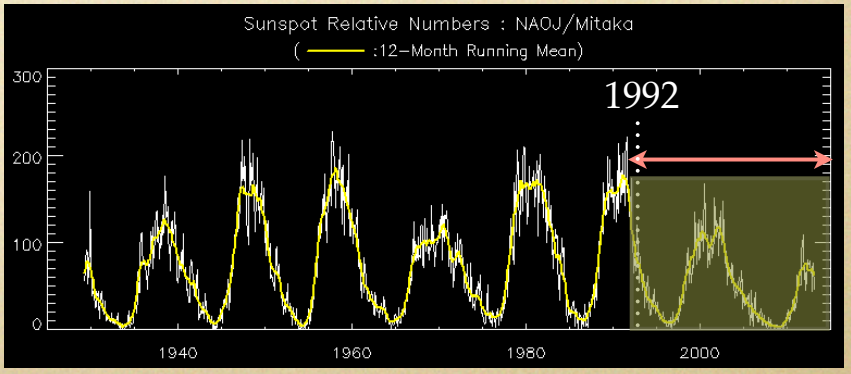
Ca II K plage index offers solar UV variation of almost a century



top: plage index derived from Ca II K images
bottom: earth's global temperature

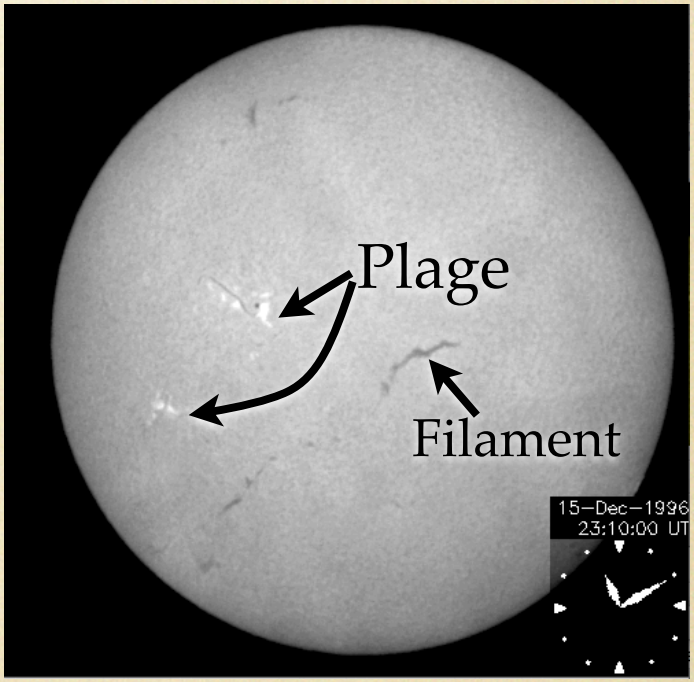
Archive of Hα images

- The most intense line from the chromosphere is ***Hα***
- Can we estimate the UV radiation by using Hα images? → ***Hα plage index***
- Archive of Hα full disk images by the Flare Monitoring Telescope, Kyoto Univ.
  - Since 1992 until today

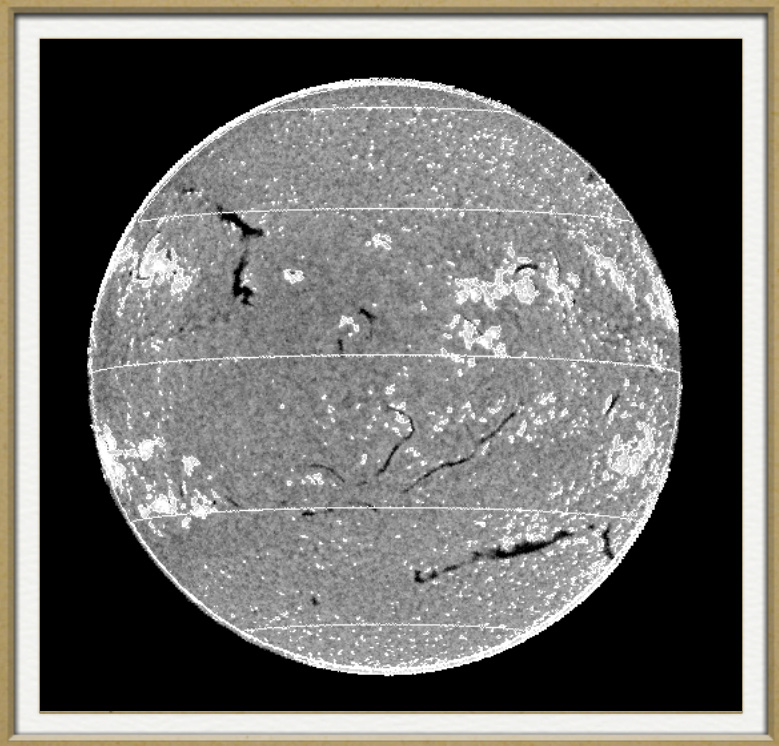


Motivation

- This is the first trial to derive *Hα plage index*
- Where is the source of the solar UV variation?
  - Low-latitude or polar
- How does the Hα plage index correlate with solar or geomagnetic indices?



