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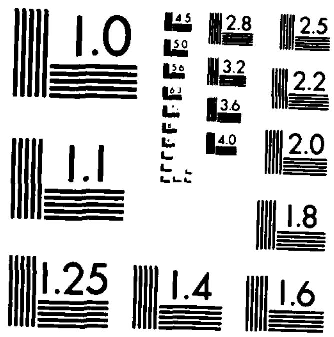
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A COMPARISON OF FOF2 BASELINES FOR USE IN STUDYING THE EFFECTS OF SOLAR ULTRAVIOLET IRRADIANCE ON THE F2 REGION OF THE IONOSPHERE

THESIS

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THESIS

Presented to the Faculty of the School of Engineering

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Steven F. Waiss, B.S.

Major, USAF

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Steven F. Waiss

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Glossary of Terms

F2 region. The F2 region is the region of the ionosphere that lies between approximately 250 and 1000 kilometers during the daytime. The nighttime base of the F2 region can be as low as 150 kilometers. The ionosphere is that part of the earth's upper atmosphere where ions and electrons are present in quantities sufficient to effect the propagation of radio waves (Glasstone, 1965:486).

Ultraviolet(UV) Wavelength Range. The wavelengths of UV range from long wavelength UV starting at 380 nanometers(nM) (3800A) down to short wavelength UV stopping at .8 nM (8A). The shorter wavelengths of UV are often referred to as soft X rays.

Parameters of the F2 Region. For the purpose of this study, the parameters of the F2 region are foF2, M(3000)F2, and Hmax.

foF2. foF2 is the critical frequency of the F2 region. The highest frequency of a vertically incident signal so returned by each of the regions of the ionosphere is called the critical frequency for that region. foF2 is the highest frequency returned to earth by the F2 region. Radio frequencies lower than foF2 are reflected back to earth or back to space. Frequencies greater than foF2 can be transmitted to space or can penetrate the atmosphere to reach the earth's surface (Manley, 1981:11; Rishbeth and Garriott, 1969:51-55).

M(3000)F2. The maximum-usable-frequency factor (M factor) is the ratio of the maximum usable frequency (MUF) to the critical frequency of the region. The ionosphere is assumed to be concentric with the earth and radio propagation takes place along a great circle path. The maximum frequency that will bounce once off of the F2 region and travel a great circle ground distance of 3000 kilometers is called MUF(3000). M(3000)F2 then is the ratio of MUF(3000) to foF2 (Manley, 1981:15; Davies, 1965:171).

Hmax. Hmax is the height of the ionosphere at which the peak electron concentration of the F2 region occurs (Rishbeth and Garriott, 1969:152).

10.7 cm flux. 10.7 cm flux (or 2800 MHz flux) is a continuously monitored indicator of solar activity. This quantity is the measured irradiance of solar radio emission at a wavelength of 10.7 cm (Rishbeth and Garriott, 1969:232).

Abstract

This study determined if one or more representations of a baseline foF2 are statistically more accurate than others in representing a background foF2 for studying the effects of solar UV irradiance on the F2 region of the ionosphere. Event days for comparing baselines were determined from satellite recorded UV bursts. Observations from an ionosonde close to local noon at the time of the UV burst were used for foF2 values. Eight baselines were rank ordered against the hourly foF2 values for the event day using eight methods of comparison.

The rankings were statistically analyzed using both parametric and nonparametric methods. Using parametric methods, only one baseline was found to be statistically worse than the others. Using nonparametric methods, baselines based on the lower quartile median and the means of the hourly values of the ten quietest days of the month using the Kp scale were found to be statistically better than four of the baselines. However, no statistical difference could be found between these two baselines and the currently accepted baseline of the monthly median values of foF2.

A COMPARISON OF FOF2 BASELINES FOR USE IN STUDYING THE EFFECTS OF SOLAR ULTRAVIOLET IRRADIANCE ON THE F2 REGION OF THE IONOSPHERE

I. Introduction

Background

The ionosphere is composed of electrically charged or ionized particles. These ionized particles enable the ionosphere to reflect radio waves. One way of defining the structure of the ionosphere is with an ionosonde. The basic theory of an ionosonde is that by simply measuring the time delay of a vertically aimed variable frequency radio wave traveling at the speed of light, the apparent height of reflection can be calculated. These ionograms are used to deduce electron density profiles of the ionosphere. Figure 1 is an example of an electron density profile for both day and night conditions (Glassman, 1965: 486-487; 507). The electron density profile shows definite cusps. The boundaries of these cusps define various regions of the ionosphere referred to as the D, E, F1, and F2 regions. In addition, the point of the F2 region where the electron density peaks is called the height of the peak electron density. This study concentrates on the F2 region.

The structure of the ionosphere is continually changing so that an exact description as suggested by the electron

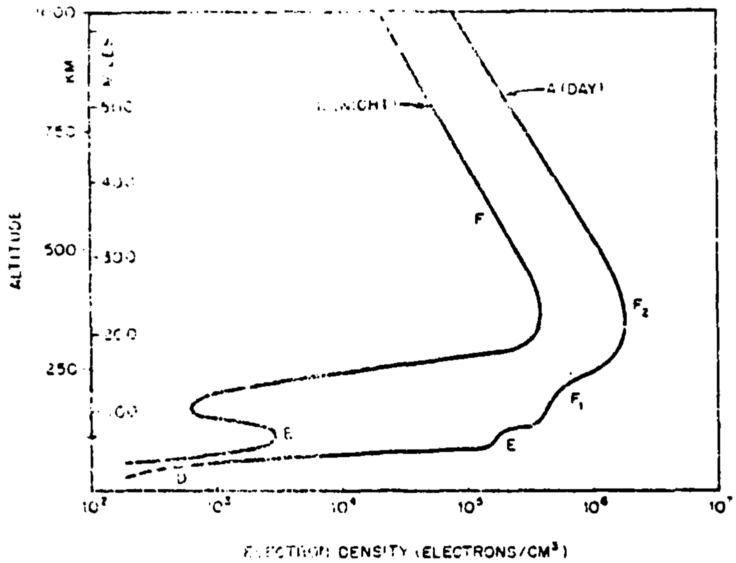

Fig 1. Electron Density Profile (Gl ..an, 1965)

density profile in figure 1 is not possible. It varies from day to night, with the season, and with latitude. In addition, it is highly disturbed by solar irradiance especially during periods of high solar activity. Although the average base of the F2 region is often defined at 250 kilometers, because of this variability, the base of the F2 region ranges between 150 and 350 kilometers. During the nighttime the D and F1 regions often disappear. Despite the variability, the regions do maintain an individual identity (Glassman, 1965: 486).

Solar variability can be examined over a range of time scales. Variations in solar irradiance range from (a) intense transitory events such as solar flares (minutes to hours), (b) changes over a solar rotation period (approximately 27 days) caused by the uneven distribution of plages on the solar disk, (c) cyclical changes due to the relative number of active regions present during a solar cycle (approximately 11 years), and (d) long-term cyclical changes in solar output (centuries - evolutionary time scales) (Cook and others,1980:2257). This study concentrates on changes in solar ultraviolet(UV) irradiance during solar flares.

Increases in radiation produced by a solar flare enhance the radiation impinging on the earth's atmosphere. These enhancements in the UV and X ray wavelengths cause variations in foF2 and Hmax. In addition, these enhancements increase attenuation of radio signals used in satellite and HF communications. The advent of over-the-horizon radar systems generated requirements for an even greater knowledge of the effects of these enhancements. The maximum efficiency of the radars require that accurate predictions of ionospheric parameters be made so that proper operational frequencies are chosen. Therefore it is important to be able to predict quantitatively and in real time the effects of a solar flare on the earth's atmosphere particularly on the parameters of the F2 region (Mariska and Oran, 1981:5868).

Current models to predict foF2 rely on older, more established indices of geomagnetic activity such as the Kp and Ap indices. The only indices of solar activity used in the models are an index based on visual identification of sunspots and 10.7 cm flux. Therefore, accurate prediction of F2 region parameters still leaves a lot to be desired

While concurring that active regions of the sun influence 10.7 cm data, Oster still brings up the subject of calibration errors and proposes a model of UV irradiance using 10.7 cm flux and another index of solar activity called K line. The K line index is based on spectral analysis of the light of the calcium II line at 393 nM. The model can be used to check the calibration of UV sensors or, as was Oster's original intention, can be used as a substitute for UV data thereby saving the expensive cost of a satellite system (Oster, 1983: 1954-1956, 1963).

