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Solar Dynamo Model

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Abstract: ***Sunspots shows vortex structure & are approximated by SLVs (single layered vortices) at solar minima &MLVs (multi layered vortices) at solar maxima. Rolling magneto convection and rotation associated with the sunspot vortex is responsible for the dynamo action in it. The sunspot vortices in growing or decaying stage participate in meridonal circulations while moving in magnetically quantised solar latitudinal belts .This results in net variation in solar magnetic field and thus solar minima and maxima. The sun spot area (SSA, i.e. visible area of sunspot on photosphere) shows delay with respect to composite total solar irradiance (CTSI). Solar magnetic field (B) is cause of delay. Delay is maximum at solar minima & minimum at solar maxima. Poloidal component of magnetic field (B_P) delays while toroidal component of magnetic field (B_T) enhances the solar energy transportation. Over a period of 3 solar cycles, the analysis shows that wrt CTSI, SSA shows a delay of 13.5 days at solar maxima and 230 days at solar minima.***

Keywords: sun, rolling magneto convection &solar dynamo, SLV, MLV, sunspot, delay

Theory

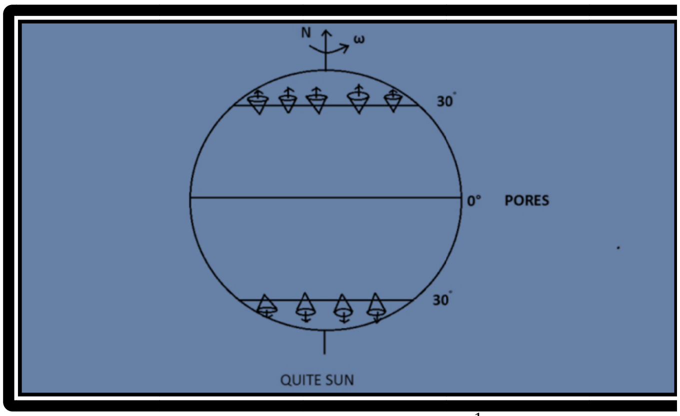

Figure 1: Sun at solar minima[1]

Sunspots appear as pores (figure 1) during solar minima (quite sun) at the higher latitudes. As they grow, slowly migrate towards the solar equator. Usually in 5 to 30 degree solar latitude sunspot activity is seen. When they move on visible solar surface (i.e. photosphere), it appears as if they are participating in a meridonal drift.

2.1 ROHINIVortex model of sunspot & magneto convection (magneto convective vortex model):

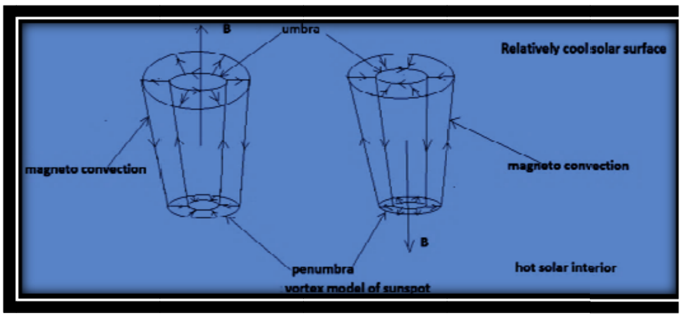

Figure 2: ROHINI vortex model of sunspot

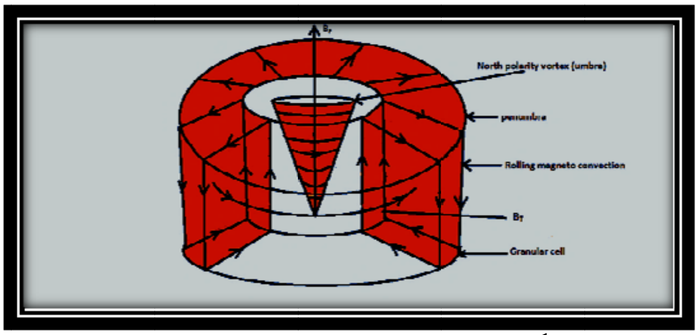

Figure 3: North polarity vortex (umbra)[1]