This work is supported by IUGONET among RISH, Kyoto-U and STEL, Nagoya-U people.



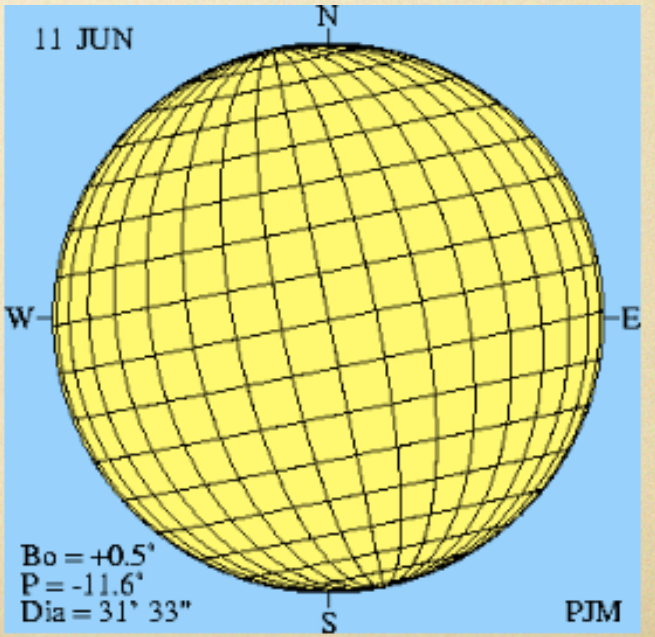
Derivation of Plage Index

Observation

- Flare Monitoring Telescope, Hα center image
- 4.2 arcsec / pixel
- Operated in Hida observatory by 2009, and then moved to Peru

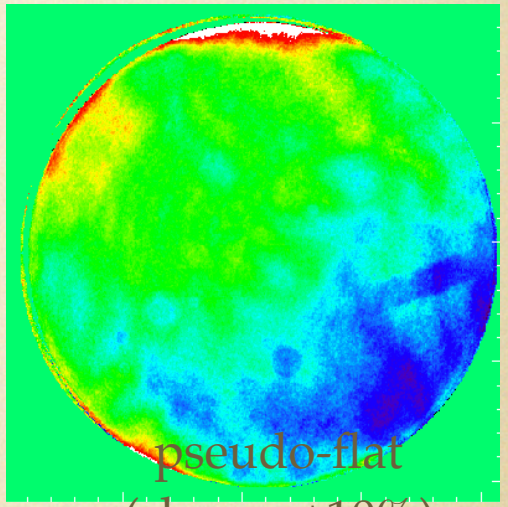
<u>Analyzed data set</u>

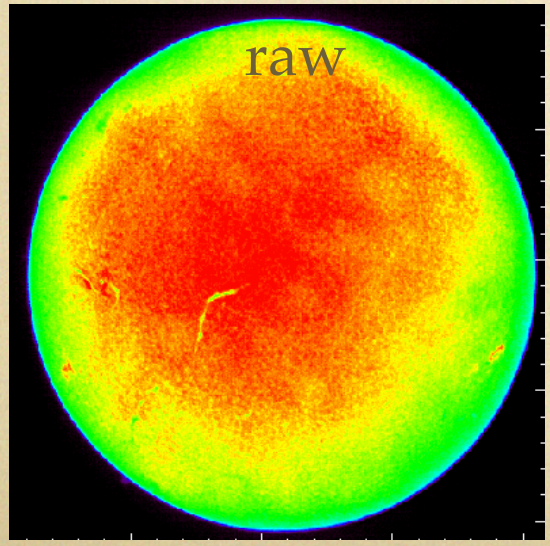
- Only June (when the solar b0 angle is nearly zero) during 1995-2012
- 1000 images randomly chosen in one month