Donnelly has studied the results from several satellites to evaluate the effects on the ionosphere of the time structure and spectra of X ray and EUV bursts during solar flares. He concludes that the strength of the impulsive EUV emissions incident on the ionosphere depends on the location of the flare on the sun. This impulsive EUV emission also produces shortlived large absolute enhancements of photo-ionization rates in the F region (Donnelly, 1976b:4745-4752)

As more data became available, the study of longer solar periods became possible. The Naval Research Laboratory (NRL) has studied the variability of solar irradiance in the wavelength band 1175 to 2100 A over a 11 year solar cycle. Their assumption is that cycle variability is caused by the fraction of solar surface covered by plages or active regions (Cook and others, 1980:2257). Similar work has been done in the same region to relate measurements in chromospheric overcome by a greater degree of control in the laboratory, by eliminating different calibration techniques between laboratories, and by using dual sets of instrumentation which can be used to "self-calibrate" the instruments after they are spaceborne (Hinteregger, 1976:791-792).

The earlier doubts over correlation of UV data with other accepted means of measuring solar and ionospheric activity have been removed in the last few years. Studies based on UV data from the Nimbus 7 satellite launched on November 1978 and still providing measurements show a direct relation between UV irradiance variation and the 27 day period for solar rotation. The authors show that nonflare variations are caused by: (1) the evolution of active regions on the sun; and (2) solar rotation induced changes in the central meridian distance of active regions which consequently cause a change in the terrestrial viewing angle and the portion of the active region being viewed near the solar limb. The second case contributes to a significant difference in UV and 10.7 cm flux variations. Because of this, the authors conclude that UV models based on satellite data provide a better indicator of solar UV irradiance than do estimates based on 10.7 cm flux (Donnelly and others, 1982:10,323). Hinteregger has also suggested that non-EUV indices of the ionosphere are valuable as a crude guide only and not for quantitative representation of the ionosphere (Hinteregger, 1981a:5-6).

with flare enhancements, 27 day variations, a possible biennial effect, and long-term variations associated with the 11 year solar cycle (Heath, 1973:2782-2791).

The first studies done with UV observations in the geophysical realm were an attempt to correlate UV irradiance with 10.7 cm flux. The 10.7 cm flux had long been used as a representative indicator of UV activity. These first experiments were of a snapshot nature with the UV data being acquired from spectrometers aboard Aerobee rockets. The spectrometers were not put into orbit so at best only several minutes of data were obtained from each flight. However, when compared with 10.7 cm data over the same time frame it was concluded early on that there was a good correlation between the two types of data (Hall and others, 1969:4181-4183; Hinteregger, 1970:6). It is also pointed out that there is no good reason for UV emissions at several different wavelengths and solar radio emission at one specific wavelength to be correlated exactly (Hall and others, 1969:4183).

These early experiments pointed out a limitation of UV measurements which still seems to persist today to some degree. The limitation is the individual absolute accuracies of the instruments used to measure UV irradiance. This limitation is caused by changes of spectrophotometrically critical components between the time of calibration in the laboratory and the time of the actual observations in space (Hinteregger, 1970:8; 1976:791). This limitation can be

1979:264-271). Matsushita (1959:305-306) conducted an early study of the variations of the maximum electron number density in the F2 region during ionospheric storms. His parameter for the F2 region was foF2. He based his results on the fact that the maximum electron number density N of the F2 region is proportional to the square of the critical frequency.

With the advent of rocket flight, the new source for information on the upper atmosphere was instrumentation from rockets and satellites. One of the earliest works still referenced today was the work of Hall and Hinteregger in cataloging the irradiance variation and absolute intensity of solar radiation over the wavelength range 270 to 1310 A. The study provided a spectral picture of this band of wavelengths, a possible ionization source for each spectral line observed, and a relative irradiance on the earth (Hall and Hinteregger, 1970:6959-6965). In earlier results from the same study, they noted that the correlation between EUV enhancement during solar flares and the class of the H alpha flare exists only statistically (Hall and Hinteregger, 1969:82). Work is still continuing on refining this spectral picture as continuing data becomes available (Hinteregger, 1981a; 1981b).

Heath used broadband information from two early Nimbus satellites to study variations in solar irradiance in wavelength bands between 1200 and 3000 A. He concluded that different types of observed variations could be associated propagation and the over-the-horizon radar, many studies have concentrated on prediction techniques based only on previous and present values of foF2. AFGL has done much work in this area (Rush and Gibbs, 1973; 1974; Rush and Miller, 1973; Rush and Edwards, 1976). The general purpose of these studies was to develop a model which would predict F2 region parameters in areas where no ionosonde equipment exists to provide routine readings of these parameters. An earlier study looked at the equatorial anomaly, a dip or trough in the value of foF2 above the magnetic equator with crests located within ±20 degrees magnetic latitude on either side of the equator. The study observed that the equatorial anomaly shows considerable day-to-day fluctuations in both its structure and its diurnal development (Rush and Miller, 1972:1085). The Air Force currently runs a computer model using only foF2, M(3000)F2, and total electron content to provide a complete worldwide specification of the ionosphere (Tascione and others, 1979:46). The Australians also have a computer model to predict foF2 which uses only foF2 as an input (McNamara, 1979). In developing this model, it was noted that if solar rotation and seasonal variations are removed from the data, hourly plots readily show the effects of ionospheric storms. In addition, the study noted that although 10.7 cm flux can be related to monthly median values of foF2, there is little apparent evidence for day-to-day variations in 10.7 cm flux being highly correlated with the changes in foF2 (Wilkinson, received frequency of a high-frequency radiowave reflects, usually from the F region of the ionosphere, increases suddenly, peaks, and then decays to the transmitted frequency (Donnelly, 1970:1) This is because increases in EUV radiation increase the photoionization rate in the ionosphere. This in turn causes an increase in the electron density and in the time rate of change of electron density, thereby producing an SFD. Although these observations cannot provide any spatial resolution of UV radiation, they are capable of high time resolution. Their accuracy in measuring absolute irradiance resolutions are good at best to only a factor of four. However, SFD observations are effective detectors of impulsive bursts in the wavelength 10-1030 A (Donnelly, 1973a:2-7).

Much research has been done to relate SIDs to other solar phenomena including X-ray bursts, solar flares, and microwave flashes (Donnelly, 1976a; 1976b; Donnelly and others, 1982; Richards, 1971). Common research today is on correlating SIDs with satellite measurements to improve the accuracy of SID measurements by providing a baseline for the measurements. In an article stating the wavelength bands needed to evaluate SIDs, Donnelly recommends the 100-500 A band of the SOLRAD 11 satellite as an effective band for evaluating both SFDs and the F region of the ionosphere (Donnelly, 1976a:180).

Due to the criticality of F2 region parameters on HF conclude that future studies in this area could be fruitful (Schatten and Mendillo, 1980:42-44). The Air Force uses a computer to generate forecasts of maximum useable HF frequencies which utilizes a combination of sunspot numbers and geomagnetic indices (Manley, 1981:77-91).

The first evidence for solar UV effects on the F2 region was found in the late 50's. These effects were noticed as increases in the total electron content of the F2 region during large solar flares (Knecht and Davies, 1961). Several explanations were put forward to explain this variation in total electron content. Research continued and in 1967, Garriott and others (1967) concluded that these variations were caused by a large increase in extreme ultraviolet (EUV) radiation that occurred simultaneously with the flares. This conclusion started the search to find ways to predict both increases in UV radiation and the variability these increases may cause in the ionosphere.

UV wavelengths do not reach the surface of the earth but rather are absorbed in the upper atmosphere. Therefore, much research has been done on finding ways to model the ionospheric effects of UV radiation from the ground. The two main parameters used today are sudden ionospheric disturbances (SIDs) and 10.7 cm flux (or 2800 MHz flux). Donnelly has done much work in the area of SIDs. One type of SID, sudden frequency deviations (SFDs) is suitable for prediction of F region effects. An SFD is an event in which the disturbances and ionospheric storms were among the first of the F2 region and continue to this day. Common indices of geomagnetic activity including a planetary average over three hours, Kp, and a twenty four hour average, Ap, have been available since the early 40's (Rishbeth and Garriott, 1969:232). Many recent attempts to forecast F2 region parameters have used some aspect of geomagnetic activity. Air Force Geophysical Laboratories (AFGL) have had success with a prediction scheme which divides a month's worth of F region data into a hierarchy based on geomagnetic data. The quietest days and the most active days of the month behave in consistent manners over the seasons. The remaining days show a predictable variability or can be divided into quiet-like or disturbed-like days (Mendillo and Lynch, 1979:12-23; 30). A concurrent AFGL study looked at several different solar influences on the ionosphere including interplanetary magnetic field sector boundaries, solar wind, and solar 27 day variability in ionizing irradiance. The only one that showed any statistical significance was a relation between 27 day variance in spectral irradiance and total electron content of the F2 region of the ionosphere. The study broke the irradiance data into quiet or active solar days and used a mean total electron content for either quiet days or active days. Although the overall results were only within one standard deviation, the fact that the data for each section was pointing in the same direction led the researchers to

II. Literature Review

Several studies have been carried out correlating diurnal, 27 day solar cycle, and seasonal variations in F2 region parameters with various indices of solar activity. Comparatively few studies have been carried out on the hourly variability of the F2 region. To date, no studies correlating UV satellite measurement of solar irradiance with the hourly variability of the F2 region has been completed. No known studies on the suitability of any particular baseline for the research of hourly variability of foF2 have been published either.