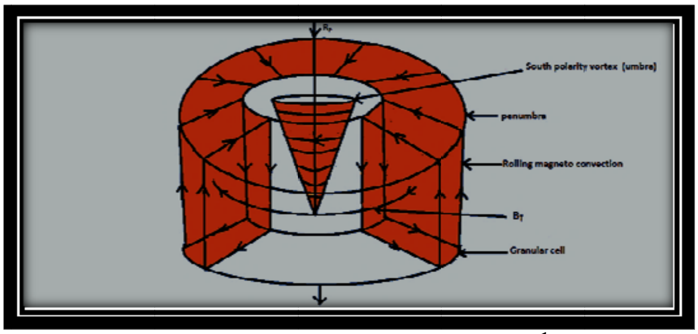

Figure 4: South polarity vortex (umbra)[1]

A pore slowly develops an umbra with a draining umbral tube associated with it. Poloidal magnetic field (B_P) appears along its axis because of the spiraling of (up / down) hot plasma in the umbral tube. The draining through umbral tube results in to convective currents surrounding it, which tries to rise the drained plasma from lower end of the umbral tube to the upper end in the area surrounding it .Convective currents in turn gives rise totoroidal magnetic field (B_T) which tries to bind all convective cells (fig 3,4). These two processes can be together called as **magneto convection.** As growing umbral tube experiences differential rotation at different depths of solar atmosphere it attains a conoidal shape, thus results in to a vortex(fig 2).The plasma in the convective currents looks like as if rolling when viewed from the top. Hence this can also be called as **rolling convection (fig 3, 4, 5).**The area surrounding umbra consisting of convective cells can be called as penumbra.

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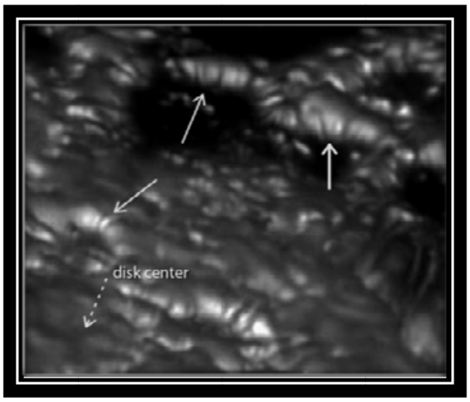

Figure 5: Pores in active regions with rolling convection. Over turning motions with down flows are visible in bright edges at the limb side of the pores[1]

The **rolling magneto convection** in turn gives rise to toroidal magnetic field (B_T) which binds together all convective cells. Thus a north polarity (fig 3) and south polarity (fig 4) vortices develops. A completely matured vortex will have a central umbra with an umbral tube associated with axial poloidal mangetic field (B_P),a penumbra with convective cells arranged around the periphery of umbra with toroidal magnetic field (B_T) binding them together(fig3 & 4).such a structure can be called as a **sunspot or sunspot vortex**. These vortices further gets coupled with other developing vortices and thus results in to a **group sunspot**.

2.2 Solar Dynamo-Rohini Model

Babcock model talks about a surface dynamo which very effectively explains formation of bipolar sunspots. **DibyanduNandi** model talks about a meriodonaly drifting sunspots which tries to explain the occurrence of solar minimas and maximas, long standing silent solar minima etc. **ROHINI model** talks about sunspot vortices and related dynamo action, quantised magnetic field belts, meridonal circulation and occurrence of solar minima & maxima. Sunspot vortices originate at higher latitudes. While growing they slowly migrate towards equator. They not only grow area wise but also volumetrically. As a result the vortex length increases. While it spreads areawise on photospheric surface it fetches more and more hot plasma from solar interior by means of rolling magneto convection which in turn producestoroidal magnetic field (**B_T**). While migrating the vortices has to spin/rotate. This rotating motion of vortex makes the hot plasma within the vortex to rotate about the axis of vortex. This results in to generation of poloidal magnetic field (**B_P**) along the axis of the vortex. Thus each vortex acts like a tiny solar dynamo which converts electric field to magnetic field.

2.3 Meridonal circulation and volumetric growth of vortex

The journey of vortex starts from higher latitudes at solar minimum. These tiny dynamos can be called as SLV's (single layered vortices) which are nothing but localised plasma vortices under rotation producing magnetic field (B_P) along the axis of the vortex. Thus dynamo action is set in. While growing volumetrically these SLVs spin & migrate towards solar equator such that every spin adds one layer. Thus those vortices near the solar equator can be called as MLV's (multi-layered vortices).