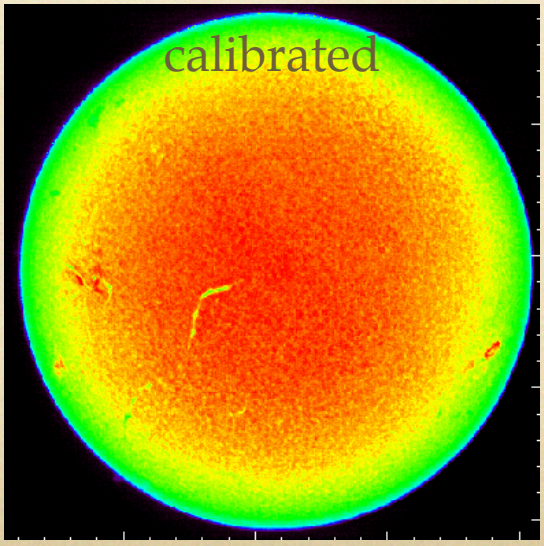


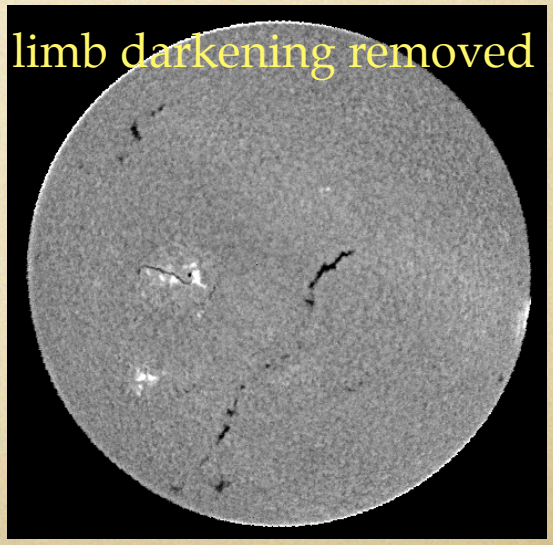
Data calibration

- No flat observation before 2009
  ⇒ Make pseudo-flat by averaging 2-month's images
- Remaining fringe pattern (daily variation) is reduced by additional treatment


pseudo-flat
(shown ±10%)