All of the completed studies naturally follow a time flow of availability of data. The first studies were of the F2 region itself which was brought about by the invention of the ionosonde in the early 30's. The earliest correlation studies related geomagnetic indices with F2 region parameters. These progressed to studies involving 10.7 cm flux and sudden ionospheric disturbances (SIDs), both easily obtainable ground frequency measurements that correlate with UV irradiance impinging on the earth's atmosphere. More recent measurements include direct rocket and satellite measurements of X-ray and UV irradiance on the earth's upper atmosphere.

Studies of the relationship between geomagnetic criteria for ranking baseline foF2's will be explained as well as the method of comparing rankings. The results and analysis of the data are listed in Chapter IV. Conclusions are presented in Chapter V. Chapter VI offers a general discussion as well as further recommendations.

with solar minimum occurring in 1974 and solar maximum occurring in 1979. The 1979 data was not initially planned to be used. However, a scarcity of data points in the first year forced the use of 1979 data to insure a statistically large data base.

4. To eliminate any variations caused by calibration errors on different satellites, data will be used from only one satellite. The SOLRAD 11B satellite launched on 15 March 1976 provided good data until it was turned off on 31 October 1979. The data from UV measurements in the bandwidth 100-500 A will be used in this study. Donnelly (1976a:180) recommends this band of frequencies for study of the F region since the 300-800 A radiation is the dominant source of ionization in the F region of the ionosphere (Donnelly, 1973b:10).

5. To eliminate diurnal variations in foF2, values for the parameter will be taken from the observatory closest to local noon relative to the time that the UV variations measured by the satellite occurred.

Preview

Chapter II contains a literature review focusing on previous studies in the F2 region of the ionosphere and the monthly median values of critical frequencies for use in predictive programs in the E and F1 region of the ionosphere. Methodology is discussed in Chapter III including reduction of UV irradiance data and correlation with foF2 values. The data, solar flare data will be checked to ensure that the variations have solar causes. The amplitude and duration of the variation in UV irradiance corresponding to the flare will then be determined. Through a simplified integration process, these measurements of UV will be converted to fluence. This fluence will then be correlated with that day's foF2. The eight different baseline foF2's will be ranked against the daily foF2 using several different criteria for judgement of the comparative rankings. These rankings of the baseline foF2's will then be statistically analyzed to determine if a "best" baseline exists.

Scope and Limitations

1. This study will be limited to hourly variations in foF2 presumed to be caused by solar irradiance.

2. Values for foF2 are taken directly from ionograms. The ionogram measurements are taken at most observatories on an hourly basis. To reduce the possibilities that a small change in UV irradiance may cause a variation in foF2 that cannot be observed on an hourly time scale, only changes in UV fluence estimated as over 100 ergs/cm^2 will be included in this research.

3. The initial research into correlation of UV irradiance and F2 region parameters will concentrate on a 34 month period. To minimize variations in solar UV irradiance from the 11 year solar cycle, data for the years 1977-1979 will be used. This is the endpoint of the upside of solar cycle 21

and several other phenomena as yet not fully understood can have greater effects at any given period on the F2 region. These other factors can tend to enhance or decrease even a month's worth of F2 values so that it becomes difficult to measure what effects one parameter such as solar irradiance has on the F2 region (Buchau, 1983; Rush, 1983).

Problem Statement

Continuous satellite measurements of solar UV irradiance have been available for several years now. Any investigation into the relationship of these UV measurements to parameters of the F2 region of the ionosphere must rely on a baseline measurement of the critical frequency of the F2 region, foF2, to be able to measure changes that occur due to solar UV irradiance versus what would happen for a particular day if a change in UV irradiance did not occur. The basic problem then is what measurement of foF2 to use for a baseline.

Research Objectives

The objective of this research is to determine if a single "best" baseline foF2 exists that UV irradiance induced changes in foF2 can be compared against. Eight different methods of defining a baseline foF2 will be used in this research. Measurements of a narrow band of satellite monitored UV wavelengths that react with F2 region constituents will be used to evaluate solar UV irradiance. On days that short term variations in irradiance occur in the satellite

(Tascione and others, 1979:369-375; Thompson and Secan, 1979:351).

Ground-based measurement of UV irradiance is impossible since the UV frequencies do not penetrate the atmosphere. It was not until the late 1960's that satellite measurement of UV was started. The accuracy and reliability of the continuous measurements of UV irradiance that are currently available are still being debated (Lean and others, 1982:10,307). However, because of the cause and effect relationships of solar UV on the ionosphere, it is felt that UV irradiance may be the best direction to proceed to improve upon the accuracy of current forecast models of ionospheric parameters (Smith, 1979:430).

Studies of the E and F1 regions of the ionosphere are simplified in that median values of foE and foF1 are reliable indicators of undisturbed backgrounds (Leftin, 1976; Rosich and Jones, 1973). Studies of the F2 region have presumed that median values of foF2 are the most accurate representation of an undisturbed background. However, this assumption has never been documented as the best baseline representation. Especially in studies of the effects of solar irradiance on the F2 region, this assumption is complicated by the fact that the solar irradiance may not be the strongest contributor to changes in F2 region parameters. Geomagnetic disturbances, the transport terms for the production and loss mechanisms of electrons, neutral winds, activity over both the eleven year cycle and 27-day solar rotation period to ground-based observations of the Ca II K chromosphere (Lean and others, 1982).

However, the use of rockets for quick look pictures still continues. These have been used both during the last solar minimum (Rottman, 1981) and during the last solar maximum (Mount and others, 1980). These flights are relatively inexpensive and allow universities and other small institutions the ability to study the upper atmosphere.

Since solar flares are a major cause of hourly variability in the ionosphere, a great deal of study today is on the effects of flares on the ionosphere. The Naval Research Laboratory has done theoretical research on the changes that solar flares cause in the ionosphere. This work is based on a standard type of change in irradiance and time for different classes of flares (Mariska and Oran, 1981; Oran and others, 1976). Hall has studied the enhancements that individual flares have caused in time and irradiance variations of the extreme ultraviolet (Hall, 1971). However, other than theoretical models and individual events, no one has studied the actual effects of solar flares as observed in the UV wavelengths on the F2 region of the ionosphere.

Predictive programs for the day-to-day variability of the F2 region using median values of foF2 have met with some success (Jones and others, 1966; Lucas and Haydon, 1966; Rush and Gibbs, 1973). These programs tend to smooth out the foF2 and would not predict the effects of increases in ionospheric parameters due to increases in solar irradiance. Although all of these studies address the deviations of foF2 about the monthly median, none of them finds the closeness of fit of daily values of foF2 to monthly medians that exists with foE and foF1. In addition, even though this closeness of fit is not found, none of the studies addresses a suitable alternative to monthly median values of foF2 for baseline representation. Instead they proceed on the assumption that this is the best available representation.

The variability of the E and F1 regions of the ionosphere is inherently more stable than the variability of the F2 region. Variations caused by solar irradiance are more readily identifiable. As a result, the median values of the respective region's critical frequencies represent an excellent baseline for comparison purposes in studying the effects of solar irradiance (Leftin, 1976:16; Rosich and Jones, 1973: 1-5; Rush and Gibbs, 1973:2).

From this review, we can come to the following conclusions. Solar flares do cause variations in UV radiation impinging on the earth's upper atmosphere. These variations in turn cause variations in the parameters of the F2 region. Geomagnetic storms also cause variations that may effect the variations caused soley by solar flares. Sufficient satellite measurements of UV irradiance now exists to support a study over the long term of effects of solar flares as measured in the UV on the F2 region of the ionosphere. A likely candidate satellite for this study is the SOLRAD 11 using the 100-500 A wavelength band detector. Before a study of this type can take place, a suitable baseline should be decided upon to use for comparison purposes. The monthly median values of critical frequencies are commonly used in studying other regions of the ionosphere. However, no one has shown whether this is true for the F2 region.

III. Methodology

The chapter on methodology is divided into five sections. Section one will discuss the reduction of irradiance data from the satellite. Section two will discuss the reduction of foF2 data. Section three will examine the criteria for determining foF2 baselines. Section four will explain the methods of determining the rankings of the foF2 baselines. Section five will review the analysis techniques used to evaluate the results.

