International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

Variation of Solar Activity during Solar Cycles 22 and 23

Lahkar, M.
Research Scientist, Centre for Radio Astronomy, Department of Physics
Cotton University, Guwahati, Assam, India
Saikia, N.
Associate Professor, Department of Physics
Cotton University, Guwahati, Assam, India

ABSTRACT:

In this study we have presented that despite their strong overall correlation, these two indices of solar activity can behave differently, especially near solar maximum and solar minimum. In particular, they may lag each other during the solar maximum in some cycles. Again there is few SFU of microwave emission even in zero sunspot numbers during the solar cycle's minimum. The flare activity indices also confirm the behavior of the two solar activity indices during the solar maximum and solar minimum period.

We studied the behavior of solar activity during the solar cycles 22 and 23 using the solar activity indices, microwave flux at 10.7cm, Zurich sunspot numbers and flare activity indices. The 10.7cm microwave flux (F) has been compared with other activity indices which arise under different physical conditions. It is found that 10.7cm microwave flux closely follows the number of sunspots visible on the solar disk. The present analysis also reveals that even in minimum of zero sunspots visible on the solar disk, there is few SFU (Solar Flux Unit) of microwave emission at 10.7cm. It is also found that there is a lag of about 2 years between the maximum of smoothed 10.7cm microwave flux and the maximum of smoothed sunspot numbers during the cycle 23, whereas there is no lag during the cycle 22.

The presence of lag in maximum in some cycles but not in others argues that some aspect of average magnetic field complexity near solar maximum varies from cycle to cycle. This variation in the magnetic complexity has confirmed with the flare activity index. The flare activity shows very low values at the maximum of cycle 23 compared to the maximum of cycle 22.

In this analysis we are using data from NASA data catalog for Sunspot Numbers and 10.7cm radio flus from Zurich observatory data catalog, Switzerland.

1. Introduction:

Solar activity is the driver of space weather, which has practical consequences on our environment; thereby it influences various aspect of human life in Earth. So, it is vitally important to develop capabilities for understanding the solar activity variations. Solar activity variations demonstrate themselves not only in electromagnetic radiations from radio frequency of a few KHz to powerful γ rays but also in particle flux. In broad physical terms, solar activity may be understood in terms of the properties and the behavior of the magnetized solar plasma. Eventually, solar activity is driven by the temporally and spatially varying distributions of magnetic flux in the Photosphere, Chromosphere and Corona.

An index of solar activity is a quantity intended to describe some aspects of solar activity as a whole. Being able to express aspects of that activity by many indices, such as the Zurich sunspot numbers, the microwave flux at 10.7cm, flare activity index, X-ray and EUV indices, etc. are useful for studying the Sun's long term behavior and its interaction with our near Earth-space environment. Expressing the aspect of that activity in terms of single indices is useful in investigating its role as a driver for various space and terrestrial phenomenon, highly variable conditions in the Geo-space environment and those on the sun persist throughout the maximum phase of solar activity.

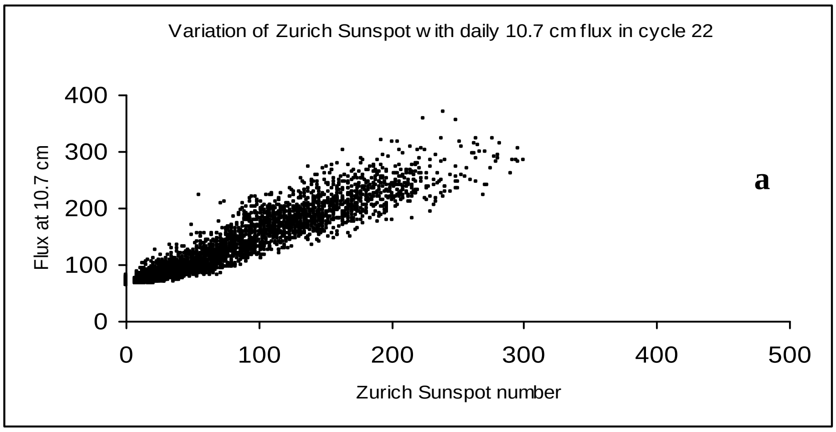
International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

It is well known that the daily 10.7cm microwave flux is correlated highly with the sunspot number and other measure of solar activity. The two indices are daily microwave flux at 10.7cm and sunspot number(s) correlates so strongly that it is tempting to regard the indices of solar activity as interchangeable, or to regard microwave flux as a quantitive replacement for sunspot numbers (Covington, 1954, 1959, 1969).

