Online Solar Databases at NGDC – RSTN Solar Radio Databases

Helen E. Coffey and Edward H. Erwin
NOAA National Geophysical Data Center E/GC2
325 Broadway, Boulder, CO 80305
Helen.E.Coffey@noaa.gov

The NOAA National Geophysical Data Center (NGDC) Website http://www.ngdc.noaa.gov provides access to a number of Space Weather databases, including the USAF Radio Solar Telescope Network (RSTN) solar radio fixed frequency and spectral data. Reduced data listings of solar radio events are available, as well as the noon values of the solar radio flux at eight fixed frequencies (see ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO). Also, the original one second data for both fixed frequency and spectral data (25-75 MHz, and more recently 25-180 MHz) from the four worldwide stations are available for downloading and plotting. Daily fixed frequency data files average 2.4 megabytes (75 mb/month). Daily spectral files average 13.4 mb (or 415 mb/month). Software to view the solar radio spectral (SRS) data, developed by John Kennewell and colleagues at Learmonth Solar Observatory, is available for download from the NGDC ftp site (see ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/SPECTRAL_RSTN). Future plans include an online interactive plotting capability. The SPIDR system allows for plots of the fixed frequency data (see http://spidr.ngdc.noaa.gov). These solar radio data can be used to investigate the activity in the Sun’s corona and its effects on the Earth’s environment. Tables of solar radio events are in the monthly report Solar-Geophysical Data (SGD) now available in PDF format at http://sgd.ngdc.noaa.gov. The NGDC website also includes educational links.

Introduction

We continue to develop web pages for the NGDC SOLAR_DATA ftp site, as requested by the recent NRC Panel Review. For this meeting, a web page for the solar radio ftp site was developed describing 6 databases-http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarradio.html. These databases include

1.) Listings of solar radio bursts monitored at fixed frequencies by the worldwide community, (1960-present),

2.) Penticton (1947-present) daily noon solar radio flux at 2800 MHz and USAF 8 fixed frequencies between 245 and 15,400 MHz, (1966-present),

3.) IAU QBSA daily solar radio noon flux values from 55 stations 1949-1986 (722 station-years, 16.6 Mbytes),

4.) USAF RSTN one second data at 8 selected frequencies from 4 worldwide sites, (1980-present),

5.) Solar radio spectral event listings 1967-present from worldwide stations, and

6.) USAF RSTN solar radio spectral three second data from 4 worldwide stations (Learmonth, Holloman, San Vito, and some Palehua, 2000-present), with viewing software.

We focus on the availability of the USAF RSTN data here.

Scientists monitor the structure of the solar corona, the outer most regions of the Sun's atmosphere, using radio waves -- the surface of the Sun is 6,000 degrees Kelvin, while the high corona can reach several million degrees Kelvin. Solar radio emissions at different frequencies allow us to observe radiation from different heights in the atmosphere. The lower the frequency is, the higher the height of origin. The frequency, like the electron density, decreases uniformly outwards: 245 MHz originates high in the corona, while 15,400 MHz originates in the low corona. The 5 MHz emission corresponds to about 10 solar radii height. For a detailed review, see McLean and Labrum (1985) SOLAR RADIOPHYSICS.

Radio bursts are associated with solar flares. The delay at Earth of the different radio frequencies during burst events is due to the outward movement of the source. Bursts can have temperatures of 10xE12 degrees Kelvin. Large bursts last 10 to 20 minutes on average. Longer radio noise storms of persistent and variable high levels of radiation originate in sunspot groups, areas of large, intense magnetic fields. These storms are strongly circularly polarized due to the intense magnetic fields.

USAF RSTN Solar Radio Fixed Frequency Data

The USAF RSTN network monitors 8 fixed frequencies – 245, 410, 610, 1415, 2695, 4995, 8800, and 15400 MHz. NGDC holds archive digital data for Learmonth 1980-present, Palehua 1982-2000, Sagamore Hill 1981-present, and San Vito 1986-present. Early data are available via a Tivoli library system – see the file rstn_tape_catalog_revised for available data. Mr. Ed Erwin transferred all these data from 9 track and 3480 tapes to the Tivoli system for easier access. Requests can be handled quickly now. Previously it was difficult to process the alpha-numeric coded tapes received from the USAF. NASA SPDS funded a software consultant to rewrite the decoding software, making it easier to process the data. All data are now in ASCII format. NGDC also holds paper recordings of fixed frequency and spectral data for the years 1977-1993. Documentation about the monitoring instruments is available online – see file RSTN.DOC and RSTNDecodingNotes.pdf.