raw

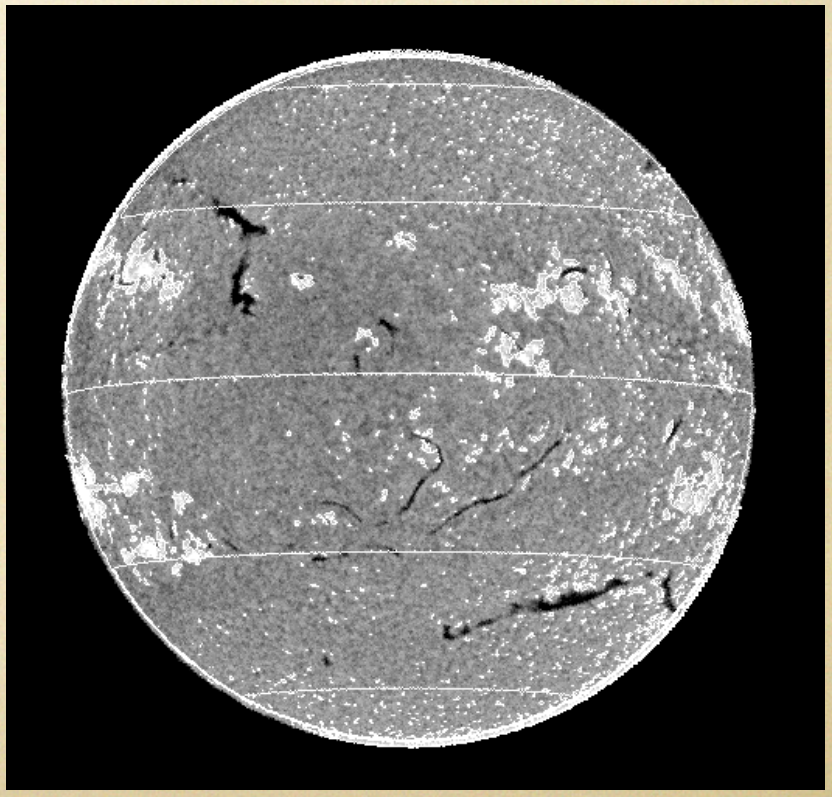

calibrated


limb darkening removed

Plage Index

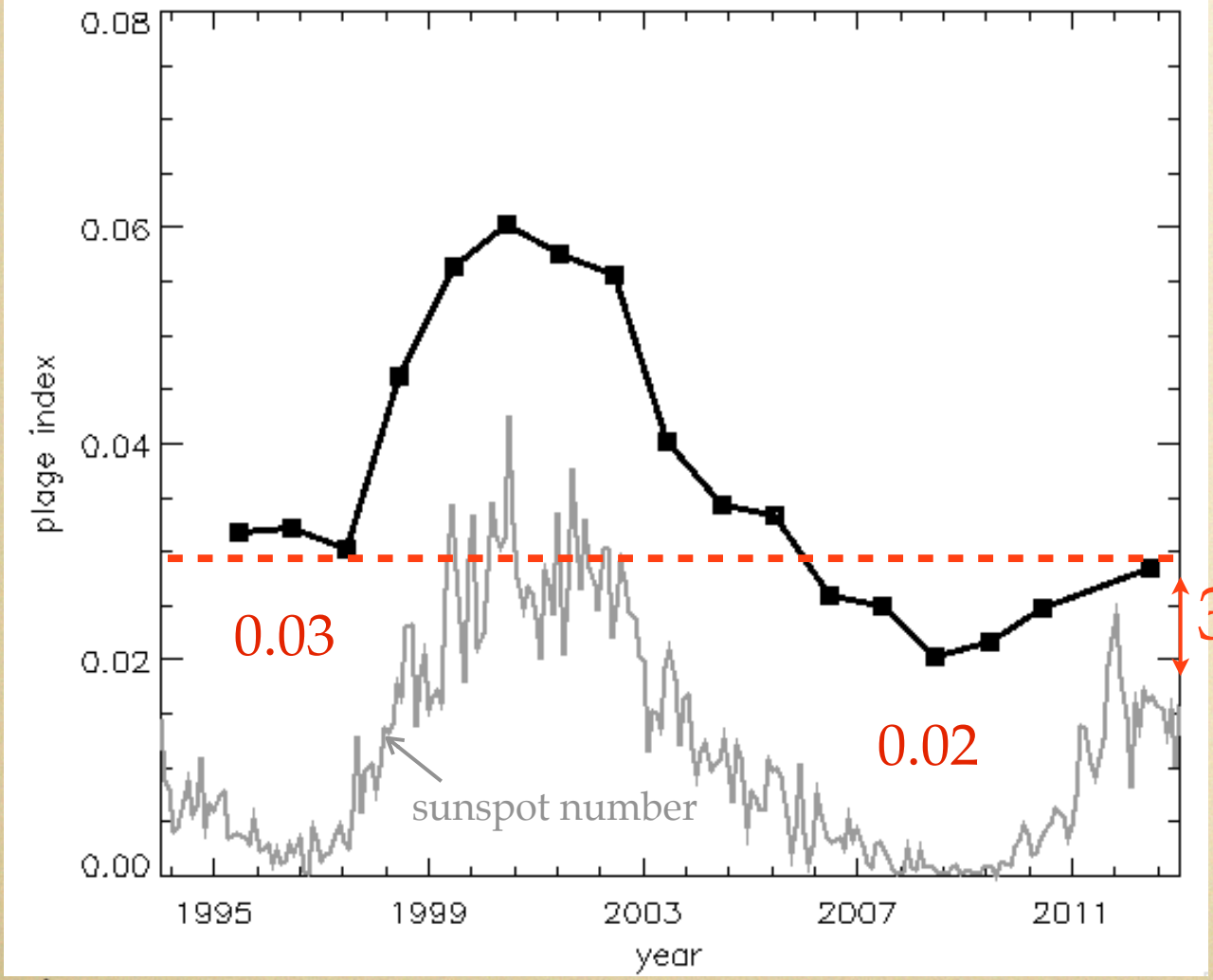
- Plage index : defined as the percentage of the area of the solar disk covered by plages + active network

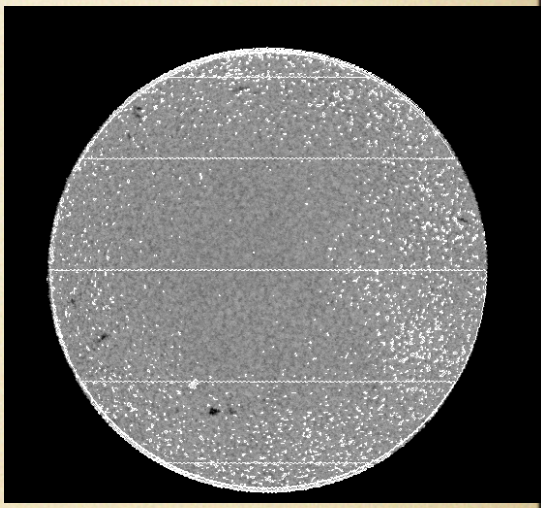
- Intensity threshold method : pixels brighter than average+2σ (standard deviation) over a normalized disk