In this present analysis a detailed and extensive data sets of the solar activity indices during solar cycles 22 and 23 is being used. In section 3 we have analyzed the behavior of microwave flux at 10.7cm with Zurich sunspot numbers during the cycles 22 and 23, and in the maximum and minimum period of these two cycles. In section 4, we have shown the variation of smoothed 10.7cm flux with smoothed sunspot numbers and the flare activity index.

2. Data Analysis

2.1 Variation of 10.7cm microwave flux with Zurich sunspot numbers during cycles 22 and 23:



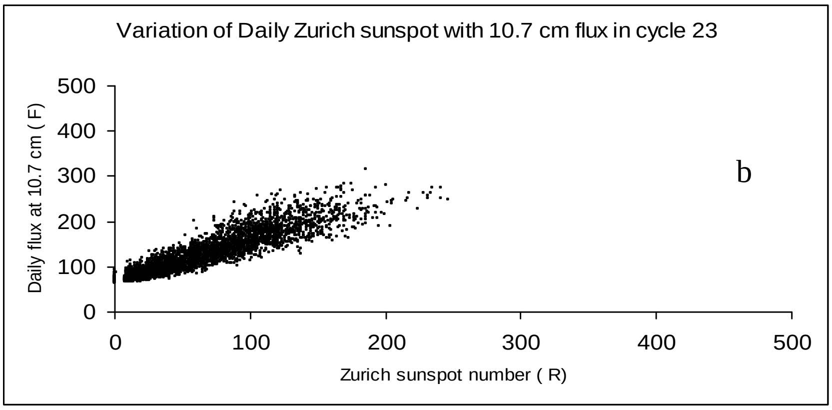


Figure 1: Variation of the of daily microwave flux at 10.7cm and Zurich sunspot numbers during the cycle 22(top) and 23(bottom) respectively.

We have examined the variations of the observed daily, mean monthly and mean yearly values of 10.7 cm flux (F) with the corresponding values of the Zurich sunspot numbers (R). The trend in the variations shown in figures 1a-1b represents the linear correlation between 10.7cm flux, which is the total emission from undisturbed solar disk plus emission from radio regions with associated and non- associated sunspot numbers during cycle 22 and 23. It appears from these figures that the correlation between these two observed parameters are very high.

The trend of variation in the behavior of these two parameters are significant in the figs. 1a - 1b, and if the trend is extrapolated to zero.

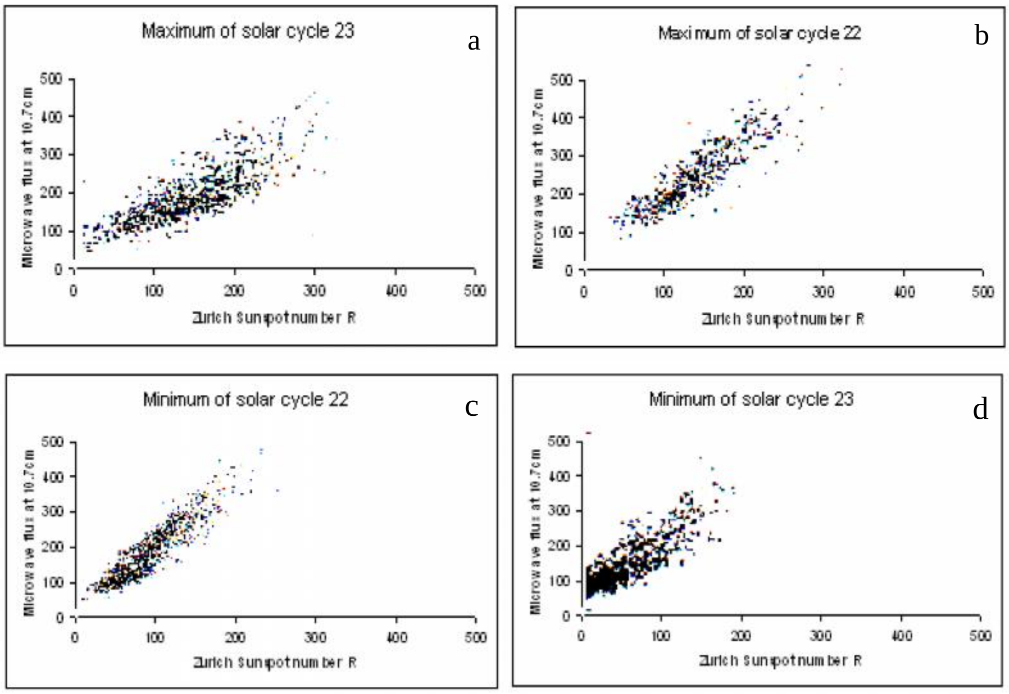


Figure 2: Variation of daily flux at 10.7cm radio flux with Zurich sunspot numbers during solar maximum and solar minimum.