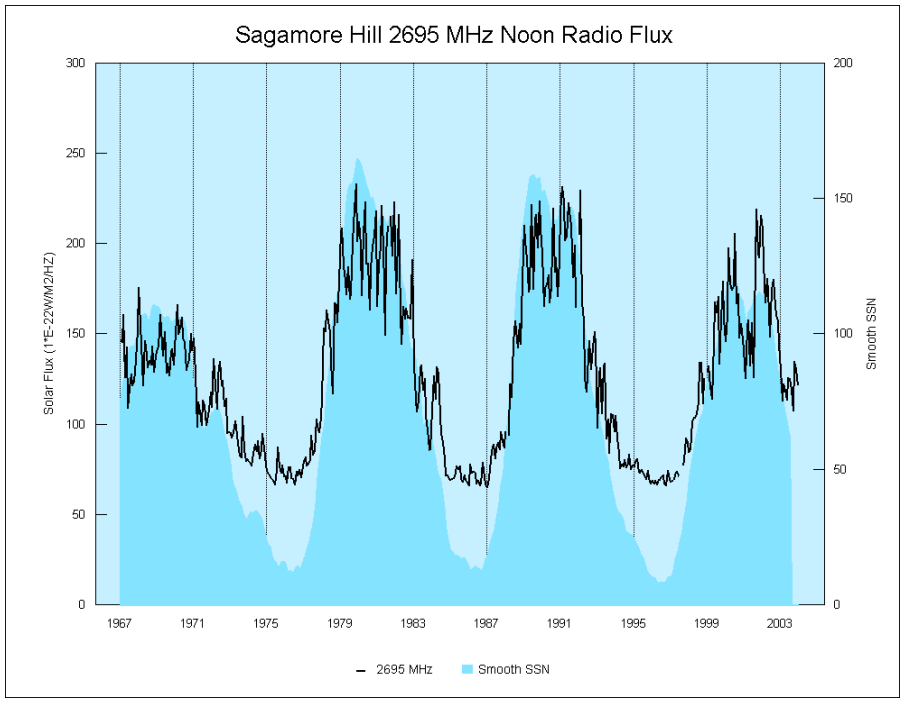
Digital one second data files for recent years are available on the NGDC ftp site, as well as in the SPIDR system. There are two cautions for users of the data. At times, the recording computer monitoring the fluxes had to be corrected for timing delays. This results in overlapping times. The raw data files on the ftp site are not corrected for this and users

must handle the problem as best suits their needs. The SPIDR data are corrected by simply dropping the overlap time values. A second timing problem exists in some data 1999-2001, a period when the fluxes were recorded in the time unit of number of seconds from January 1, 1970. Data at this time were plotted for the real time Soltech user using the flux deviation from a baseline level. A computer program by John Kennewell recalculates the correct time, taking into account changes in the Microsoft operating system. Learmonth data are corrected for this. Other station's dates were calculated from the number of seconds from January 1, 1970. These data will be run through the Learmonth software to include the additional time corrections. The online files are available at ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/RSTN_Radio_Solar_Telescope_Network_1second_data.

Reduced burst reports and **daily flux values** from each RSTN station are sent by the USAF sites in real time to the NOAA Space Environment Center (SEC). After 30 days these data are sent to NGDC for archiving. NGDC has computer programs that reformat and quality control these reports. Preliminary reports are deleted and only final reports are kept. Other checks on the database include deleting duplicate data reports, and flagging errors in different fields of the reports, e.g. erroneous frequency, alpha character in numerical field, etc. The data are combined with other station reports from the worldwide network, and a bracketed table of events is published in the monthly report SGD. The online files are available at ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/BURSTS.

