New Approach to Sunspot Number Data Set Production

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Authors thank Dr. Angie Cookson of San Fernando Observatory and
Dr. Garth Patterson of Learmonth Observatory for their data support

DATA

1. Sunspot number data, according to their classification, are collected by United States Air Force/Mount Wilson (USAF/MWL) observatory and the available online at the National Geophysical Data Center (NGDC) web site. The USAF/MWL includes measurements from Ramey Solar Observatory (RAMY), Holloman Solar Observatory (HOLL), Palehau Observatory (PALE), San Vito Solar Observatory (SVTO), Learmonth Solar Observatory (LEAR), and others. For the investigated solar cycles (22 and 23), we used the HOLL station data as the principal data source.
2. The ISSN, F10.7 and the Ap index data are taken from National Geophysical Data Center (NGDC).
3. The Dst index data are taken from World Data Center for Geomagnetism at Kyoto University.
4. Facular Area (FA) data were taken from San Fernando Observatory
5. The CME speed data are taken from SOHO / LASCO CME catalog for each event.

What is the Maximum Coronal Mass Ejection Speed Index (MCMESI) ?

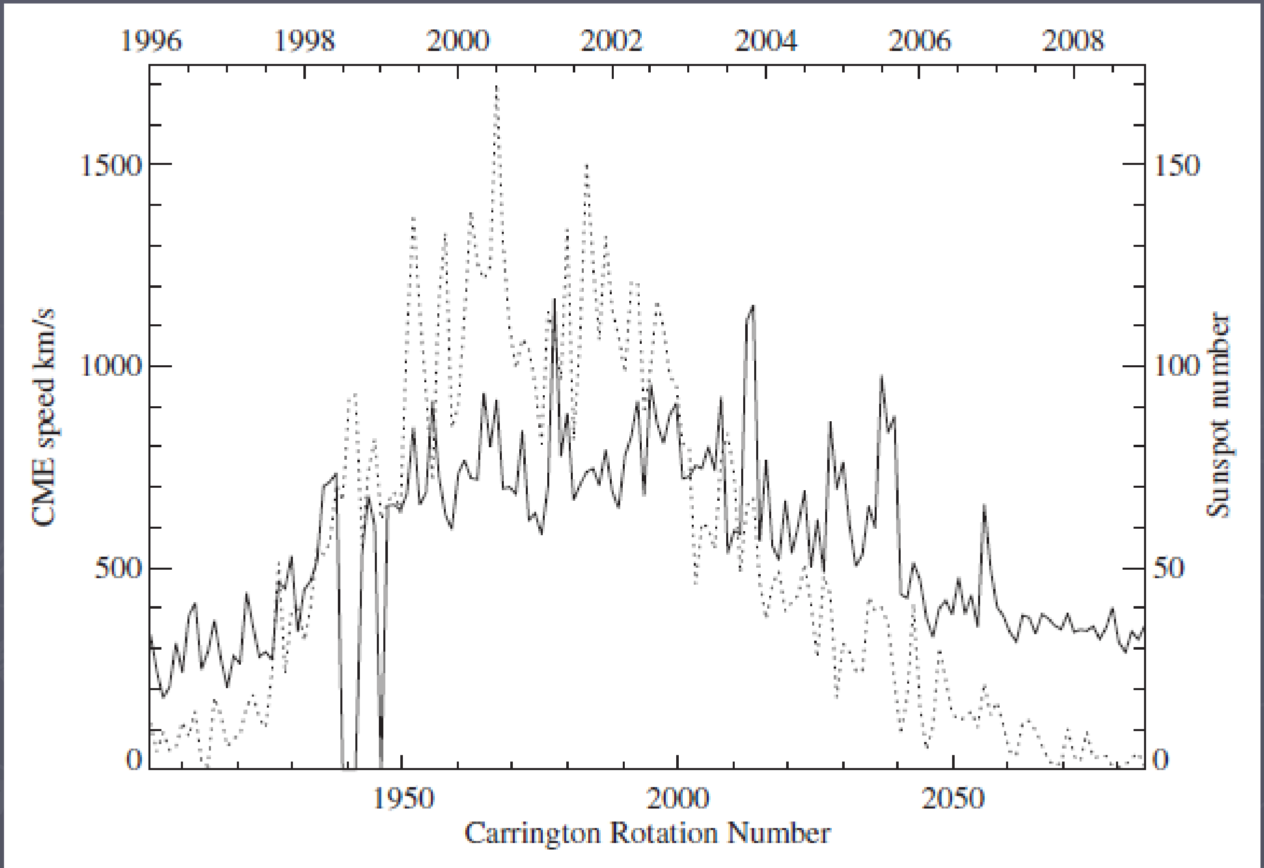


Figure 1. Comparison of monthly data sets for solar cycle 23. For display purposes, ISSN (dotted line) values were scaled.

Differenced cross-correlation coefficients between the MCMESI and both geomagnetic indices indicate that the main contributor to these correlations are fluctuations in the 11 year solar activity cycle

Table1: Results of the cross-correlation analysis. The values in brackets show differenced data cross-correlation coefficients

Geomagnetic Indices	ISSN	CME Speed Index
Ap	0.51 ± 0.13 (0.15)	0.68 ± 0.10 (0.52 ± 0.13)
Dst	-0.37 (-0.08)	-0.53 ± 0.13 (-0.40)

The MCMESI is a powerful index to describe both solar and geomagnetic activity.