The extrapolated Sunspot number(s), the corresponding value of microwave flux represents the basic component or the quiet sun emission. The emission above the base level is found variable, and is related to the presence of sunspots and sunspot groups and is called as slowly varying component (SVC). The figures 1a-1b reveal that at the beginning of cycles 22 and 23, the microwave flux at 10.7cm is not in a fixed minimum level which suggest that the magnetic field strength contained in the beginning of each cycle never goes down to a fixed minimum level. This variation in the minimum level may be the influence of the strength of magnetic field of the preceding cycle.

We have also examined the linear relationship between the daily values of radio flux at 10.7cm and the corresponding values of Zurich sunspot numbers for the ascending and descending branch of the solar cycles 22 and 23. It reveals that the behavior of the daily values of the parameters F and R should be analogous during the maximum and minimum period of solar activity cycles. Figures 2a to 2d show the plot of daily Zurich numbers against daily flux at 10.7cm for the cycles 22 and 23 in their maximum and minimum phase. The figures 2a - 2b represent the variation of the Zurich sunspot numbers corresponding to the flux at 10.7cm, which shows that the trend of the behavior of these two parameters is a little bit scattered in comparison to the points in figures 2c - 2d. Figures 2c - 2d represents the behavior of F and R during the minimum phase of solar activity in cycles 22 and 23. The scattered points in figures 2a-2b, reveal the radio flux powered by the evolution of new sunspot groups during the maximum phase of solar activity cycle. In other words, the Zurich numbers is influenced more strongly by the number of sunspot groups evolved during the solar maximum; correspondingly it enhances the microwave emission at 10.7cm.

In figure 3, we have shown the correlation plot extrapolated to zero Zurich number. The interesting features observed in this figure is that if the trend between F and R is extrapolated to zero Zurich number, it cuts the solar flux axis with a positive intercept, which implies that the solar microwave flux at 10.7cm is not zero, but positive though even when the sun should be considered completely quiet in terms of observed sunspot. According to Das Gupta and Basu (1964) this quiet level microwave emission is varying of the order of 10-15 flux units at the beginning of each solar cycle. It appears from the figure that the trend between the two parameters intersect the flux axis with a positive

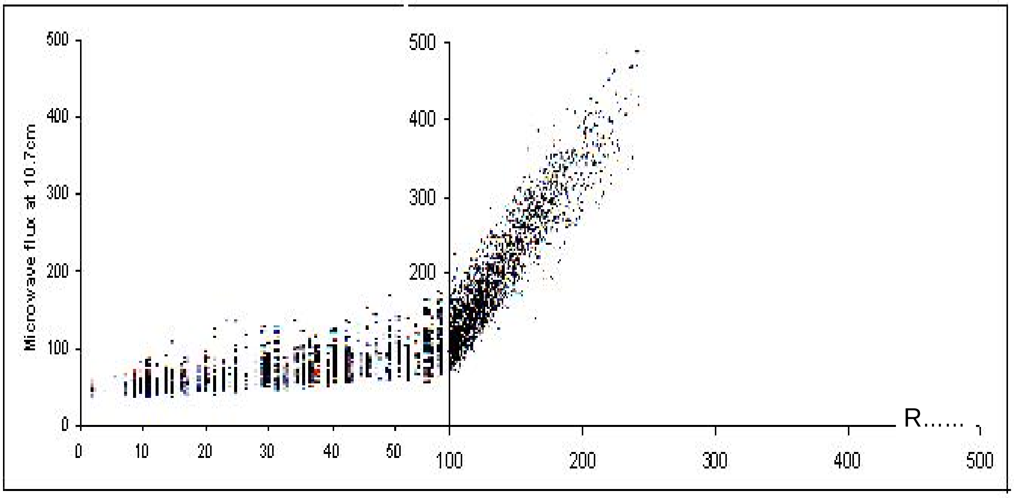


Figure 3: Correlation plot between F-R extrapolated to zero sunspot numbers showing the positive intercept in the flux axis. intercept of the order of 60-100 flux units, when it is extrapolated to zero Zurich number. This feature has revealed that the radio emission at 10.7cm is dependent upon the state of solar activity which agrees with the Wald Meier's (1971) conclusion. As shown in figure 3, the left hand side of each plot corresponds to the quiet level of solar activity representing the minimum number of sunspot and the right hand side represents the increasing solar activity with increasing sunspot numbers.