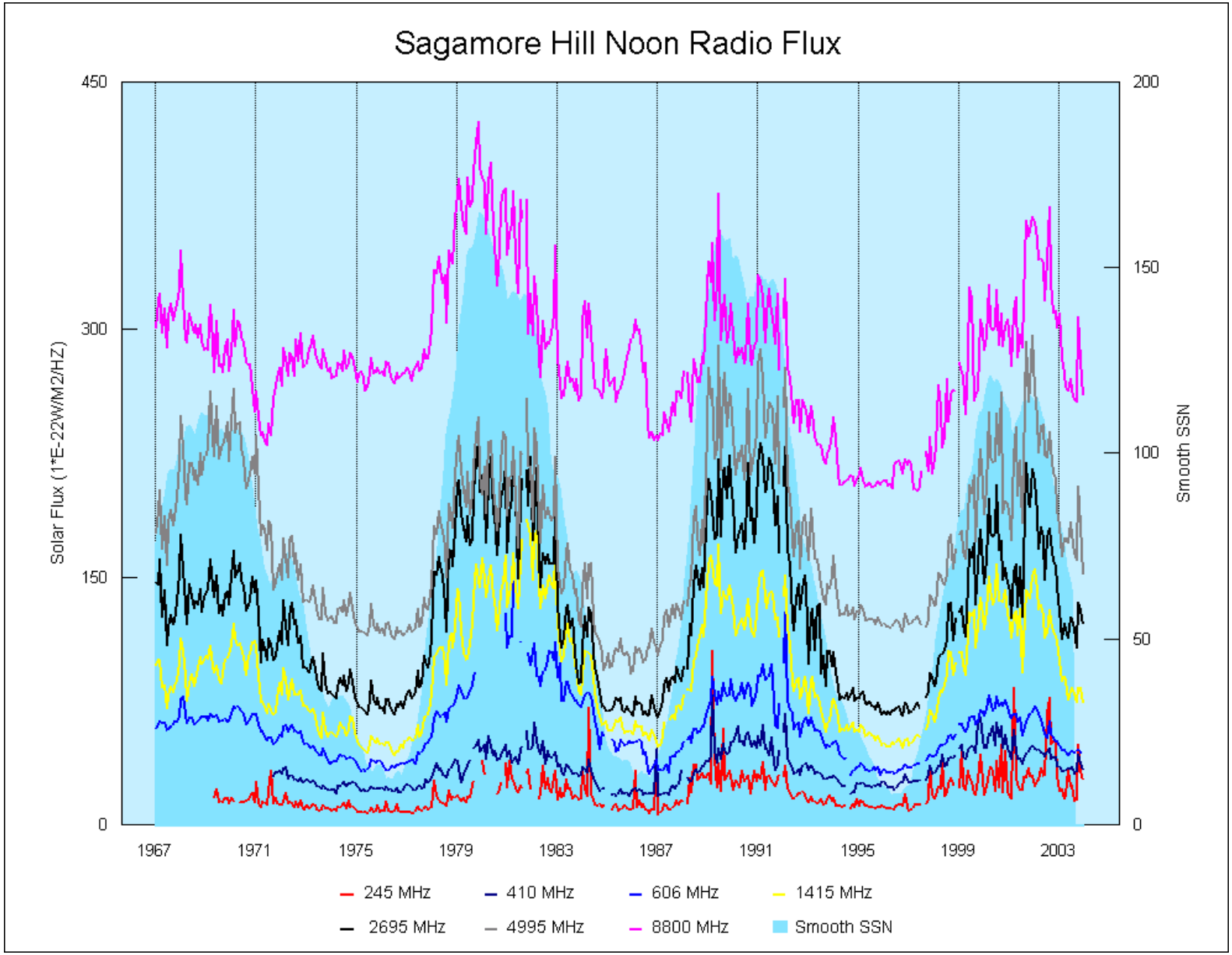
Files of the noon values from Learmonth (1988-present), Palehua (1988-present) Sagamore Hill (1966-present) and San Vito (1988-present) are available at ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/FLUX/USAF_NOON_FLUX, and via the web page. The microwave wavelength 2800 MHz daily radio flux correlates

highly with the daily sunspot number and the two databases are used interchangeably. A plot of the Sagamore Hill daily Noon 2695 MHz Radio Flux 1966-2003 and the smoothed sunspot number is shown here.



The 2800 MHz, or 10.7 cm, responds to the same conditions that produce changes in the visible and X-ray wavelengths. Schmahl and Kundu (1995, 1997) find that the solar radio fluxes in the spectral range 1000-9400 MHz correlate well with the total solar irradiance. The intermediate frequencies (at 2800 and 3750 MHz) are produced mainly by free-free gyroresonance emission from sunspot structures, while 1000 and 9400 MHz flux are produced mainly by free-free processes from structures associated with plages. They can distinguish plage-associated emission from spot-associated emission in the time series of microwave flux. Both contribute opposing effects on the total solar irradiance.