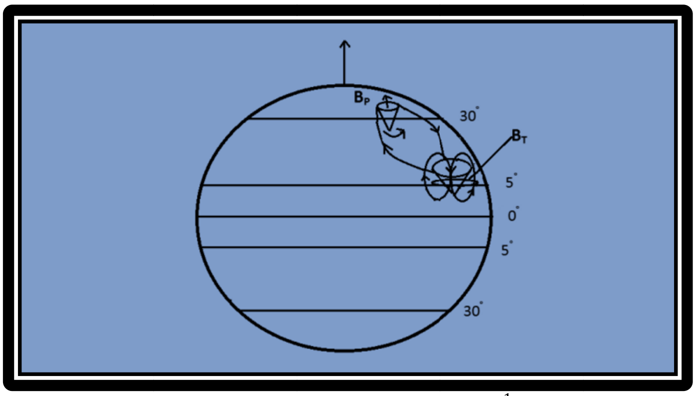

Figure 6: Field flipping in a vortex [1]

SLVs have a magnetic field oriented along its axis ,ie.poloidal field(B_P).During solar minima poloidal magnetic field dominates . SLVs are oriented such that their axis are parallel to solar north-south axis.The net solar magnetic field is sum of all such poloidal fields produced by sunspot vortices in form of SLVs.Thus at solar minima magnetic field is given by,

i.e. $\mathbf{B= B_{P\ max}=\sum_i B_{Pi}}$ **(1)**

Where i is the vortex (i.e. SLV) index number as MLVs dominate during solar maxima & solar magnetic field is toroidal in nature during solar maxima it implies that MLVs should produce toroidal magnetic field .Thus during a change from solar minima to maxima SLVs gets converted to MLVs with a flip of magnetic field from poloidal to toroidal. This requires a structural & orientation changes in sunspot vortex as shown in fig7.

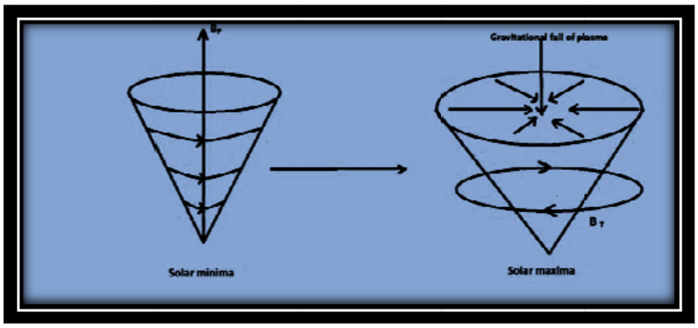

Figure 7: Poloidal to toroidal field conversion- Gravitational collapse[1]

The net solar magnetic field during solar maxima will be

i.e. $\mathbf{B=B_{T\ max}=\sum_k B_{Tk}}$ **(2)**

Where k is index number of individual MLVs producing toroidal field due to gravitational collapse (figure 7). During the period between solar maxima and minima, Total solar magnetic field (B) will be

$\mathbf{B_j=\sum_i B_{Pi} + B_{Tj}}$ **(3)**

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At j thtoroidal ring Such that

$$\mathbf{B} = \sum_j \mathbf{B}_j = \sum_j \left(\sum_i \mathbf{B}_{Pi} + \mathbf{B}_{Tj}\right) \quad (4)$$

Where i is the vortex index number, j is the toroidal ring index number. In eqn (3) first term takes in to consideration the contribution by individual SLVs which still donot form toroidal field ring, Second term takes in to consideration the contribution of j thtoroidal ring formed by SLVs.