Using this figure we can have a first estimation of the quiet sun emission at 10.7cm by extrapolating the best linear approximation to the flux axis.

In figure 4, the smoothed monthly values of radio flux has been plotted against smoothed monthly values of Zurich sunspot numbers for the solar cycles 22 and 23 have occurred almost at the same time, but the

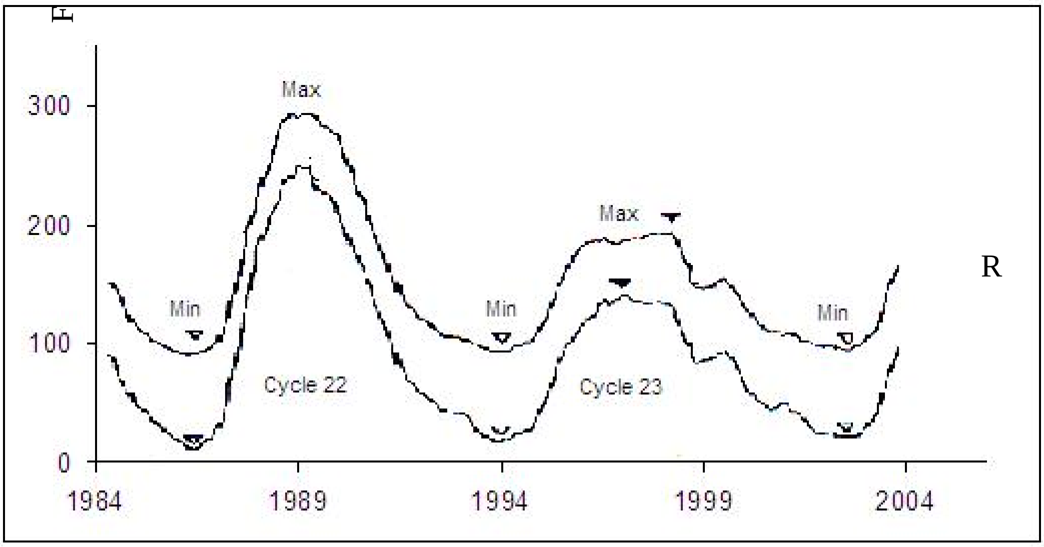


Figure 4: Smoothed monthly values of radio flux(F) at 10.7cm and smoothed monthly values of Zurich sunspot numbers(R) during solar cycle 22 and 23.

maximum of these two parameters have shown slight delay in the cycle 23, whereas in cycle 22 both the maximum coincide. The delay is maximum in cycle 23 is around 2 years. From figure 4, it is significant that these two solar activity indices, solar flux at 10.7cm and Zurich sunspot numbers, which is a composite quantity (R=1OG+N, where G presents number of sunspot Groups and N is individual sunspots), may behave differently near solar maximum. As we have shown the behavior of F and R during solar maximum and solar minimum for each cycle in figure 3a to 3d, that the behavior of F and R is not very linear during solar maximum, which suggest that the evolution of new sunspot groups increase the complexity of magnetic field in the solar atmosphere which influences the radio emission to emit non-linearly, i.e. emission of radio flux is powered by the evolution of new sunspot groups.

2.2. The amplitudes of solar cycles 22 and 23 in the three activity indices.

We compared the amplitudes of solar cycles 22 and 23 in relation with microwave flux at 10.7cm, Zurich sunspot numbers and flare activity index, which are produced at different layers in the Solar atmosphere and by different physical processes. Each of them reflects different physical conditions in the solar atmosphere. It has been established that odd numbered cycles are more active than the even numbered cycles. The present analysis is following the well-known G-O even-odd effect (Gnevyshev and Ohl, 1948), which is established on the basis of monthly averaged or smoothed Zurich sunspot numbers, where odd numbered cycles amplitudes are seen to be larger than the even numbered cycles amplitudes.