A plot of the Sagamore Hill daily Noon Radio Fluxes for 7 frequencies for 1966-2003 is shown here.



Solar Radio Spectrograph (SRS) Data and Viewer -- Documentation

The RSTN solar radio spectrograph (SRS) sweeps the frequency range 25 to 180 MHz every 3 seconds. It monitors solar radio emissions originating mainly in the solar corona. It has a low band (25 to 75 MHz) antenna (non-tracking semi-bicone) and a high band (75 to 180 MHz) antenna (tracking log-periodic). Digital data files on CD-ROM are sent monthly to NGDC (WDC Boulder) since 2000 from Holloman, Learmonth, and San Vito. Digital data are also available from Palehua. Sagamore Hill maintains paper records of SRS data. NGDC holds paper recordings of fixed frequency and spectral data for the years 1977-1993. Event listings for the worldwide network are online, covering the period 1967 to present at ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/SPECTRAL.

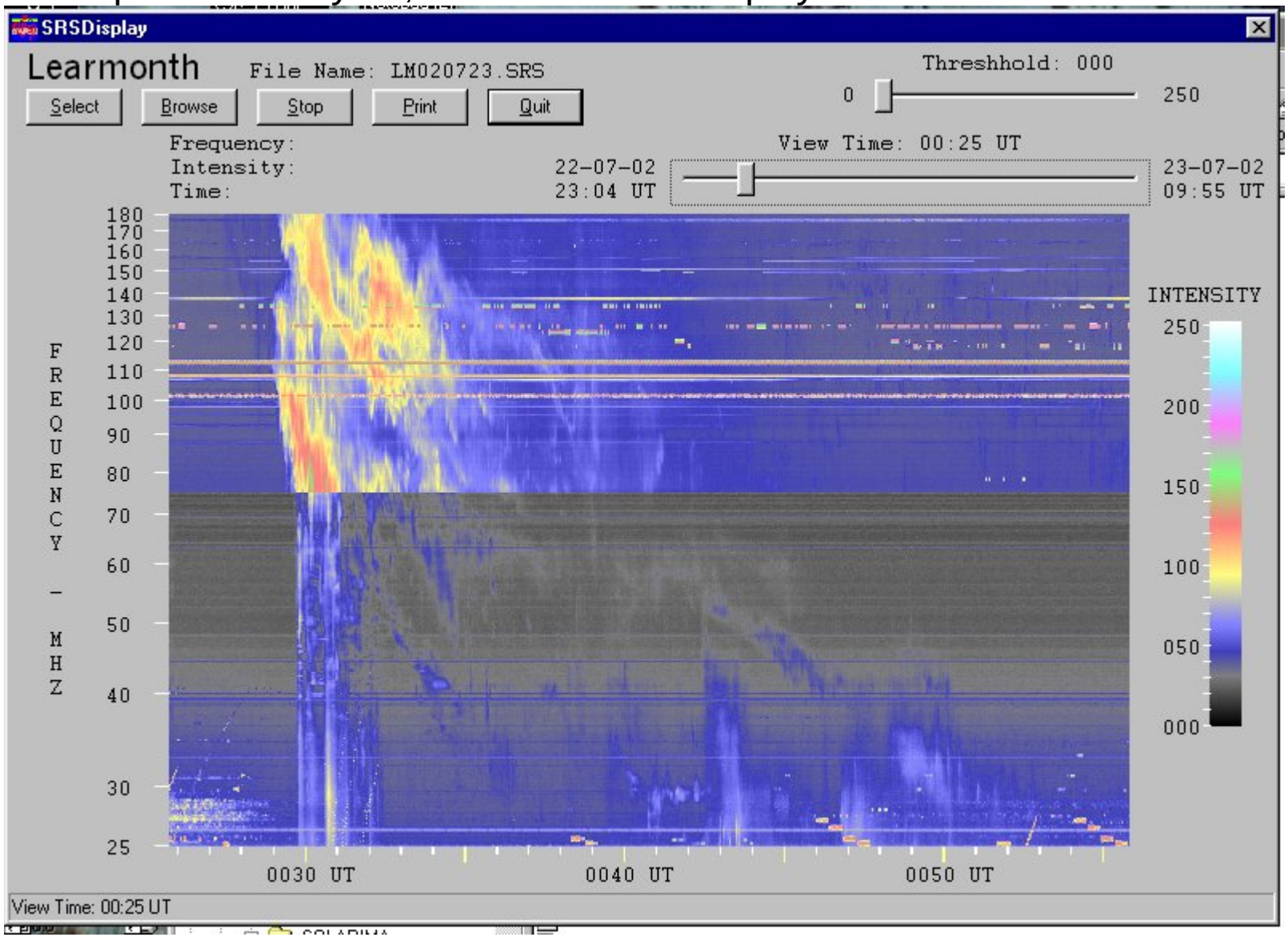
For specifics on the format of the digital SRS archived data, please see the documentation file Srsdispl.doc written by John Kennewell and Graham Steward, IPS Radio and Space Services, Learmonth Solar Observatory, Australia. The file Srsdispl.doc includes a description of the SRS, the format of the SRS archived data, SRSDisplay – an SRS Data Viewer, and a short course in data interpretation. The software and documentation files are available on the NGDC ftp site, along with the data.