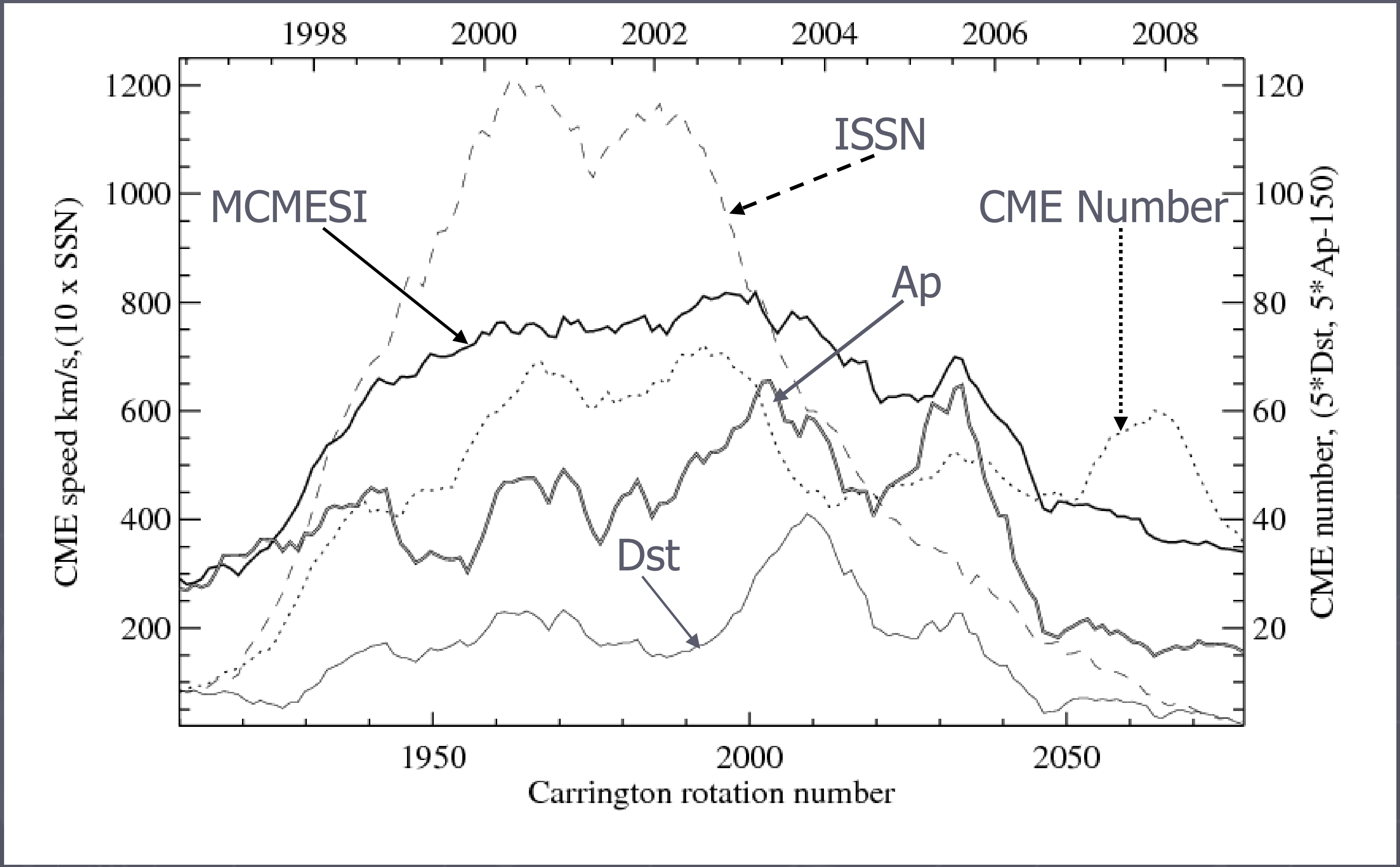


Figure 2. Time profiles of 12 point running averaged monthly data sets.

- ISSN and Small ARs peaked at the first maximum of the solar cycle, while Large ARs and F10.7 peaked during the second maximum
- The number of Large ARs was nearly the same (slightly higher) in cycle 23 as compared to cycle 22