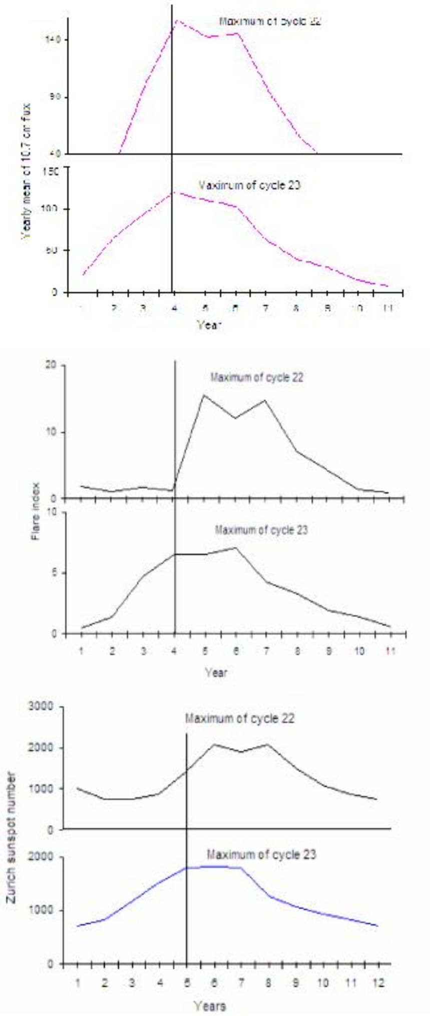


Figure 5: Show the amplitude variations of the solar cycle 22 and 23 (a) Zurich sunspot numbers (b) Microwave emission at 10.7cm and (c) flare activity index.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

Observation and analysis show that in the solar cycle 23 the sunspot groups are smaller and less complex compared to the solar cycle 22 and the flare activity shows very low values at the maximum of cycle 23 compared to the maximum phase of cycle 22. In figures 5.a-c, the comparisons of the amplitudes have shown for the cycles 22 and 23 in all the three activity indices. These figures show that there is a violation of G-O rule. The violation of the G-O rule is not a random phenomenon, but can be interpreted as the cause of the appearance of the declining phase of a longer solar cycle, i.e., may be 100 or 200 years solar cycle (Komitov and Bonev, 2001). As we have mentioned earlier that the observation shows slow growth of sunspot groups, and the complexity of the magnetic field is less in cycle 23 compared to cycle 22.

However, the flux at 10.7cm closely follows the number of sunspot groups, therefore, the radio emission shows very less growth in its intensity.

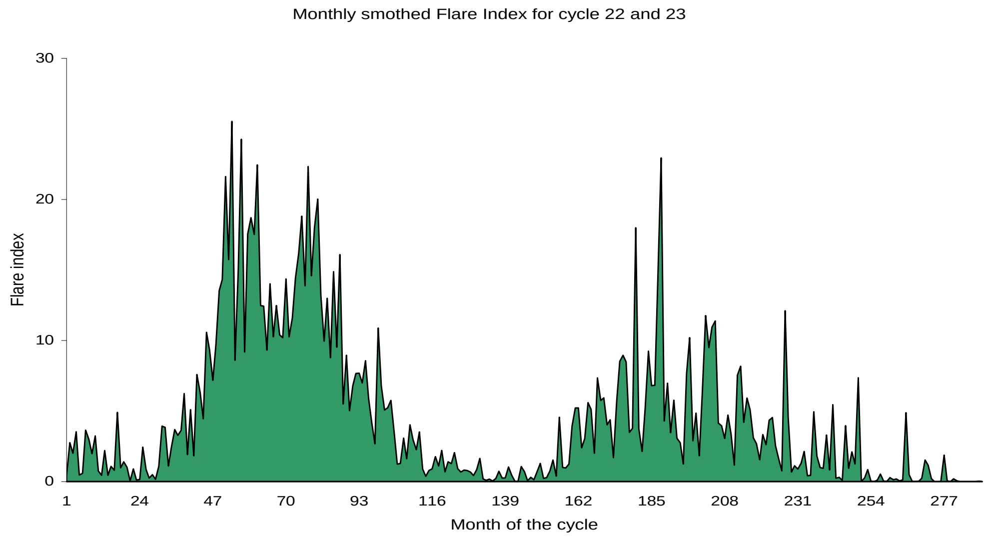


Figure 6: Show the monthly average value of M and X class flare during solar cycle 22 and 23.

There is another interesting feature observed in the flare activity index that the flare activity shows a very high maximum during cycle 22 compared to cycle 23, and the declining phase of the activity cycle 22 is more rapid than the declining phase of the activity cycle 23. Recently, Hathaway et at. (2003) reported that a deep meridional flow towards the equator is driving the current, and more importantly, the following cycle. During the time of increased amplitudes we would expect the short period cycles and during the time of decreased amplitudes, we would expect long period cycles as in cycle 23. In figure 6, we have shown the monthly averaged value of M and X class flares during the two solar cycles 22 and 23. From the figure it can easily be understood that solar flare activity suddenly goes to minimum level (in figure 6) in cycle 22 and there is gradual decrease in flare activity in cycle 23.