Software (SRSDisplay.exe) is available to view the SRS daily data files. The viewer code was developed by Graham Steward, and documentation is included in the Srsdispl.doc file. The executable file runs on a PC, under Windows 95, 98, or 2000 Microsoft Windows operating systems. The viewer generates plots of 25-180 MHz on the y axis versus UT day on the x axis. After selecting the day file of data, the viewer lets you automatically step through half hour increments of time with its browse capability. It allows you to stop at any place, make prints, and move a pointer to any specific time of interest. One can also calculate the shock speed of a type II burst by selecting either the fundamental or the

harmonic signature of the burst and clicking 4 or more points along the type II bottom edge. A screen pops up giving the shock speed and regression fit correlation, with a plot of R/Rs (height in fractional solar radius) on the y axis and time (sec) on the x axis. It lists the fundamental or harmonic shock speed, the regression correlation coefficient, and the extrapolated time of the event at the photosphere (assuming a constant velocity projected backwards in time). One can also change the intensity threshold (color coded) from 0 to 250 to view the plot with higher intensity fluxes only.

A PowerPoint presentation (SRSData.ppt) “SRS Data Examples” by Kennewell and Steward shows samples of some types of radio emissions observed on the Solar Radio Spectrograph. Typical non-solar signals that might be seen include pagers, satellite transmissions, FM stations, aircraft communications, ionosondes and CB transmissions. Samples are shown of local interference like machinery and lightning discharges. Meteors are seen as echoes from distant transmitters, often in the FM band. At the beginning of each day, the SRS system automatically performs a self calibration, seen as a sequence of vertical bars. The most common type of radio signal produced by the Sun is the type III (fast drift) solar radio burst – see sample. Type II (slow drift) solar radio bursts are much less common and indicate major eruptions on the solar surface. The velocity of the burst can be determined from these views, using models of the propagation of the disturbance through the solar atmosphere – the Srsdisp.exe software uses Gordon Newkirk’s original model of coronal electron density. Man-made signals are usually narrow horizontal lines, while solar signals are wider vertical or sloping structures.

A sample of the July 23, 2002 SRS data display for Learmonth is shown here:



In his summary, Kennewell notes that the SRS displays are useful for the study of solar radio bursts, but can also be used in studies of ionospheric radio propagation and in other fields.

SUMMARY

The NGDC ftp site and SPIDR web give access to a number of different solar radio databases. These data can be downloaded for use in research efforts. The data include radio burst events, fixed frequency noon values, fixed frequency one-second data, spectral event listings, and three-second spectral data files. A viewer for the 3-second spectral files is available, along with descriptive texts. The web page link for all these data is http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarradio.html.

Acknowledgements

We acknowledge with gratitude all of the stations contributing valuable data to the scientific community. The RSTN data originate at several USAF monitoring stations. Dr. John Kennewell and Graham Steward, IPS Radio and Space Services, Learmonth Solar Observatory, Australia, contributed SRS documentation and a PowerPoint presentation that describe the data and how to interpret them. NASA SPDS funds enabled us to have a computer consultant rewrite the decoding software for the original fixed frequency data. Ed Erwin converted much of the fixed frequency data to an ASCII format. NOAA ESDIM funds funded the conversion of the early daily noon flux data from paper copy to digital form. Finally, we acknowledge the continuing cooperation of the USAF with NOAA to bring these valuable data to the user community.

References

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