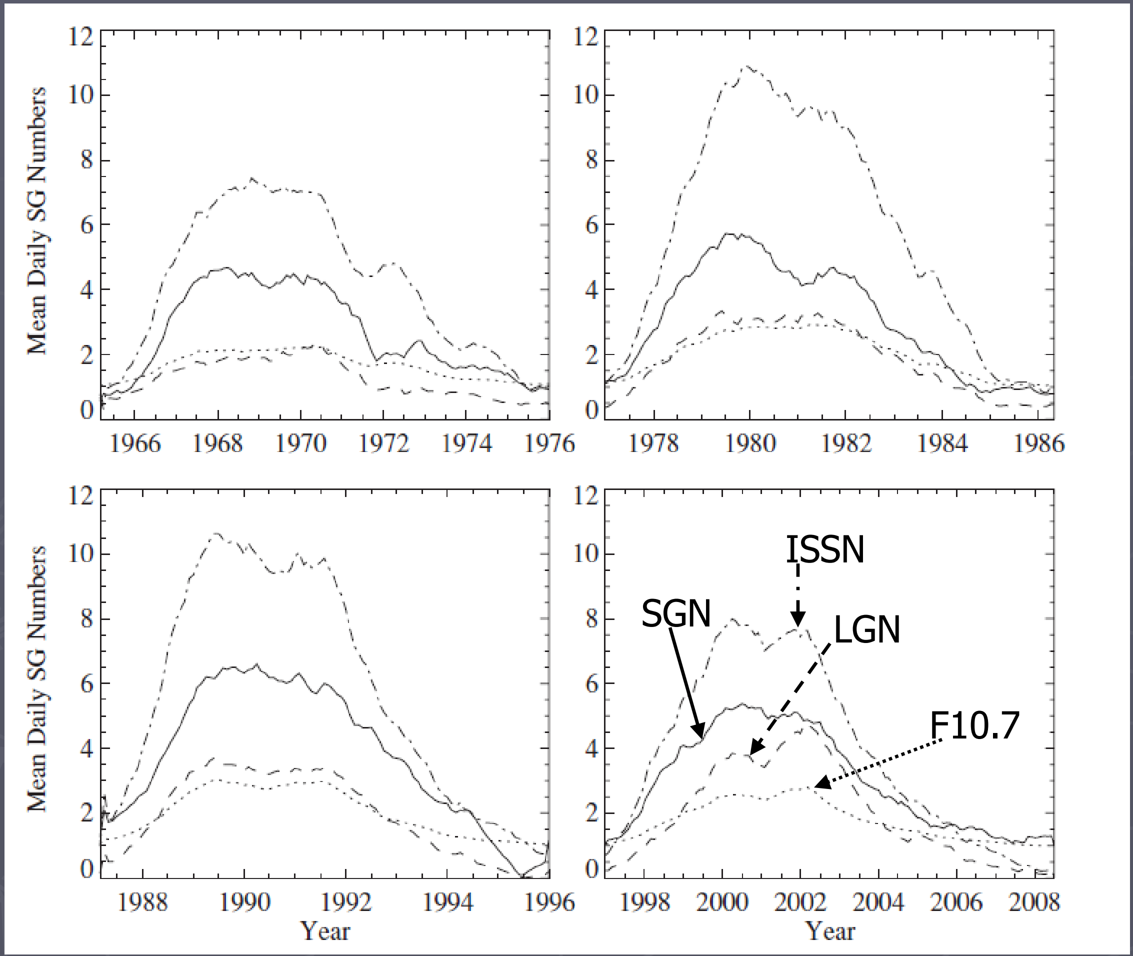


Figure 3. Solar cycle variations of selected parameters smoothed with a 12 step running average filter. For display purposes, the ISSN and 10.7 cm solar radio data were re-scaled: the ISSN was divided by 15, while the F10.7 cm radio flux is divided by 700.

Large ARs tend to reach their maxima nearly half-way through the solar cycle (phases 0.45–0.5), while the ISSN generally peaks at solar cycle phase of 0.29–0.35.