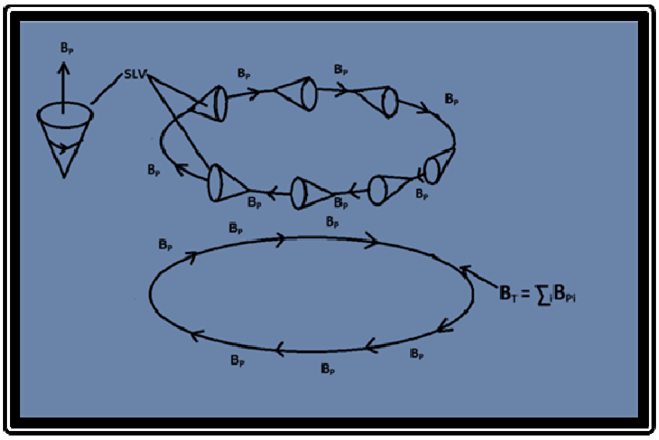

Figure 7A: SLVs flipping to form toroidal ring

If SLVs completely participate in formation of quantised toroidal magnetic field ring (fig 7A) then

$$\sum_i \mathbf{B}_{Pi} = \mathbf{B}_{Tj} \quad (5)$$

Where j is the toroidal ring index number such thatthe total magnetic field will be

$$\mathbf{B} = \sum_j \mathbf{B}_{Tj} \quad (6)$$

ThusSLVs slowly gets converted to MLVs while drifting from pole to equator. While drifting the poloidal magnetic field (associated with SLVs along their axis) rearrange such that a closed magnetic field ring (i.e. toroidal magnetic field) is created. Thus quantised magnetic field rings are produced at different latitudinal levels. SLVs jump from one such level to another viameridonal longitudinal wise circulations which drifts the SLVs towards the equator while they get converted to MLVs(fig8).When sunspots are observed they appear as if drifting along the longitudes on photospheric surface of sun. This longitudinal drift is nothing but jumping from one quantised magnetic level to another. The volumetric growth of SLVs automatically changes their poloidal field magnitude such that SLVs jump to next quantised magnetic level. Thus each quantised level decides the size of SLVs, their poloidal field magnitude.

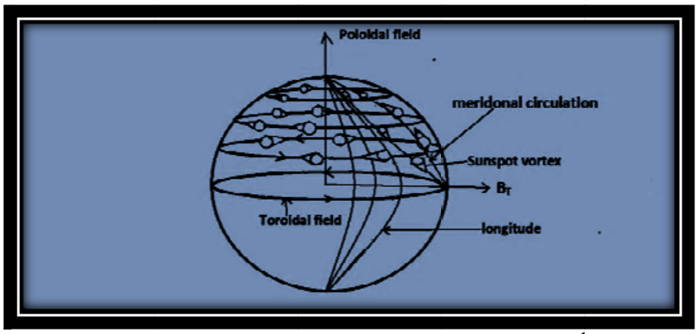

Figure 8: Meridonal circulation and toroidal field[1] (ROHINI MODEL)

As SLVs grow length of vortex increases, they fetch more and more energy from solar interior by means of sustained convection. Which implies that lower tapering end of the SLVs must point towards hot solar interior while broader end appears on the relatively cooler photosphere. The length of the vortex will be maximum at solar maxima. When SLVs gets completely matured (i.e. MLVs created) & reaches quantised solar latitude belt near the equator they gets rearranged such that their tapering ends points towards hot solar interior while broader end towards solar exterior with convective currents. As a result the toroidal field ring breaks and individual toroidal rings appear around each MLV binding together all magnetoconvective cells (fig 8A).

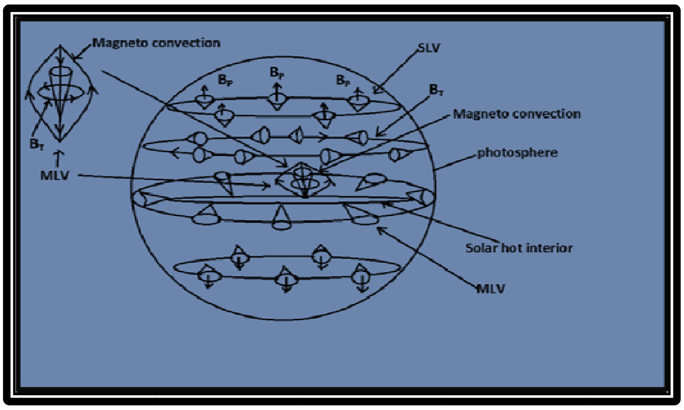

Figure 8A: Flipping of SLV's and formation of MLV's2.4 Magneto convection and delay

Because of magneto convection MLVs can fetch & deliver very easily solar energy from solar interior layer to exterior layer. Hence energy flows without any delay. As SLVs do not show any magneto convection they delay the energy transportation. Hence during solar maxima, maximum energy is transported compared to solar minima.