Satellite Data Reduction

Satellite data is obtained from experiment 7A on the SOLRAD 11B satellite (Horan and others, 1982:30-36). All of the data from 1 January 1977 until 31 October 1979 is examined for this study. When an apparent rise in irradiance is noted, the Hydrogen alpha solar flare data for that day (Solar Geophysical Data Comprehensive Reports, September 1977-March 1980) is cross-checked to see if there is indeed solar activity closely corresponding to the rise in irradiance. It must be emphasized that the solar flare data is only used to eliminate any doubts about the satellite data such as extraneous noise causing a rise in irradiance that does not correspond to solar activity. The solar flare data is not used anywhere else in this study. This initial data search provides 142 UV irradiance enhancement events to work with.

The data tapes from experiment 7A are accessed to obtain enlarged graphs of each of the events. After this search, 13 events with obvious faults such as insufficient data to obtain a start time, a stop time, or a peak rise in irradiance are eliminated.

A simplified time integration of the irradiance is carried out to determine the fluence of each event. Using a method similar to that of Williams and Donnelly (1982:214), an estimate of change in irradiance is made. The start time for each UV burst is measured as the time when the irradiance first rises above the background level by 10% of the estimated change in irradiance. Similarly the stop time for the burst is measured as the time when the irradiance falls back below the level of the background level plus 10% of the estimated change in irradiance. The actual change in irradiance is then measured from 10% above the background level to the peak irradiance.

The fluence is obtained by assuming that the UV burst can be approximated by a triangular function. The fluence (ergs/cm^2) then becomes the area underneath the triangle or simply 1/2 the change in irradiance (ergs/cm^2/sec) multiplied by the time of the UV burst converted from minutes to seconds. The exact value of the fluence is not critical for this study. For five of the events, the UV burst does not reach its background level before another smaller burst occurs. In these cases, a double triangular function is assumed. The fluence for each of the bursts is estimated by a separate triangular function. The fluences are then added to obtain a total fluence for the double burst.

Figure 2 is an example of the amplified satellite data and shows how the method is applied. For this point, the baseline is estimated as 1.47 ergs/cm^2/sec and the estimated change in irradiance is 0.91 ergs/cm^2/sec. Ten percent of this change is 0.09 so the starting irradiance is 1.56 ergs /cm^2/sec and the start time of the UV burst is 1902UT. The point where the irradiance falls below 1.56 ergs/cm^2/sec is found and the stop time is found to be 2152UT. The actual change in irradiance is the peak irradiance of 2.38 ergs/cm^2 /sec minus the starting irradiance of 1.56 ergs/cm^2/sec or 0.82 ergs/cm^2/sec. The fluence is then 1/2 the change in irradiance (0.82 ergs/cm^2/sec) times the duration of the burst (170 minutes = 10,200 seconds) or 4182 ergs/cm^2.

Figure 3 shows how the method is applied to a double UV burst. The start time for the first burst is 0429UT and the stop time (start time for the second burst) is 0457. The stop time for the entire event is 0517. The change in irradiance for the first burst is 0.39 ergs/cm^2/sec and for the second burst is 0.25 ergs/cm^2/sec. The fluence for the first burst is then 328 ergs/cm^2, for the second burst is 150 ergs /cm^2, and for the entire event is 478 ergs/cm^2.