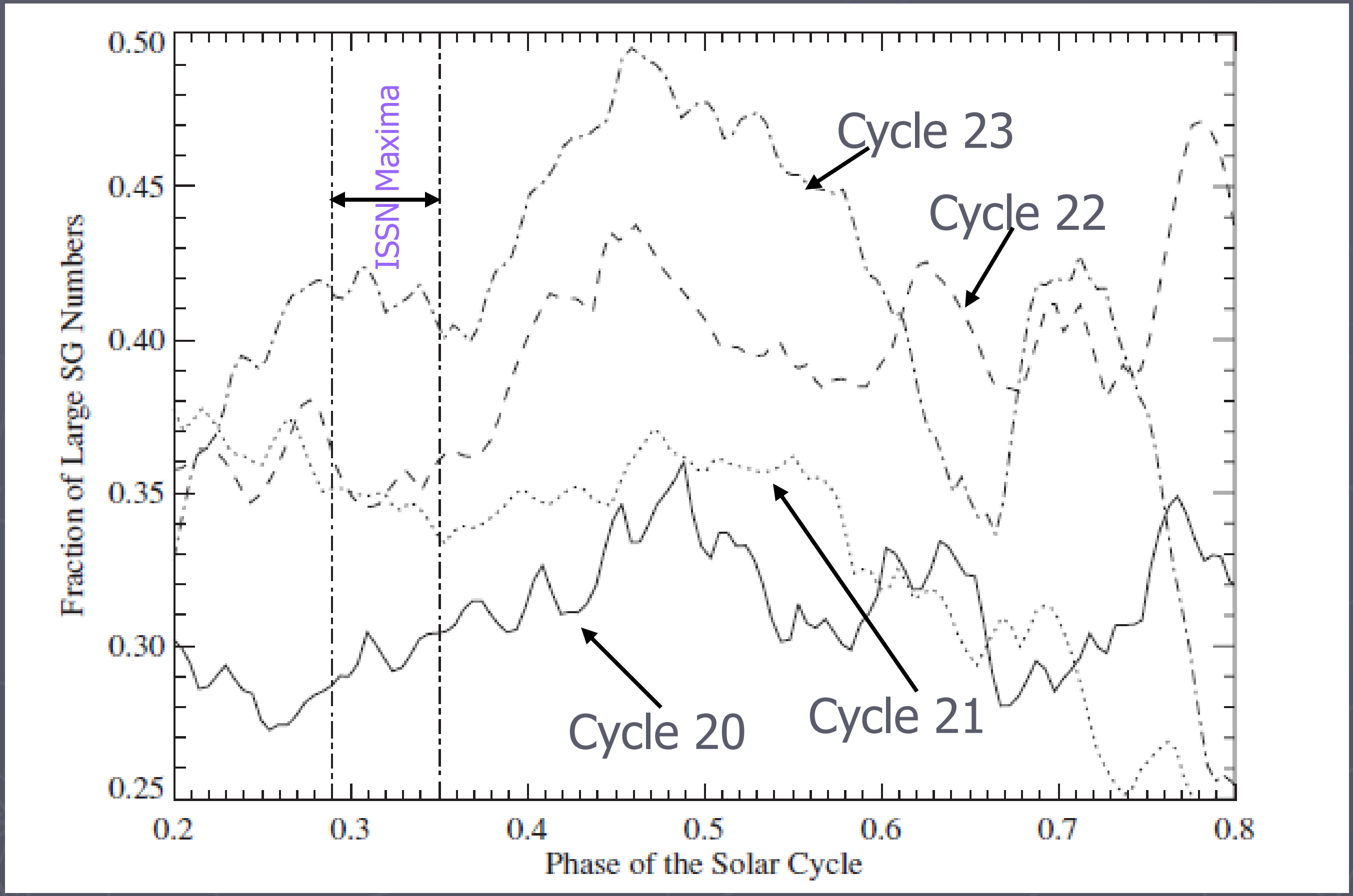


Figure 4. Ratio of the large groups to the total number of all active regions (i.e., sum of small and large groups) plotted vs. the solar cycle phase.

- The number of sunspots in small ARs in cycle 23 was about half of that in cycle 22; the number of sunspots in large ARs decreased by only about 20%
- In both cycles the number of sunspots in small ARs peaked at the first maximum of the solar cycle, while the # of sunspots in large ARs behaved differently (reason of double maximum).

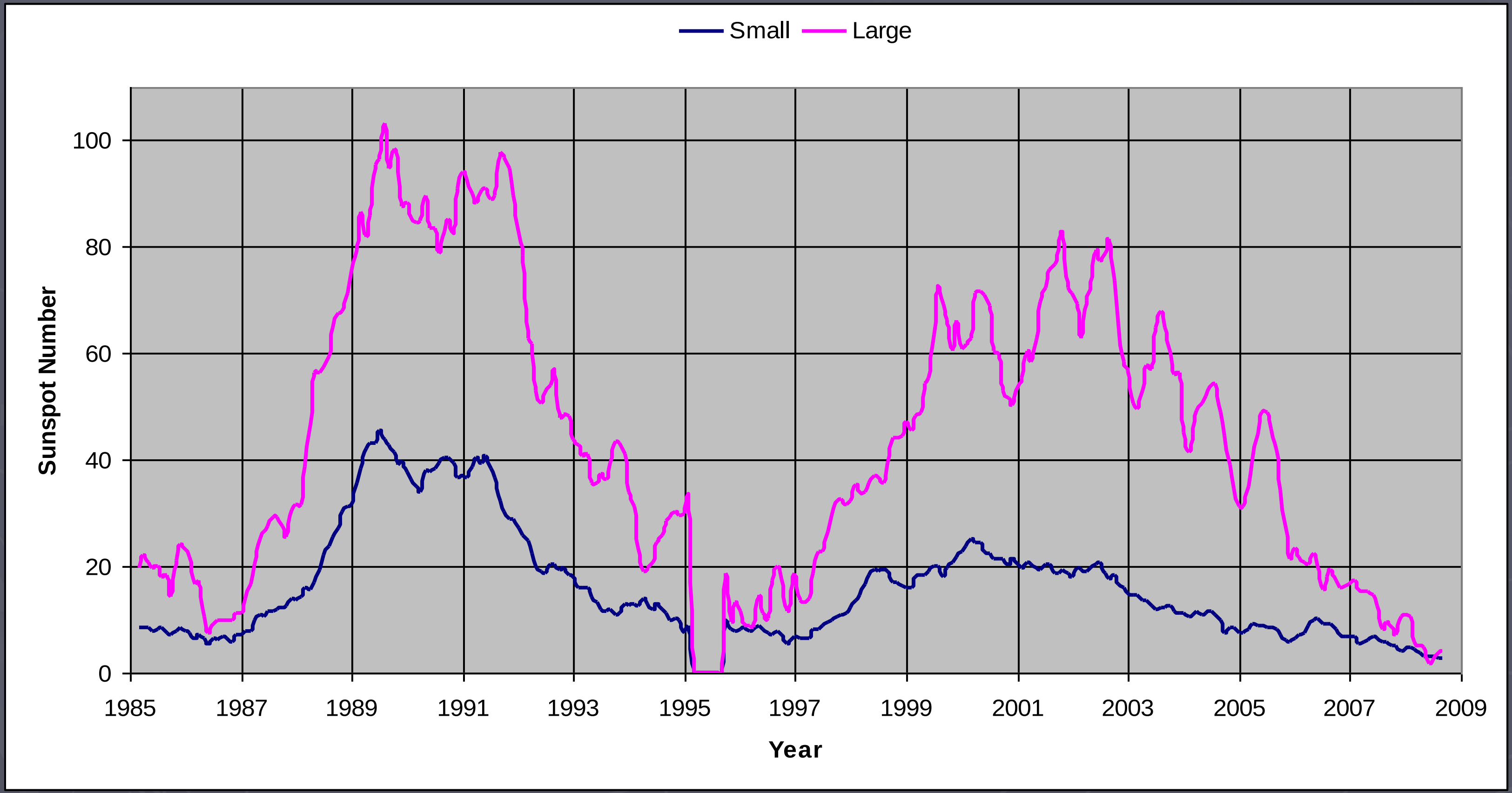


Figure 5. Comparison of monthly small and group sunspot numbers.

- $Rz = k*(10*g+f)$, where g is the number of ARs and f is the number of sunspots, k – correction factor
- Modified SSN = $Z*g_S+f_S+10*g_L+f_L$ where Z is the weight factor; $z=1$ (blue), 5 (pink), 10 (yellow); Note, Z weighting was applied to small ARs only.