If this fact is correct ,the solar data should show the above trend i.e. at solar maxima, solar energy transportation is without delay while during solar minima with delay wrt sunspot appearance .Keeping this in mind an analysis of solar data is done for 3 solar cycles 21,22,23 and indeed a delay is observed between the appearance of sunspots and composite total solar irradiance(CTSI).The 27day averaged data shows that the delay is maximum(230 days) at solar minima while it is minimum (13.5 days)at solar maxima.

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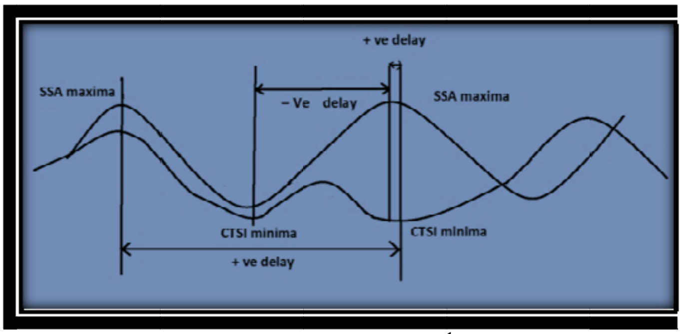

Figure 9: Delay analysis[1]

As MLVs transport maximum solar energy it implies that rolling magneto convection associated with MLVs is in such a direction that it favourably releases heat radiations (i.e. solar radiations) with respect to receiving agent/observer such that the delay between release and receiving of radiations is reduced. Thus ROHINI MODEL very clearly explains the conversion of the poloidal magnetic field to toroidal magnetic field when sun passes through solar minimum to maximum phase. During solar maxima energy transportation is maximum as compared to solar minima. As toroidal field is maximum at solar maxima and poloidal field is maximum during solar minima it implies that toroidal magnetic field is favourable for solar energy transportation compared to poloidal field. As population of MLVs are more at solar maxima MLVs favour energy transportation compared to SLVs. Thus SLVs delays energy transportation compared to MLVs.

Method

The data for daily values of SSA, CTSI, B for 3 solar cycle 21, 22, 23 are down loaded from URLs cited in data reference section. A composite database of above 3 parameters without data gaps is prepared.27day averaged data of above 3 parameters (27SSA, 27CTSI, 27B) are used in the analysis. Simultaneous graphical analysis of 27SSA, 27CTSI reveals the fact that 27SSA shows delays w.r.t. 27CTSI.The delayed events are identified& their corresponding values of 27SSA, 27CTSI, 27B are tabulated and further subjected to analysis.