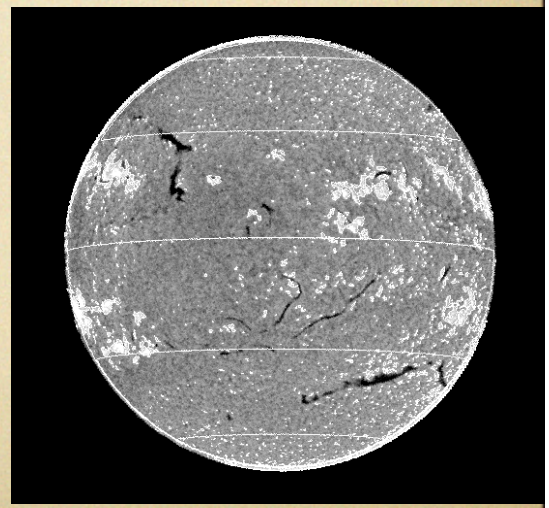


Result

Plage index (full-sun) monthly averaged

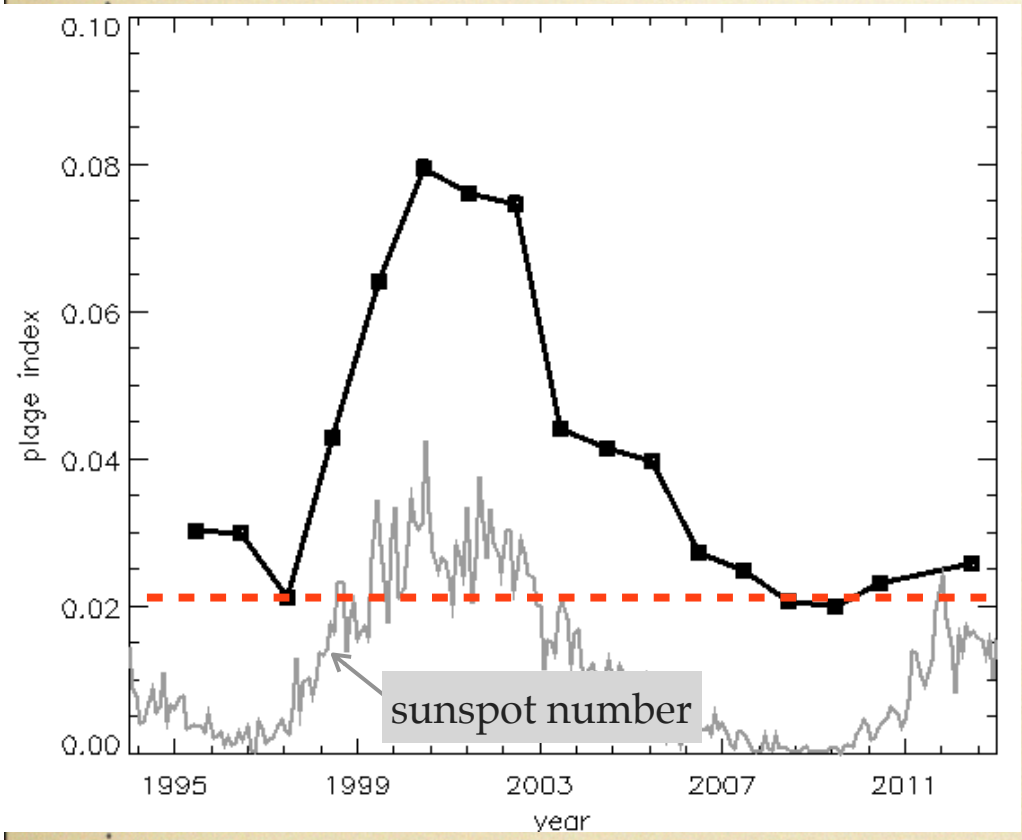




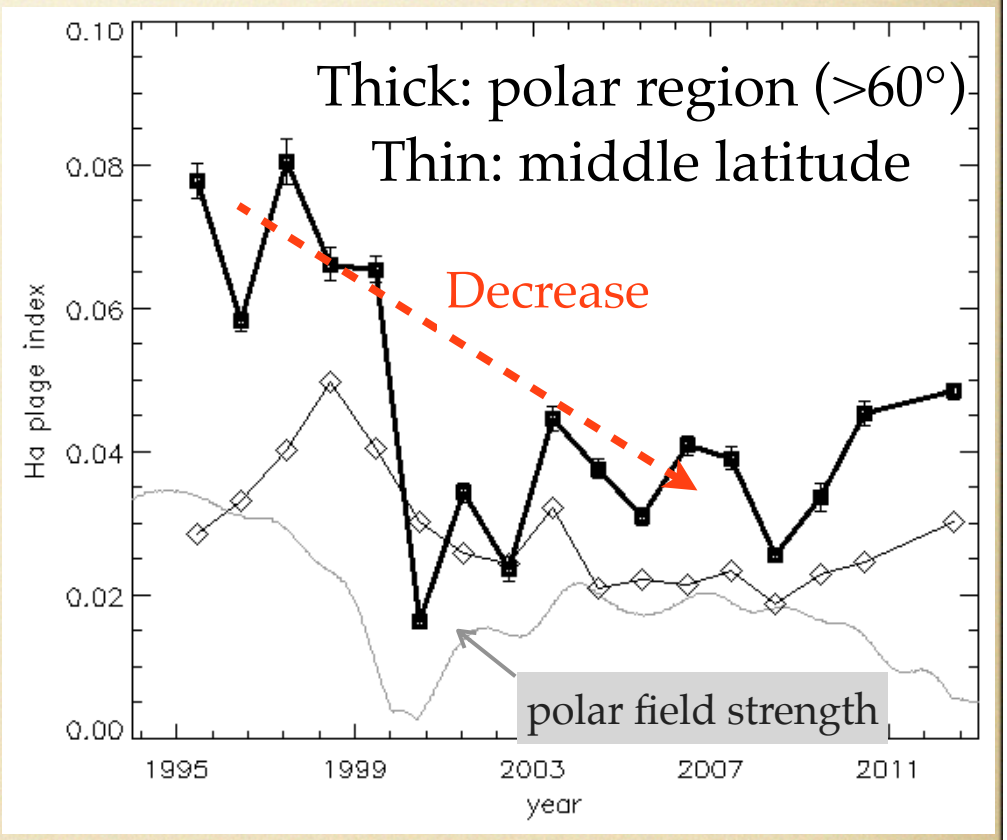


Latitude Variation

Low latitude (active region belt)