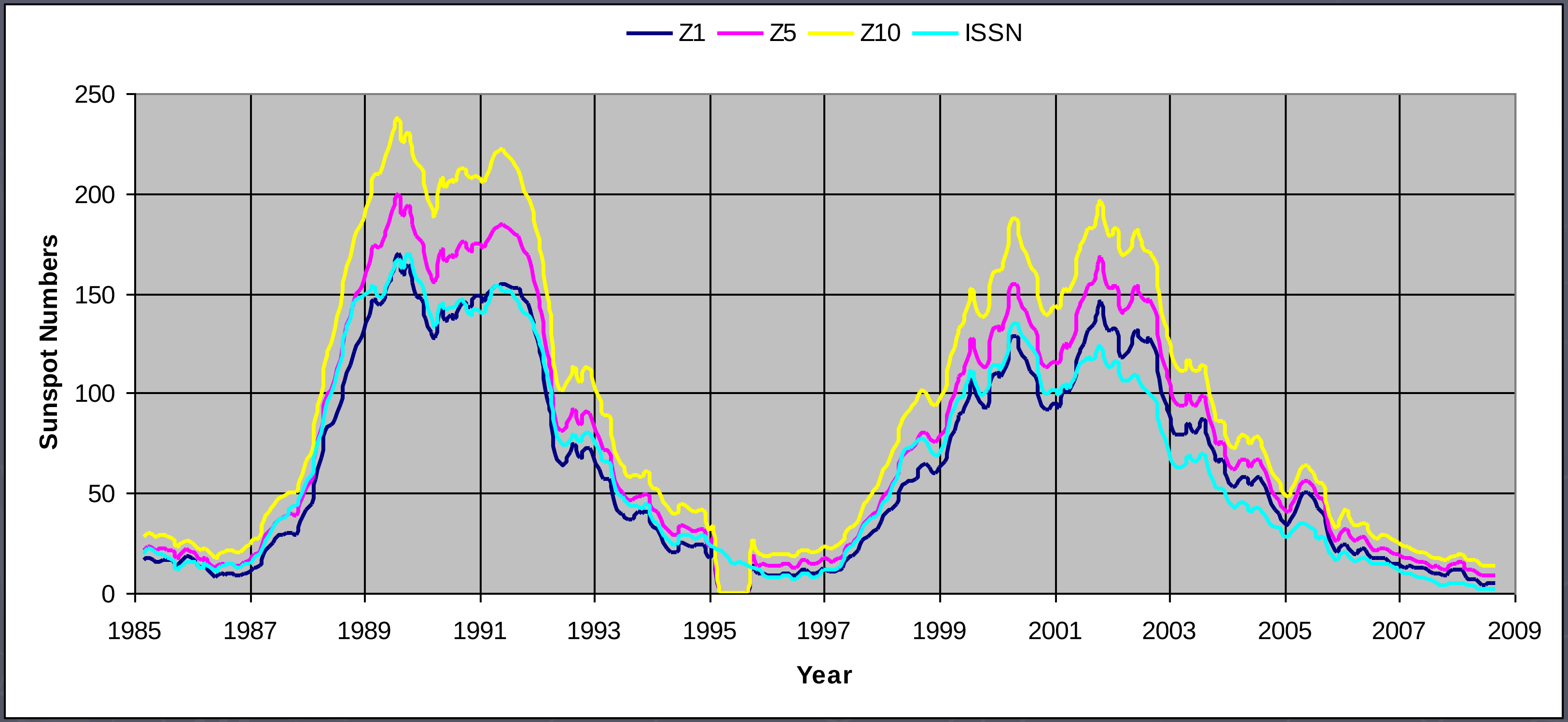


Figure 6. Comparison of modified sunspot numbers with the ISSN. All data sets are smoothed with 6 months running average. Note that the "k" correction factor in the modified Rz equation was set to 1.

- *Z1* version is more sensitive to SSA than ISSN is
- *Z1* reached the maximum nearly simultaneously with SSA and FA in cycle 23, while ISSN reached the maximum about two year earlier