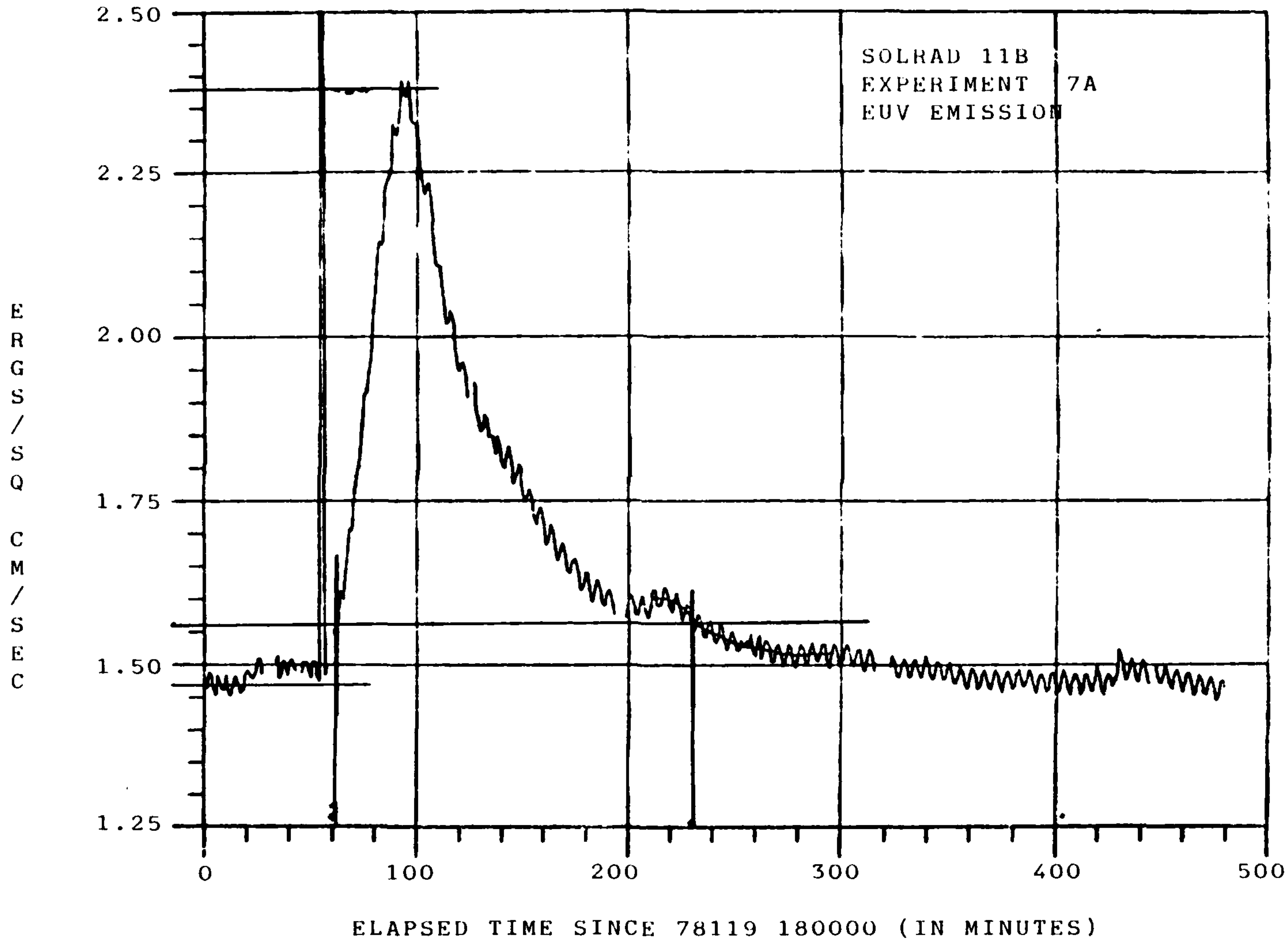

Fig 2. *Calculation of Fluence for Single UV Burst from Satellite Data*

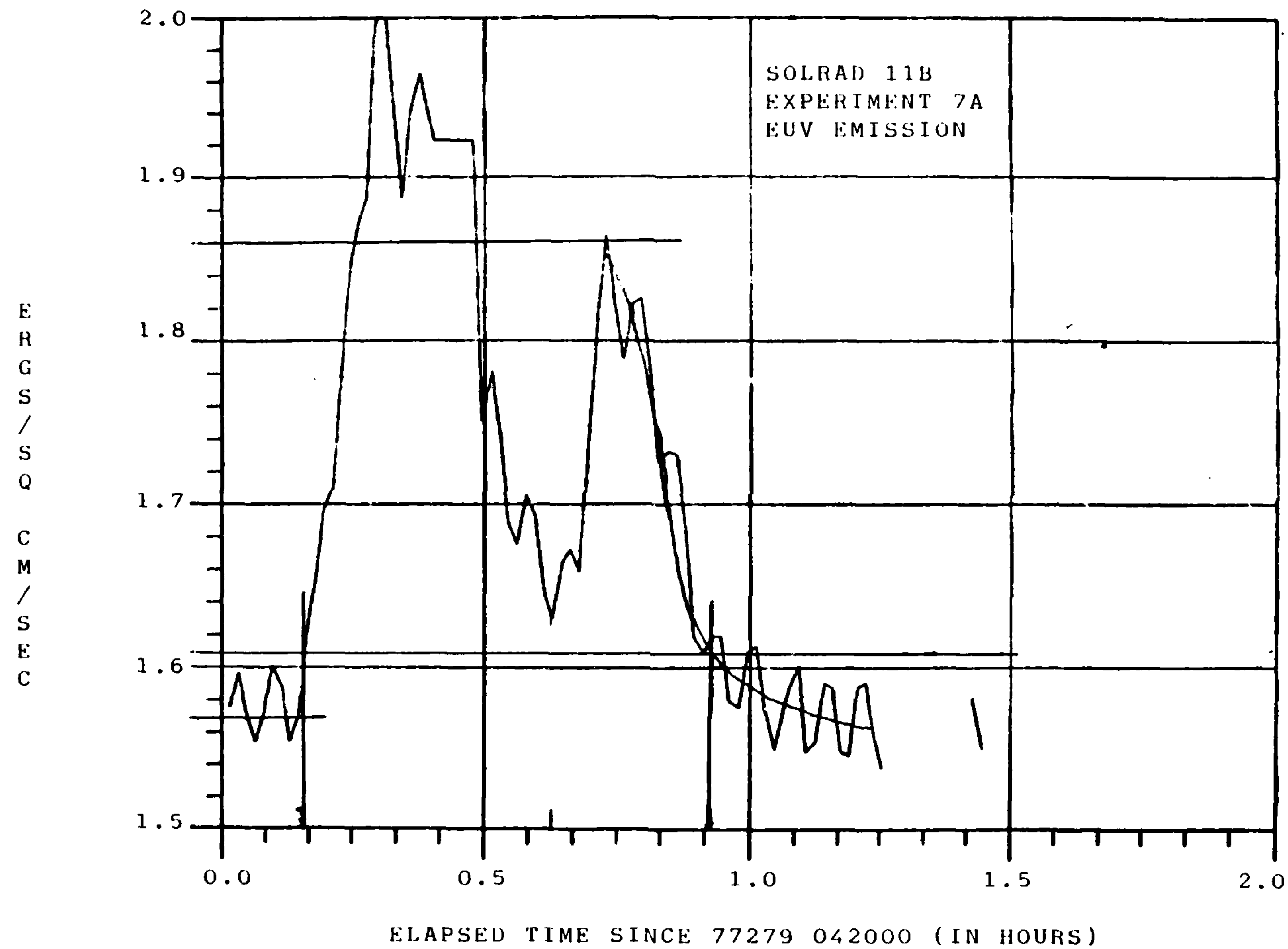

Fig 3. Calculation of Fluence for Double UV Burst from Satellite Data

foF2 Data Reduction

The foF2 data is obtained from hourly ionograms. Table I is a list of the ionosonde observatories used in this study along with their geographic position, geomagnetic latitude, and the time difference for the observatory from universal time. To eliminate auroral effects, only observatories below 60° N/S latitude were used for this study. At the start of each UV burst, the foF2 data from the closest ionosonde relative to local noon is obtained. This serves two purposes: first, diurnal variation of the F2 region is minimized by taking all data as close to the same local hour as possible; second, the foF2 should be close to its peak and any further rise in foF2 can more readily be assumed to have a causal relationship to an increase in irradiance on the F2 region.

Unfortunately, foF2 data is not available for each of the remaining UV burst events. This is usually either an equipment problem in the ionosonde for the particular time that data is required or the physical reality that it is difficult to place ionosonde observatories in the middle of an ocean. To minimize this situation, data is obtained from the next closest observatory whenever possible. In addition, the foF2 data for many points does not continue rising after the start time of the burst. This is thought to be primarily a time resolution problem in that the UV burst is not large enough to cause changes in foF2 that can be resolved with

Table I

Ionosonde Observatories

Observatory	Geographic Latitude	Geographic Longitude	Geomagnetic Latitude	UT to LT Conversion
Christchurch	44S	173E	-49	+ 12
Norfolk Island	29S	168E	-35	+ 12
Canberra	35S	149E	-45	+ 10
Khabarobsk	48N	135E	+38	+ 9
Chung-Li	25N	121E	+15	+ 8
Irkutsk	52N	104E	+40	+ 7
Tomsk	56N	085E	+45	+ 6
Ashkabad	40N	058E	+33	+ 4
Moscow	55N	032E	+50	+ 2
Lindau	51N	010E	+52	+ 1
Lannion	48N	003W	+50	+ 0
Dakar	15N	017W	+22	- 1
Wallops Island	37N	075W	+48	- 5
Boulder	40N	105W	+48	- 7
Vandenberg AFB	35N	121W	+42	- 8
Maui	21N	156W	+20	- 10

foF2 points an hour apart. To minimize this problem, a fluence of 100 ergs/cm^2 is chosen as a minimum value that should be resolvable with one hour foF2 values. Finally, it is not always possible to find an ionosonde observatory that correlates to within one hour of the UV burst. In this situation, the closest observatory is used even though the time will be more than an hour from local noon.

Table II is a summary of the 47 testable events remaining from the original set. The universal time of the UV burst is included along with the values used in obtaining the estimate of fluence. It should be noted that six of these events are not within one hour of local noon for the observatory that is used to obtain foF2 values. This includes a event for Norfolk Island, Australia. If the times were based on geographical location with fifteen degrees of longitude for each hour of time, this point would be within one hour of a relative local noon.

Criteria for Determining foF2 Baselines

Eight different criteria for determining a baseline for foF2 are used throughout this study. Six of these criteria use foF2 values based on days during which values of the three-hourly index of geomagnetic activity, Kp, (Lincoln, August 1977-February 1980) were at values described later in this study.

Table II

UV Bursts Used In This Study

Date	Start Time (UT)	Change in Irradiance (Ergs/Cm^2/Sec)	Duration of UV Burst (Minutes)	Fluence (Ergs/Cm^2)
770412	0948	0.32	65	624
770805	1412	0.2	33	198
771006	0429	0.64[1]	58[1]	478
771008	1236	0.06	80	144
771206	1934	0.26	13	101
780108	0710	0.52	44	686
780203	0444	0.6	44	792
780203	0354	0.11	38	125
780211	2340	0.07	137	288
780213	0145	0.36	630	6804
780221	2240	0.04	97	116
780306	1138	0.18	205	1107
780418	0108	0.12	41	148
780429	1902	0.82	170	4182
780507	0326	0.47	73	1029
780508	1208	0.22	104	686
780524	1910	0.08	170	408
780530	1925	0.16	55	264
780622	0238	0.07	59	124
780622	0600	0.05	78	117
780708	1947	0.16	88	422
780709	1821	0.65	79	1541
780710	1713	0.41[1]	167[1]	1157

1. Two UV bursts integrated separately and counted as one.

Table II(cont)

UV Bursts Used In This Study

Date	Start Time (UT)	Change in Irradiance (Ergs/Cm^2/Sec)	Duration of UV Burst (Minutes)	Fluence (Ergs/Cm^2)
780711	2228	0.44	49	647
780712	0245	0.18	61	329
780721	1856	0.26	140	1092
780729	1036	0.03	141	127
780904	0810	0.1	78	234
780916	1323	0.08	87	209
780924	1719	0.11	67	221
781006	1642	0.19	65	370
781110	1359	0.09	41	111
781129	0508	0.1	95	285
781130	0152	0.07	59	124
781210	0441	0.08[1]	171[1]	200
781213	2355	0.24	85	612
781224	2219	0.05	78	117
790113	1929	0.24	38	274
790205	0636	0.08	42	101
790218	1636	0.5	80	1200
790225	0641	0.07	138	288
790309	1011	0.3	161	1449
790517	2317	0.05[1]	138[1]	105
790604	0356	0.34	124	1265
790908	0644	0.12	66	238
790911	1639	0.12	90	324
791017	0653	0.14[1]	121[1]	252

1. Two UV bursts integrated separately and counted as one.

Kp is a planetary or worldwide figure of geomagnetic activity. In addition, solar flares cause increases in the solar wind. These increases in the solar wind can cause fluctuations in the earth's magnetic field. Kp measures these fluctuations. As a result, Kp correlates well with the 27 day and 11 year solar sunspot cycles. Measurements of activity from ground magnetograms over a three hour period at twelve different observatories are combined to arrive at each value of Kp. The value of Kp is based on a scale of units from 1 to 9 with Kp determined to an accuracy of one-third of a unit. The quietest value of Kp is 0o and the most disturbed value is 9o with +, o, or - indicating one-third of a unit. Each day, the eight Kp values are summed. These summed Kp values are then rank ordered over a month. The five highest sums are termed the five disturbed days of the month with the highest sum being the most disturbed day. The ten lowest sums are termed the ten quiet days of the month with the lowest sum being the quietest day of the month (Rishbeth and Garriott, 1969:231-233).