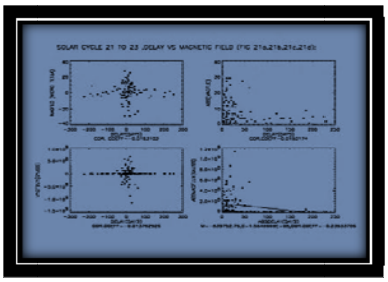

Figure 10: a, b, c, d: Solar magnetic field vs. delay

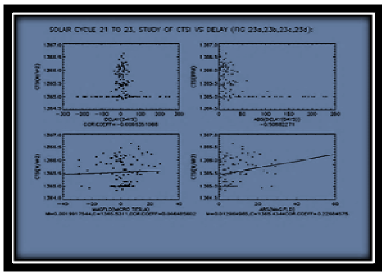

Figure 11: a, b, c, d: ctsi vs. delay

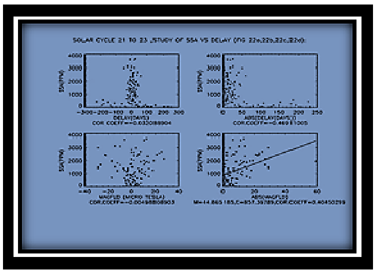

Figure 12: a, b, c, d : SSA vs. delay

In fig10a solar magnetic field (B) and delay are anticorrelated (corr.factor-0.0193102) implies increase in B decreases delay and vice versa. South and north polarity sunspot vortices show the same property. Negative delays show the growth phase while positive delay shows the decay phase of sunspot vortex. If ABS (B) is studied as function of ABS (delay) (fig10b) the correlation factor rises to 0.0150174.II am trying improvement of correlation is an indication of the fact that magnitude of delay depends on magnitude of B not on its direction. Delay is minimum for maximum value of B.ie rise of B reduces delay. In fig 11a & b behaviour of CTSI (solar energy received at 1AU distance from sun in form of electromagnetic radiations/waves) resembles that of B in fig 10 a and b. Hence it implies that for minimum delay solar energy received is maximum with maximum magnetic field B.

In figure 12a & b behaviour of SSA resembles that of B (in 10a&b) & CTSI (in 11a&b)which implies that for minimum delay sunspot vortices will have maximum facial area(sunspot area seen on photosphere) with maximum magnetic field B which enables maximum transportation of solar energy. Hence solar magnetic field (B) developed is of special type which enhances or favours energy transportation in form of electromagnetic solar radiations (i.e. heat radiations) in a direction perpendicular to solar north-south polar axis. The direction of energy propagation decides the plasma flows around the vortices. As maximas in fig 10, 11, 12 are located near solar maxima the sunspot vortices are in MLV state producing toroidal magnetic field (B_T) around itself. As net solar field at solar maxima is sum of individual B_T (equation 2), the enhanced energy transportation is due to toroidal magnetic field. As magneto convection is the mechanism which produces toroidal magnetic field, hence study of delay gives an idea about appearance and disappearance of magneto convection.13.5 day delay is produced MLVs While 230 day delay is produced by SLVs. Hence 13.5days is required to send solar energy to 1 au distance by MLVs at solar maxima while 230 days for SLVs at solar minima

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from sun. Also delay is an indicator of life span of SLV and MLV.

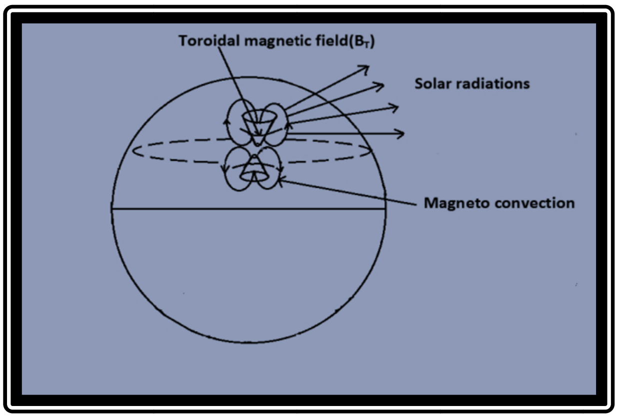

Figure 13: Toroidal magnetic field and solar radiations 4

Conclusions

1. Sunspots are approximated by vortex model
2. Sunspots appear as SLVs at higher latitudes and develop into MLVs while migrating towards solar equator.
3. SLVs show poloidal magnetic field while MLVs show toroidal magnetic field.
4. SLVs delays while MLVs enhances solar energy transportation.
5. SLVs develops into MLVs by circulating in magnetically quantized orbits and participating in meridonal circulation
6. The quantised magnetic orbits split in to individual orbits around each MLV when they are near to solar equator.
7. Delay is an indicator of life span of vortices i.e. SLV at solar minima & MLV at solar maxima.

Reference

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Data Reference

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1978-PRASENT (01/10/2003), COMPILED BY C.FROHLICH AND JEAN URL USED is ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_IRRADIANCE/composite_d25_07_0310a.dat

b) Solar SSA database

ftp://fenyi.solarobs.unideb.hu/DPD/data/1)16/11/1978 to 31/12/1982 Greenwich daily data
URLS used are
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1978.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1979.sum
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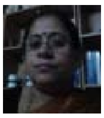
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1981.sum
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_REGIONS/GREENWICH/DAILY/1982.SUM
2) 01/01/1983 TO 31/12.1985 data not available3) 1986-2002 DPD DAILY DATA
URL used is ftp://fenyi.solarobs.unideb.hu/DPD/data/

c. Solar magnetic database

URL used is ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUN_AS_A_STAR/STANFORD/STANFORD.PLT

Author Profile



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