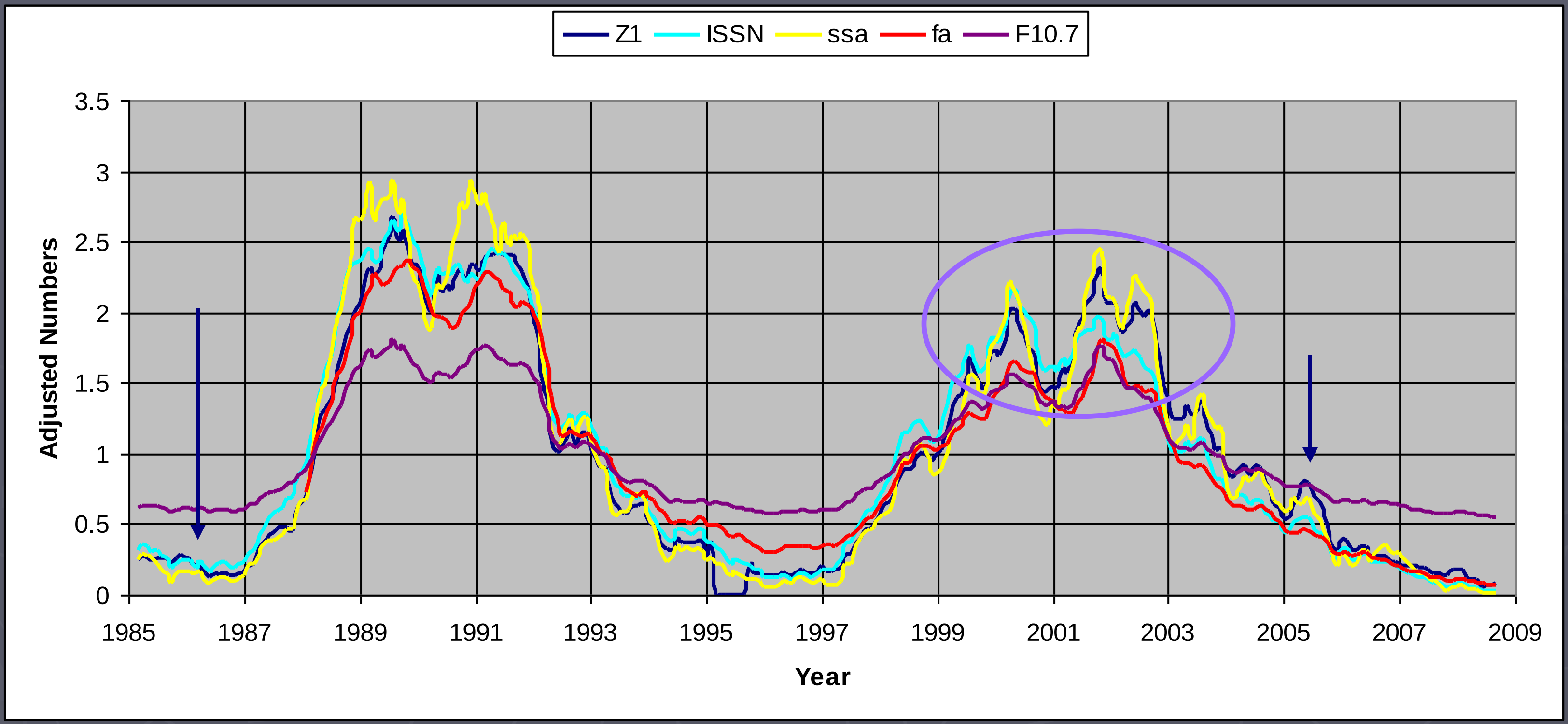


Figure 7. Comparison of smoothed monthly Zurich numbers (Z1) with other solar activity indicators (ISSN, SSA, FA and F10.7) used here. For display purposes all data series were divided by their own average values.

• Z1 is better describing the geomagnetic activity than ISSN does

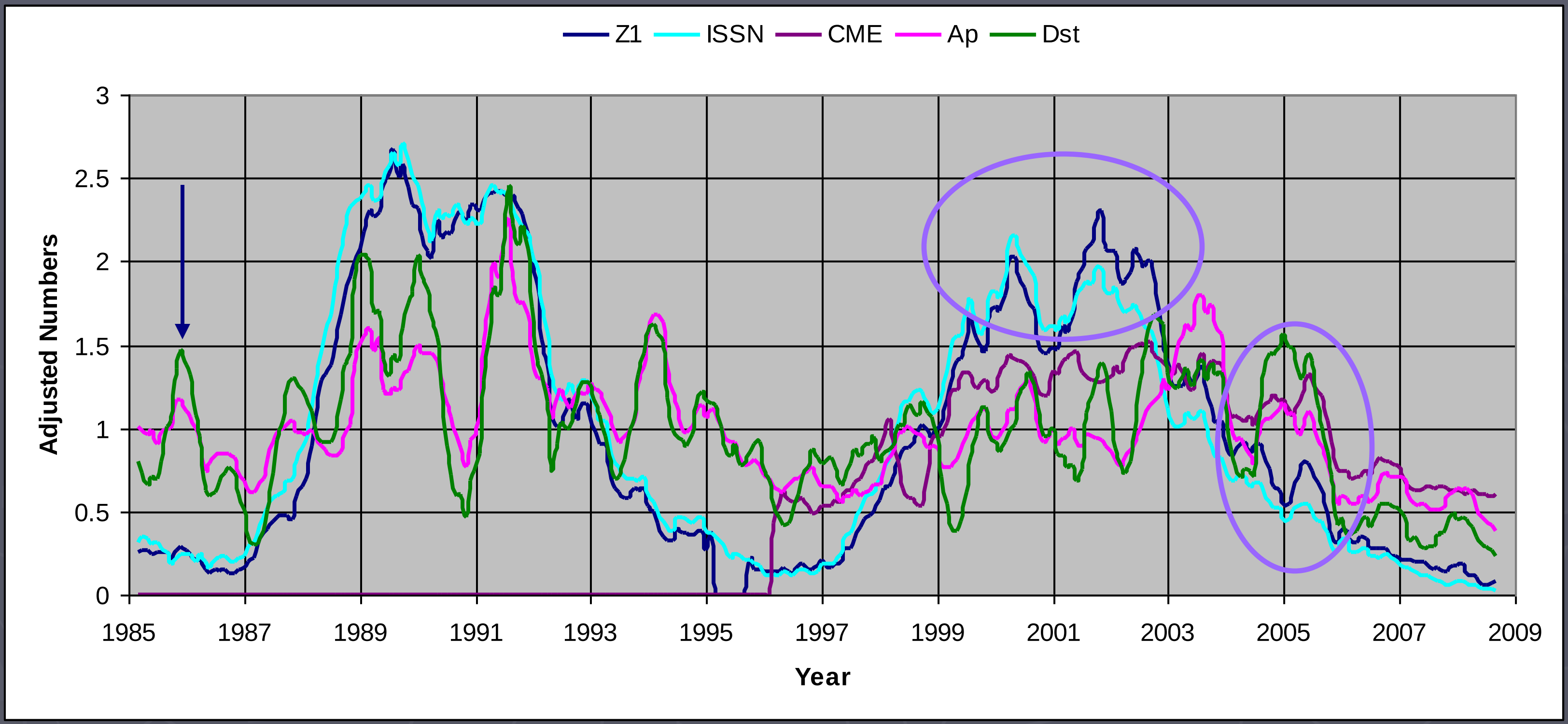


Figure 8. Comparison of smoothed monthly Zurich numbers (Z1) and ISSN with geomagnetic activity indicators (MCMESI, Ap and DsT) used here. To display purpose all data series were divided by their own average values.