Based on the previous information, the eight baselines are now defined:

Monthly Medians. The monthly medians are the hourly medians of the values of foF2 for each month. This is the baseline that is commonly used in studies of the F2 region. Monthly medians are abbreviated as "Mnth" in tables throughout this study.

$$|R_i - R_j| \leq z[(kn(n + 1)/6)\exp 1/2] \qquad (2)$$

where z is dependent on the desired alpha level and is obtained from a table of critical j values for p multiple comparisons (Gibbons, 1976:432). n and k are as defined in the Friedman test.

Kendall Coefficient of Concordance. The Kendall coefficient of concordance is similar to the Friedman test. However, the Kendall coefficient of concordance is used to test the null hypothesis that the baselines are independent or that a strong measure of agreement exists between the baselines (Gibbons, 1976:301-305). The Kendall coefficient of concordance, W, is defined as

$$W = 12S/k^2n(n^2 - 1) \qquad (3)$$

where S, k, and n are as defined previously in the Friedman test.

The value of W is always between 0 and 1. If the value of W is 0, the interpretation is that no agreement exists between the baselines. If the value of W is 1, the interpretation is that perfect agreement exists between the baselines.

However, this does not give any statistical probability for determining acceptance or rejection of the null hypothesis. This is done using equation 1 to find the Q statistic. The method for finding the P-value is then the same as it is for the Friedman test. If the null hypothesis is rejected, A: At least two of the Mu_j's differ from each other.

To determine which alternative to accept, S, the sum of squares of the deviations between observed and expected column sums is calculated. These sums are the sums of the rankings for each of the baselines used in this study. After S is determined, the test statistic Q is calculated from

$$Q = 12S/kn(n + 1) \qquad (1)$$

where k and n are as previously defined.

This value of Q is then entered into a Chi-squared distribution table for right-tail probability (Gibbons, 1976:386) along with degrees of freedom for the Chi-squared distribution of $df = n - 1$ where n is the same as previously defined. The resulting P-value tells whether to accept or reject the null hypothesis, H. If P is very small, the null hypothesis should be rejected.

Test of Multiple Comparisons. If the null hypothesis from the Friedman test is rejected, the next step is to determine which treatment effects or baselines differ significantly from each other (Gibbons, 1976:313-315). To do this, all possible differences between the sums of rankings for each baseline are determined. If R_i and R_j are defined as the sums of rankings for two different baselines, then the probability is at least one minus alpha that the two baselines differ if the following inequality is satisfied:

which of the baselines are significantly different. By hypothesizing that the means of the rankings for each baseline using each method of ranking is continuous and approximates a normal distribution, nonparametric methods of analysis may also be employed. This is accomplished by using the means of the rankings for each of the first eight methods and applying a one-way analysis of variance (ANOVA) to the means to determine if a further delineation of the baselines can be made. This delineation is made with both the Tukey procedure for multiple comparisons and the Duncan multiplerange test. The basic theory of ANOVA is covered in college level statistics books. The basic theory for each of the remaining tests follows.

Friedman Test. The Friedman test (Gibbons, 1976:306-315) is concerned with the inference of homogeneity of ranked objects. The data to be analyzed consists of k sets of rankings. These k sets are the number of events used for each method of ranking and are listed in Table 3. With the Friedman test, a useful inference can be made concerning n treatment effects. In this study, the treatment effects are the baselines. Letting Mu_j denote the average effect of the jth treatment (the jth baseline), the null hypothesis of interest is that the treatment effects are homogeneous, or

$$H: Mu_1 = Mu_2 = \ldots = Mu_j$$

and the alternative is

have any effect on the rankings. The rankings are compiled for all observatories having four or more events.

Summation Method. The summation method is a summation of the results for the first eight methods. The total summations of the rankings for each baseline for each method are used for further nonparametric testing. The mean rankings for each baseline for each method are used for the ANOVA testing. The purpose of this method is to see if a sum of ranks from all applicable methods will define differences between baselines in greater detail than is possible with the individual methods.

Methods of Analysis

Since the rankings of each of the baselines produces data that is on an ordinal scale, the primary means of quantitative analysis is with nonparametric methods of statistics. The specific method of nonparametric analysis used in this study is association analysis. For analyzing the baselines for each individual method, the Friedman test is used to determine if there is any difference between the various baselines. If there is, the test of multiple comparisons is used to determine which of the baselines are significantly different. For the summation method, the Kendall coefficient of concordance is used to determine if there is any difference between the various baselines based on several methods of ranking the baselines. If there is, the test of multiple comparisons is again used to determine

Method 9. The rules of ranking for method 9 are the same as for method 8 except that the lower quartile baseline is eliminated from the rankings. In doing the rankings for method 8, it appears that for most of the events the lower quartile is the closest baseline for those baselines that are entirely above the event day foF2 values. Conversely, for those baselines that are entirely below the event day foF2 values, the lower quartile appears to be the most distant baseline. This method is used to check if there is indeed a distinction to be made.

Seasonal Method. The seasonal method uses the same rules of ranking as method 3. However, the data is then split into four seasons to see if this affects the rankings. The four seasons are January to March, April to June, July to September, and October to December.

Geomagnetic Method. The geomagnetic method also uses the same rules of ranking as method 3. However, this method is to see if geomagnetic latitude has any effect on the rankings. The data is split geomagnetically into low latitude and mid latitude. The low latitude data is from those observatories located below 30° geomagnetic latitude. The mid latitude data is from those observatories located between 30° and 55° geomagnetic latitude.

Individual Observatory Method. The individual observatory method also uses the same rules of ranking as method 3. However, this method is to see if individual observatories on amount of movement for the second hour prior to the burst.

The appropriate rules of ranking are applied to the relevant events for each method. Ties in the ranking of baselines are handled by the mid-rank method. The results of the rankings are tallied for each method. The sums of the rankings are calculated for each baseline. The mean rank is figured for each baseline and a relative ranking from 1 to 8 is assigned to each baseline. The results are then statistically analyzed to determine if any of the baselines are statistically better than the other baselines.

The number of events utilized in the first eight methods are listed in Table III. Method 1 utilizes one less event than the remainder of the methods using all events. This event is for Lannion, France on 6 October, 1977.

Table III

Number of Data Points Used for Methods 1 - 8

Method #	1	2	3	4	5	6	7	8
# of Points	46	47	47	29	21	47	39	43

The point is unusable for method 1 because there are no event day foF2 values previous to the hour prior to the Euv burst.

In addition to these eight methods of ranking the baselines, five different criteria are applied to either method 3 or method 8 to see if individual attributes have any effects on the rankings.

value are eliminated. However, events where all baselines lie above the peak event day fof2 value are not eliminated for this method.

Method 5. The rules of ranking for method 5 are similar to those for method 4 except that events where all baselines lie above the peak event day fof2 value are also eliminated for this method.

Method 6. The rules of ranking for method 6 are the same as those for method 3 except that baselines are ranked irregardless of where they lie in relation to the event day peak value of foF2. In other words, the baseline may lie either above or below the event day peak foF2 value.

Method 7. The rules of ranking for method 7 are the same as for method 6 except that all doubtful events are removed. Doubtful events are defined to be those where one baseline is automatically rated last because of insufficient foF2 values to accurately determine an order of ranking.

Method 8. Method 8 does not follow any of the previous rules. The baseline is not shifted to the event day foF2 values. Instead the first ranking is based on how far the baseline must be shifted to match the event day foF2 value in the hour previous to the UV burst. The less the baseline must be shifted the higher the ranking. In addition, those baselines that are below the event day foF2 value in the hour previous to the UV burst are ranked ahead of those baselines that lie above the event day value. The tie-breaker is based the event day foF2 from the hour prior to the burst until after the effects of the UV burst disappear. The goodness of fit of the baseline to this theoretical curve is used as a judgement of rankings.

Method 3. The methods of ranking for method 3 are the same as those for method 2 except that all values of foF2 are rounded to the closest tenth of a megahertz. Some of the ionosondes measure foF2 to hundredths of a megahertz. In addition, the two day averages of foF2 can have a resolution greater than tenths of a megahertz. However, the accuracy rules for individual measurements of foF2 from ionograms require only tenth of a megahertz accuracy although qualifying effects can lower these accuracies (Piggott and Rawer, 1961:23-24). Since the previous two methods can have tie-breakers decided on hundredths of a megahertz, it is felt that using tenths of a megahertz for the greatest measurement accuracy will take into account measurement uncertainties. This accuracy will be maintained for the remainder of the methods.