3. Discussions and Conclusions:

We have studied the solar cycles 22 and 23 in relation with solar activity indices such as radio flux emission at 10.7cm, Zurich sunspot numbers and flare index. The investigation carried out with the microwave emission at 10.7cm(2.8GHz) during the cycles mentioned above have demonstrated that microwave emission provides unique information required for the analysis and interpretation of energetic events. The observed microwave emission at various frequencies together with the sunspot numbers, sunspot groups and observed magnetic complexity can provide valuable information and interpretation regarding the amplitude and length of a solar cycle. The study of these activity indices can also be used as the precursor of the origin of solar activity variations such as convective flow of plasma material which influence the current as well as following cycle. The microwave observations with high time and spatial resolution can be used as valuable probes of the magnetic field and energetic electrons population of flares, particularly when used together with x-ray observations.

The studies of these activity indices provide the information of the progression properties (e.g. strength, length of the inclining and declining phase of the solar cycle, complexity of magnetic field, etc.,) throughout the solar cycle. Therefore, we can use these activity indices as an indicator for the long term i.e. 100 and 200 years solar activity variations. Recent research on the long term solar variability show that our epoch is at the onset of an upcoming minimum of the 100 years Gleissberg cycle (Bonev, Penev and Sello, 2004). Therefore, it can be expected that the ongoing solar cycle may be magnetically weaker than the previous solar cycle.

REFERENCES:

[1] Anderson, T.W., & Finn, J. D. 1996, in The New Statistical Analysis of Data, Springer-Verlag, New York
[2] Aurass, H., Hofmann, A., Vrs'nak, B., 2002, Solar Variabitlity: From Core to Outer Frontiers, ed. J Kuijpers, ESA Special Publication, 506, 423.
[3] Carmichael, H. 1964, in AAS-NASS Symp. on Physics of Solar Flares, pp. 451
[4] Carrington, R. C. 1859a, MNRAS, **19**, 81
[5] Forman, M. A., Ramaty, R., & Zweibel, E. G. 1986, in Physics of the Sun,Vol.II, ed. Sturrock, P. A., D. Reidel Publishing Company, pp. 249
[6] Gopalswamy, N. 1998, in Solar Physics with Radio Observations, NRO Report 479, pp. 141
[7] Gopalswamy, N. 2006, Sun & Geosphere, **1(2)**, 5
[8] Hudson, H., Fletcher, L., Khan, J. I., & Kosugi, T. 2004, in Solar and Space Weather Radiophysics, eds. Gary,D.E. & Keller,C., Astrophysics and Space Science Library, **314**, pp. 153
[9] Hudson,H.S.,Bougeret, J.,-L, & Burkepile, J.2006, Space Sci. Rev., **123**, 13
[10] Das Gupta and Basu, Nature, Volume 203, Issue 4945, pp. 626-627 (1964)
[11] Joshi, B., Pant, P., & Manoharan, P. K. 2006, A&A, **452**, 647
[12] Joshi, B., Manoharan, P. K., Veronig, A., Pant, P., & Pandey, K. 2007, Sun & Geosphrere, **1(2)**, 17
[13] Kundu, M. R. 1965, Solar Radio Astronomy, John Wiley & Sons
[14] Covington, 1954, Journal of the Royal Astronomical Society of Canada, Vol. 63, p.125
[15] Lin, J., Soon, W., & Baliunas, S. L. 2003, New Astron. Rev., **47**, 53
[16] Lou, Y., Wang, Y., Fan, Z., Wang, S., & Wang, J. 2003, MNRAS, **345**, 809
[17] Low, B. C. 2001, JGR, **106**, No. A11, 25141
[18] Manoharan, P. K., & Ananthakrishnan, S. 1990, MNRAS, **244**, 691
[19] Manoharan, P. K. 1993, Solar Phys., **148**, 153
[20] Waldmeier, M. 1961, Zurich: Schulthess
[21] Waldmeier, M. 1971, Astron. Mitt., Eidgen, Sternwarte Zurich: No, 304
[22] Webb, D. F. 2002, in From Solar Min to Max: Half a Solar Cycle with SOHO, **ESASP-508**, pp. 409
[23] Covington, Arthur E., Solar Physics, Volume 9, Issue 1, pp.241-245