• the number of sunspots in large ARs shows much better agreement with geomagnetic activity indices (MCMESI, Ap, Dst) than ISSN does

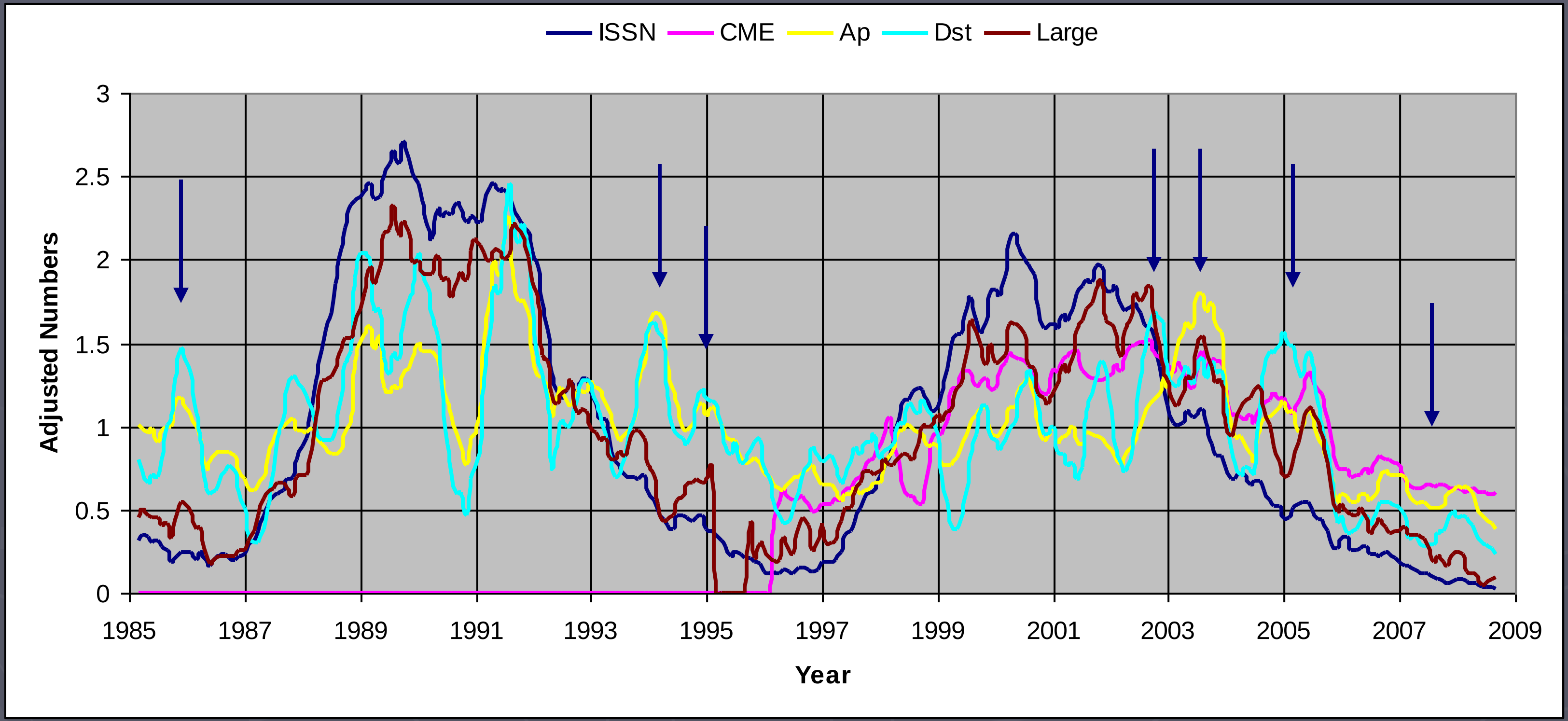


Figure 9. Comparison of smoothed monthly Large group sunspot numbers and SSN with geomagnetic activity indicators (MCMESI, Ap and DsT) used here. To display purpose all data series were divided by their own average values.

- The best correlation between solar and geomagnetic activity appears when we consider the number of sunspots in large ARs
- Correlation between the geomagnetic indices and the modified sunspot number is increasing with decreasing weight of small ARs