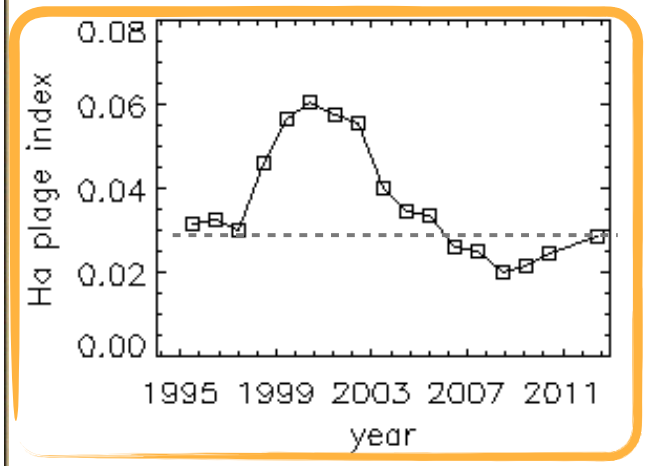


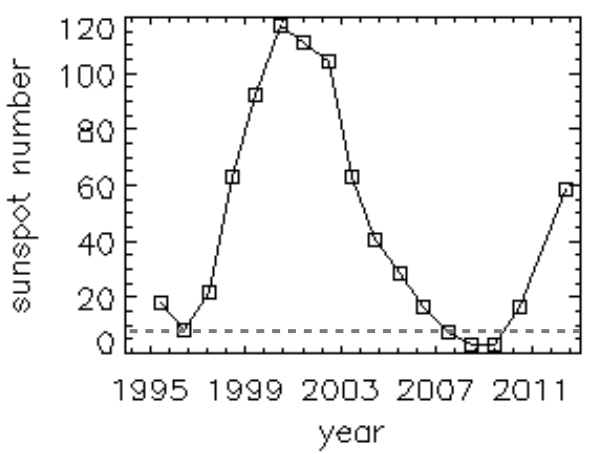
High latitude

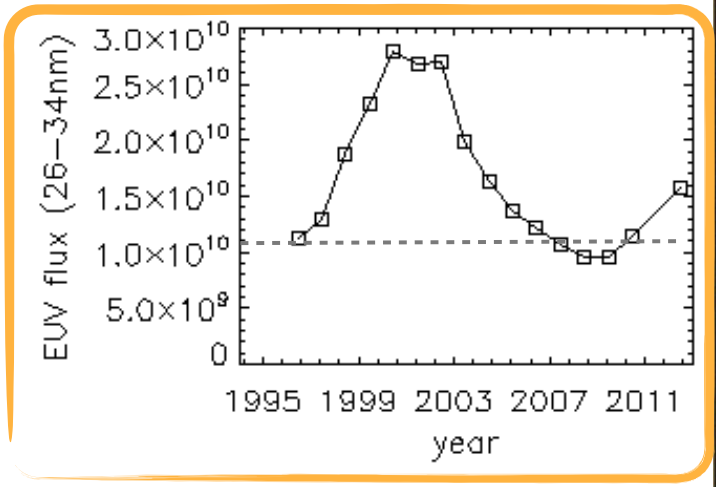


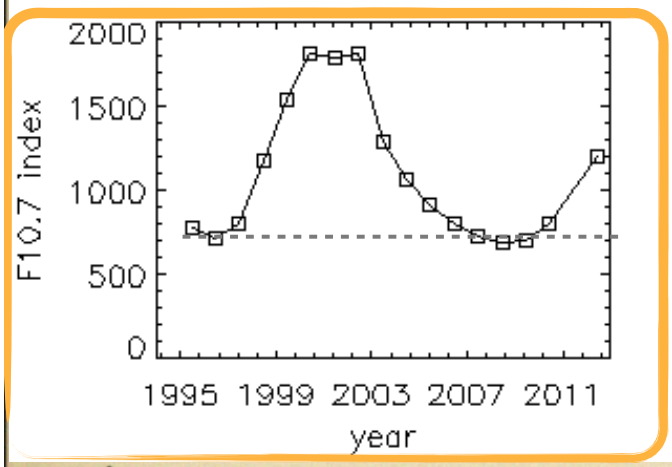
Lower plage index in 2008 minimum comes from the reduction of polar field strength