Method 4. The rules of ranking for method 4 are the same as for method 3 except that all doubtful events are removed. Doubtful events are defined to be those where one baseline is automatically rated last because of insufficient foF2 values to accurately determine an order of ranking. In addition, those events where some of the baselines are below the peak event day foF2 value while others are above the peak

Method 1. After shifting the baseline and determining if the baseline lies below the peak of the event day foF2, rankings are determined by how close the shifted baseline is to the event day foF2 value for the second hour prior to the UV burst. If the rankings are still tied, the difference in fof2 values for the third hour previous are used. The next tie-breaker is the fourth previous hour. If the rankings are still tied, the last tie-breaker is to compare the difference in foF2 at the hour past the UV burst where the event day foF2 declines to at or below its pre-burst value.

This method is an attempt to match the slope of the foF2 prior to the burst. By measuring differences in pre-burst foF2 values, the goodness of fit of the baseline slope prior to the event is being used as a judgement of rankings.

Method 2. After shifting the baseline and determining if the baseline lies below the peak of the event day foF2, rankings are determined by how close the shifted baseline is to the event day foF2 value for the hourly point past the UV burst where the event day foF2 declines to at or below its pre-burst value. If the rankings are still tied, the difference in foF2 values for the hour previous to the burst as in method 1 is used. The next tie-breaker is the next hour past the point where foF2 declines to its pre-burst value. Ties are broken by alternating back and forth between the next hour previous and the next hour past.

This method is an attempt to match the baseline foF2 to

The first judgement for rankings for most of the methods is whether the peak value of foF2 for the baseline remains under the peak value of the event day foF2 over the previously determined time frame. Since the cause and effect relationship of this study is that an increase in solar irradiance will cause an increase in foF2 over normal values, the baseline should be below the hourly values of the event day foF2 for this relationship to remain true. Those methods of ranking that do not rely upon this relationship will be pointed out in the ensuing discussion. Those baselines that remain under the event day peak foF2 are ranked first.

The last general rule for all the methods of ranking is that if one baseline does not have enough hourly foF2 values to accurately determine its ranking, this baseline is automatically rated last. This rule allows the data base to remain large since several of the events have one baseline that falls into this category.

In addition, several of the events have large values of fluence that cause foF2 to rise to the point where their value cannot be accurately recorded from ionograms for one or two hours after the UV burst occurs . In these cases, the event is still kept and all baselines are assumed to fall below the event day peak value of foF2.

The remaining rules for determining rankings are slightly different for each of the methods. These rules for the eight different methods are:

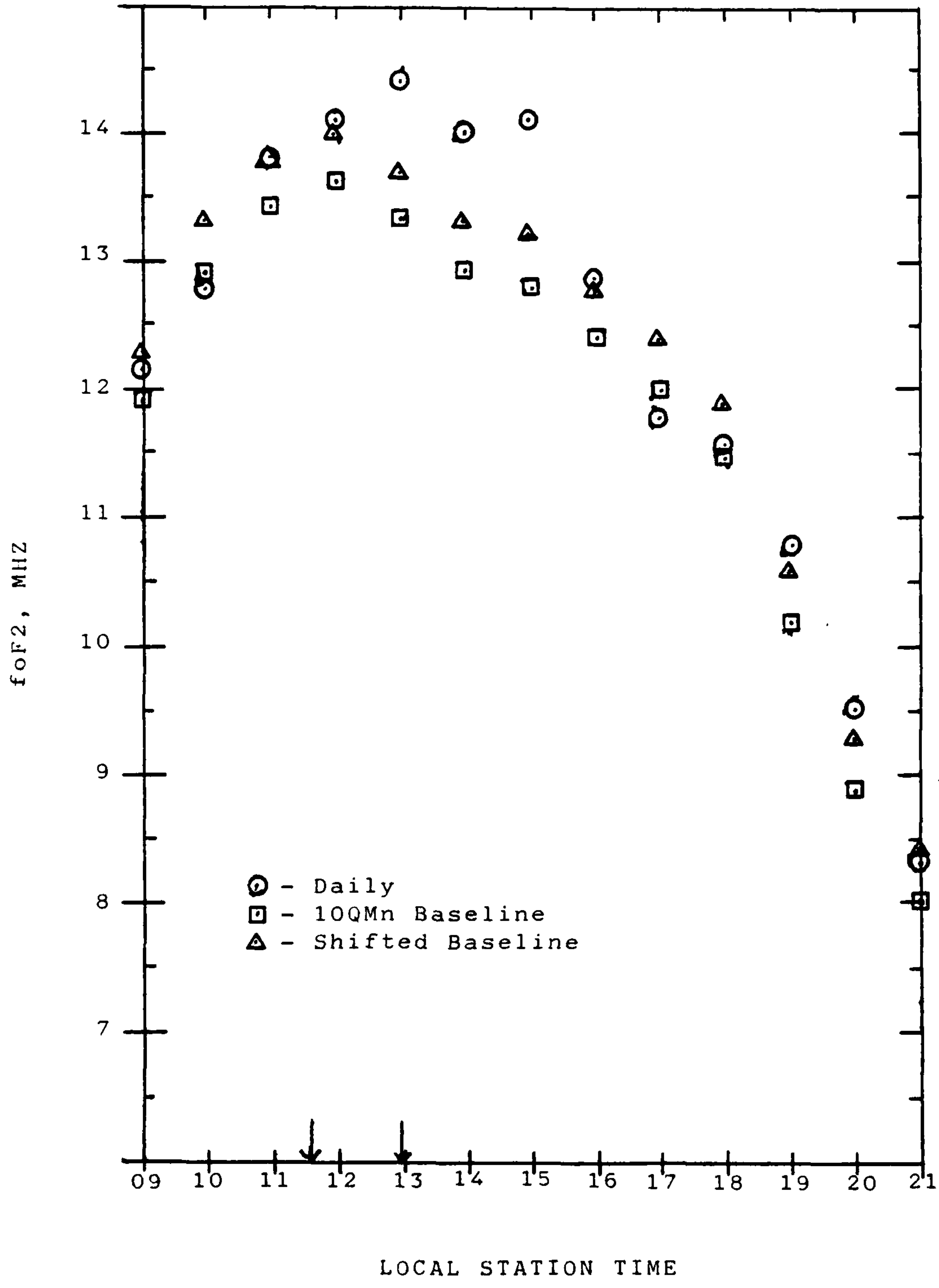

Fig 4. Illustration of Baseline Shifting

for each baseline. Each pairing of baseline and daily values are put on a separate graph. The first step in each of the first seven methods after the foF2 values are graphed is to shift the entire baseline until the foF2 value for the hour prior to the UV burst for the baseline day matches the foF2 value for the event day under study. If the burst begins on the hour, this is the hour to which the baseline is shifted.

Next, the point is determined after the burst where the event day foF2 declines to at or below the value it had in the hour prior to the burst. The peak value of foF2 between these two points is determined. On those days when the event day foF2 starts to decline and then begins rising again, the point where the rise begins is determined to be the end point for ranking purposes if the UV burst is over. If the UV burst is not over, this rising may still be caused by the ongoing burst and the first method of determining the end point still applies.

Figure 4 illustrates these first two points. The hourly values of foF2 for the event day are plotted against the Ten Quiet Day Means baseline. The UV burst starts at 1136LT so the baseline is shifted upwards to match the event day value of foF2 of 13.8 MHz at 1100LT. The UV burst ends at 1256LT. The hourly value of foF2 for the event day is declining at 1400LT. However, at 1500LT it rises slightly. Since the UV burst ended at 1256LT, the value of foF2 of 14.0 MHz at 1400LT is taken as the end point for ranking purposes.

the first previous and the first post day that are not one of the five disturbed days of the month according to the Kp scale. As in the previous baseline, if the day being studied is close to the beginning or the end of the month, one of these non-disturbed days may be determined by the previous/post month of geomagnetic Kp data. The averages of the previous/post closest non-disturbed days are abbreviated "Nond".

Averages of the Previous/Post Closest Days with Kp<4. The averages of the previous/post closest days with Kp<4 are the averages of the hourly values of foF2 for the first previous and the first post day in which the values of Kp are less than -4 for three hours prior to local noon relative to the observatory whose foF2 data is being used to nine hours past local noon relative to the observatory. As in the previous two baselines, if the day being studied is close to the beginning or the end of the month, one of the days with Kp<4 may be determined by the previous/post month of geomagnetic Kp data. The averages of the previous/post closest days with Kp<4 are abbreviated Kp<4.

Methods of Determining Rankings

Eight different methods are defined to determine the rankings of the baselines. In each method, the baselines are compared to the hourly values of foF2 for the event day on an individual basis. This is done by graphing the hourly values of foF2 for the event day under study with the values of foF2

Lower Quartile. The lower quartile are the foF2 median values for each hour of the lower half of a month's worth of data. Lower quartile is abbreviated as "Qrtl".