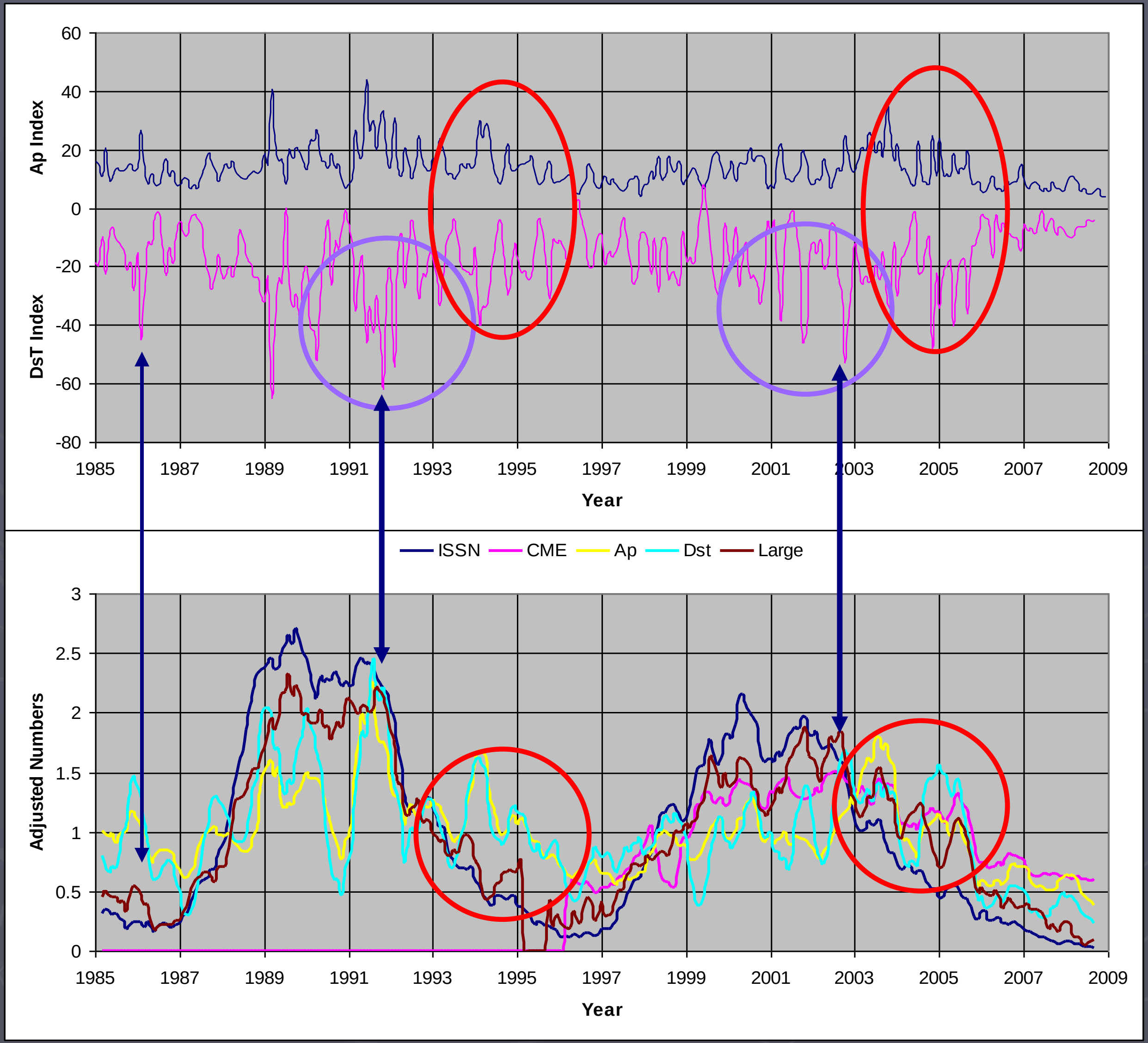
Table2: Pearson correlation coefficients between compared data sets.

	F10.7	SSA	FA	MCMESI	AP	DST
Z1	0.995	0.995	0.974	0.919	0.665	-0.754
Z3	0.996	0.995	0.977	0.913	0.663	-0.751
Z5	0.996	0.995	0.978	0.906	0.661	-0.749
Z10	**0.997**	0.994	0.981	0.893	0.657	-0.744
Z5x5	0.996	0.996	**0.982**	0.904	0.667	-0.754
Z1x1	0.992	**0.997**	**0.982**	0.912	0.674	-0.764
ISSN	0.989	0.985	0.979	0.844	0.644	-0.732
GSSN	0.976	0.988	**0.982**	0.932	0.724	**-0.805**
LgSSN	0.973	0.981	0.964	**0.953**	**0.726**	**-0.805**
SgSSN	0.924	0.942	0.960	0.761	0.674	-0.754

The higher number of sunspots in large ARs indicates higher complexity and fragmentation of magnetic fields – the conditions that favor flare activity

Is the solar cycle 23 anomalous? THE ANSWER IS NO

1. As evident from the monthly averaged Dst and Ap index, the geo-mag activity was more intense during cycle 22
2. The number of sunspots in large ARs show similar trend during the declining phases of cycle 23 and 22 (0.5 and 0.7).



- As seen from Figure 3 and 5 the number of both large ARs and sunspots in large ARs (DEF groups) peak at the second cycle maxima, while small ARs (ABCH) and the number of sunspots in them peak at the the first maximum of the sunspot cycle. This may explain the reason of double peak in the sunspot cycle.

- The number of sunspots in small ARs in cycle 22 was about twice of that in cycle 23, while the # of sunspots in large ARs was about 20 % less in cycle 23 than in cycle 22.
- The number of large ARs were nearly the same in both cycles, with cycle 23 having slightly bigger number

- Modified SSN number, with lower weight of small ARs, showed better correlation with geomagnetic activity (Ap, Dst, and MCMESI) and they also showed about same level of correlation with other solar activity indicators. The best correlation between solar and geomagnetic activity appeared when the number of sunspots in large ARs was considered.

- According to sunspot data the maximum of sunspot cycle 23 occurred in 2000, but most of the other activity indicators (FA, SSA, F10.7) reached to their maximum in 2002.

- Finally we suggest that to obtain a better relationship between sunspot numbers and geomagnetic activity we should i) decrease the weight of small ARs, ii) count directly the sunspots without w/o taking into account the number of ARs on the disk.

Thank You For Your Attention !