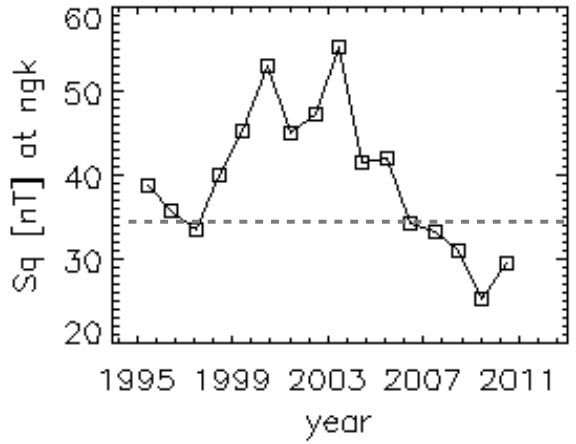
Correlation between Indices

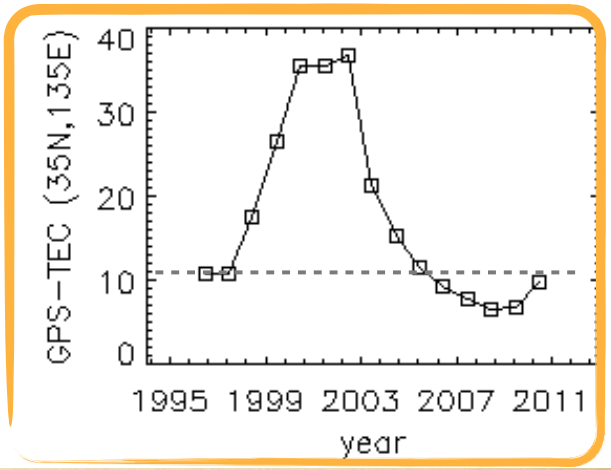












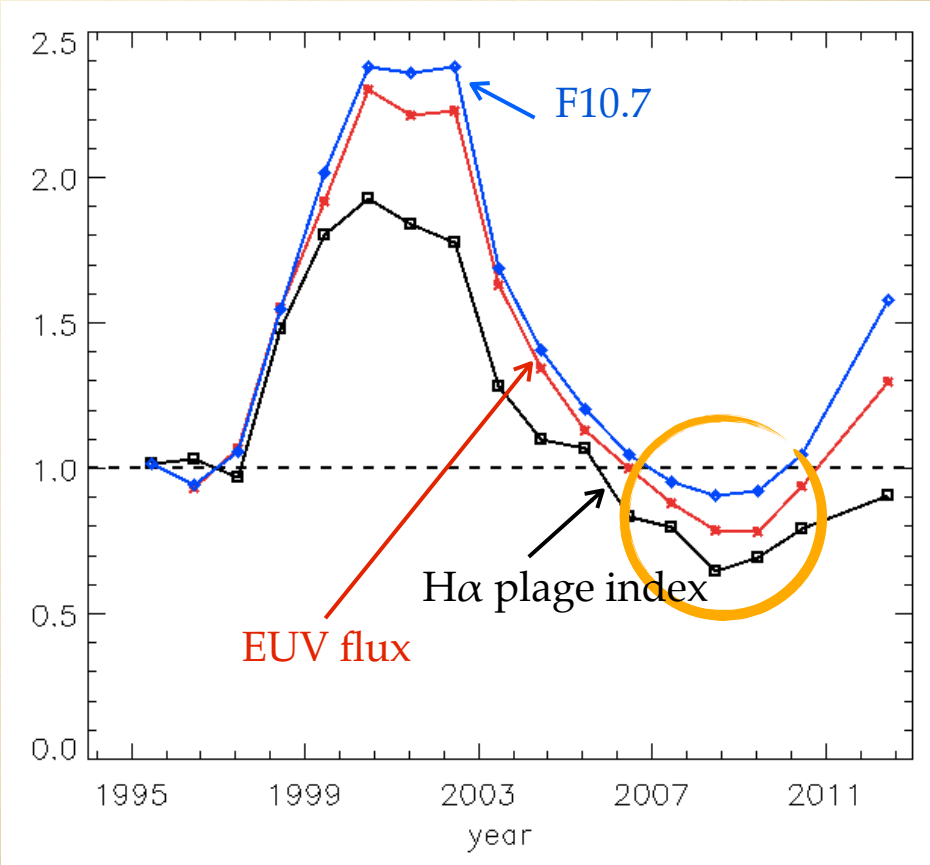
- Plot 1-year average of each parameter

Correlation with UV flux

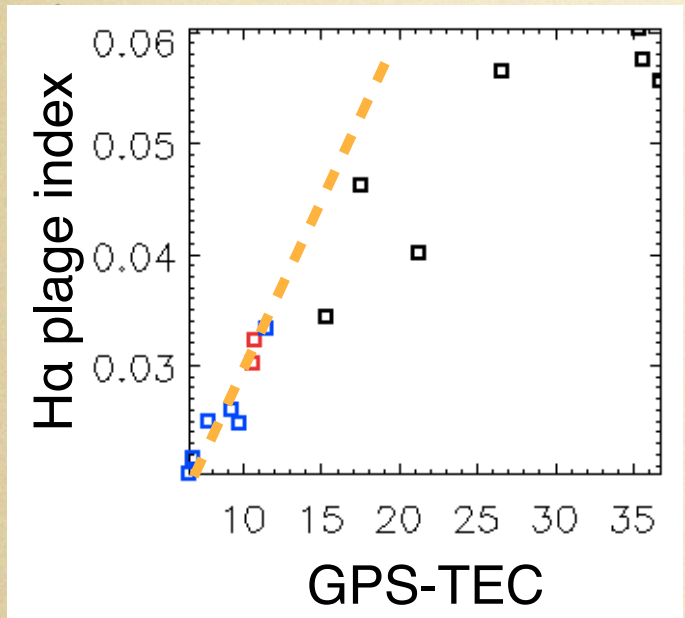
- EUV flux is measured by SOHO/SEM from 1996
- Take 1-year average
- Normalize by the level of 1996-1997

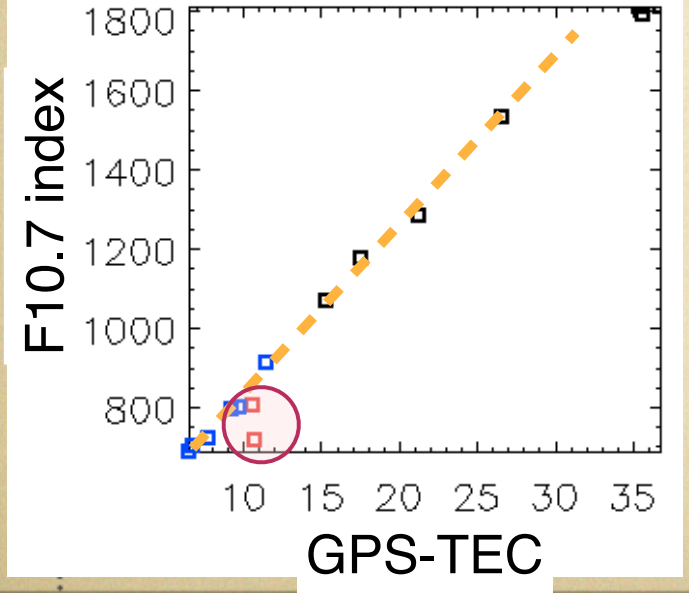
- Linear coefficient b/w Hα plage index and EUV flux is 0.97

Black: Hα plage index
Red: EUV flux (26-34nm)
Blue: F10.7 index



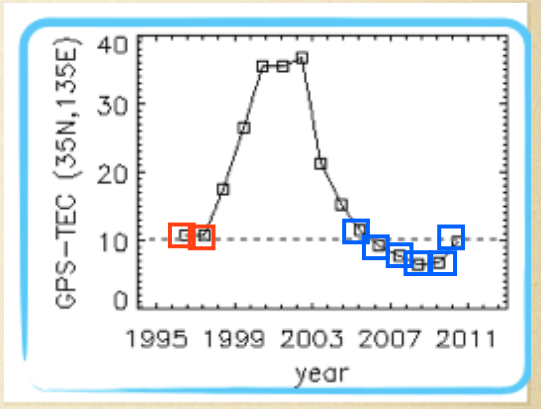
Scatter between GPS-TEC





Red: 1996-1997

Blue: 2005-2010



- Hα plage index and GPS-TEC show a linear relation during solar minimum
- The linear relation between F10.7 and GPS-TEC breaks during solar minimum

SUMMARY

- “Hα plage index” is newly developed to know the long-term variation of the solar UV radiation.
  - Full disk Hα observation starts in 1911 in India
- F10.7 works as a proper UV estimate during solar maximum, but it deviates during solar minimum

⇨ Hα plage index can offer a complementary estimate of UV during solar minimum