Ten Quiet Day Medians. The ten quiet day medians are the hourly medians of the values of foF2 for the ten quietest days of the month according to the geomagnetic Kp scale. The ten quiet day medians are abbreviated as "10QMd".

Five Quiet Day Means. The five quiet day means are the hourly means of the values of foF2 for the five quietest days of the month according to the geomagnetic Kp scale. The five quiet day means are abbreviated as "5QMn".

Ten Quiet Day Means. The ten quiet day means are the hourly means of the values of foF2 for the ten quietest days of the month according to the geomagnetic Kp scale. The ten quiet day means are abbreviated as "10QMn".

Averages of the Two Closest Quiet Days. The averages of the two closest quiet days are the hourly averages of the values of foF2 for the two quiet days that are closest to the day being studied. On days being studied that are close to the beginning or the end of the month, these quiet days may be from the previous/post month of geomagnetic Kp data. The averages of the two closest quiet days are abbreviated as "Av2Q".

Averages of the Previous/Post Closest Non-disturbed Days. The averages of the previous/post closest non-disturbed days are the averages of the hourly values of foF2 for the multiple comparison test is used to determine which rankings are significantly different.

Tukey's Procedure. If the computed value of the F statistic in the ANOVA is significant, the next step is to determine which of the baselines differ from each other as in the multiple comparisons test. One method of determining differences in baselines is Tukey's procedure (Devore, 1982: 355-357). The procedure involves a test statistic Q (different from the Q in the previous tests) called the studentized range statistic. Q is determined from a table of critical values for the studentized range distribution (Devore, 1982: 626-627) with alpha critical value, I numerator degrees of freedom and I(J - 1) denominator degrees of freedom where I is the number of baselines and J is the number of methods being compared. Once the Q statistic is determined, the value w can be determined and is defined as

$$w = Q[(MSE/J)\exp 1/2] \tag{4}$$

where MSE is determined from the ANOVA.

The baseline means are then listed in increasing order. Any pair of baseline means which differ by more than w are then judged to be significantly different. The same inference can be made about the actual baselines.

Since the critical value alpha no longer refers to a particular interval but to an experiment as a whole, it is called an experimentwise error rate instead of a confidence interval. This is interpreted to mean that one minus alpha percent of the time no erroneous claim would be made that two baselines differ if they actually have no statistical difference.

Duncan's Multiple-Range Test. Another method for determining which of the baselines differ from one another is the Duncan multiple-range test (Meek and Turner, 1983:478-480). Although Duncan's multiple-range test is of equal robustness with Tukey's procedure, the Duncan test is not as general. Therefor it has a better chance of determining statistical differences even though it is restricted to samples of equal size and to pairwise comparisons. First the standard error of the mean, s, must be determined. s is defined as

$$s = [(MSE/n)\exp 1/2] \quad (5)$$

where MSE is the mean square error from the ANOVA and n is the number of observations on which each mean is based.

Then the least significant range (LSR) must determined. LSR is defined as

$$LSR = r*s \quad (6)$$

where r is determined from a table of standardized ranges for Duncan's test using the number of means inclusive between the ordered pairs for which a difference is sought, the degrees of freedom for error used in determining MSE, and the confidence level desired (Meek and Turner, 1983:773).

The baseline means are then listed in increasing order. The comparison between any two baselines depends upon the number of means between them and the LSR. If the difference between the two baseline means is greater than the LSR, then the baselines are determined to be significantly different.

IV. Results and Analysis

This chapter is divided into three sections. Section one will analyze the results of individually applying each of the first eight methods of ranking to the baselines. Section two will analyze the results with the summation method to see if an improvement in delineating baselines can be made. Section three will analyze the effects of geographic parameters on the rankings of the baselines and the effect of removing the lower quartile from method 8.

Individual Results of First Eight Methods

The rankings for the individual events are listed in Appendix A for the first eight methods of ranking. Table 4 presents the results of the sum of the ranks, the mean rank, and the relative rank for each of the baselines.

To determine if there is any significant differences between the baselines for each of the methods, Friedman's test is applied to each of the methods. For each application of the test, the k sets of rankings are the number of events listed in Table III of Chapter III. The n treatment effects are the eight baselines being tested. The value of S is determined from k, n, and the sum of the ranks listed in Table IV. The test statistic Q is determined by these values. This Q value with 7 degrees of freedom is entered into the Chi-squared tables to determine a P value. Table V lists the

Table IV

Rank Summary for Methods 1 - 8

Method#		Mnth	Qrtl	10QMd	Baselines 5QMn	10QMn	Av2Q	Nond	Kp<4
	Rank Sum	176	226	161	209	173	236.5	232	239.2
1	Mean Rank	3.83	4.91	3.5	4.54	3.77	5.14	5.04	5.2
	Rel Rank	3	5	1	4	2	7	6	8
	Rank Sum	200	191	209	215	193	232.5	228.5	223
2	Mean Rank	4.26	4.06	4.45	4.57	4.11	4.95	4.86	4.75
	Rel Rank	3	1	4	5	2	8	7	6
	Rank Sum	204	195	209	215	183	234.5	227.5	224
3	Mean Rank	4.34	4.15	4.45	4.57	3.89	4.99	4.84	4.77
	Rel Rank	3	2	4	5	1	8	7	6
	Rank Sum	126	115	142	142	118	151.5	126	123.5
4	Mean Rank	4.35	3.97	4.9	4.9	4.07	5.22	4.35	4.26
	Rel Rank	4.5	1	6.5	6.5	2	8	4.5	3
	Rank Sum	96	83	97	96	85	111.5	91.5	96
5	Mean Rank	4.57	3.95	4.62	4.57	4.05	5.31	4.36	4.57
	Rel Rank	5	1	7	5	2	8	3	5
	Rank Sum	208	193	221	221	189	232.5	220.5	207
6	Mean Rank	4.43	4.11	4.7	4.7	4.02	4.95	4.69	4.4
	Rel Rank	4	2	6.5	6.5	1	8	5	3
	Rank Sum	166	162	194	192	163	194.5	173	159.5
7	Mean Rank	4.26	4.15	4.97	4.92	4.18	4.99	4.44	4.09
	Rel Rank	4	2	7	6	3	8	5	1
	Rank Sum	178	164	183	211	205	221.5	186.5	199
8	Mean Rank	4.14	3.81	4.26	4.91	4.77	5.15	4.34	4.63
	Rel Rank	2	1	3	7	6	8	4	5

Q values, the range of P values, and whether the P value is significant.

Since the Friedman test can only tell if two or more baselines are statistically different, if the P value is significant, the multiple comparison test is performed to

Table V

Friedman's Test for Significance

Method #	Q	P range	Is P Significant?
1	20.88	.01<P<.001	YES
2	6.29	.50<P<.70	No
3	7.45	.30<P<.50	No
4	6.85	.30<P<.50	No
5	4.23	.70<P<.80	No
6	5.62	.50<P<.70	No
7	7.12	.30<P<.50	No
8	9.78	.20<P<.30	No

determine which of the baselines are statistically different. The initial alpha level for the multiple comparison test is .30. If more than two baselines are found to differ, the alpha level is decreased until an alpha level of .05 is reached or until no more than two baselines are found to differ.

For method 1 with a 95% confidence level, the Ten Quiet Day Medians baseline is found to be significantly different from the Averages of the Two Closest Quiet Days and the Averages of the Previous/Post Closest Days with Kp<4 baselines. If the confidence level is lowered to 90%, the Ten Quiet Day Medians baseline is also found to be significantly different from the Averages of the Previous/Post Closest Non-disturbed Days baseline. If the confidence level is lowered to 85%, in addition to the previous baseline differences, the Ten Quiet Day Means baseline is found to be significantly different from the Previous/Post Closest Days with Kp<4 baseline. With a 70% confidence level, in addition to the previous baseline differences, the Ten Quiet Day Means baseline is found to be significantly different from the Averages of the Two Closest Quiet Days baseline, the Monthly Medians baseline is found to be significantly different from the Averages of the Two Closest Quiet Days and the Averages of the Previous/Post Closest Days with Kp<4 baselines, and the Lower Quartile baseline is found to be significantly different from the Ten Quiet Day Medians baseline.

In methods 2 thru 8, the results of the Friedman test imply that the null hypothesis of no significant differences between any of the baselines should be accepted.

Results for the Summation Method

The first analysis of the summation method still applies nonparametric techniques. The individual ranks for each of the first eight methods are summed. These sums are then divided by the sum of the events used in each method. This sum, 319, also becomes the k value for the Kendall coefficient of concordance and the multiple comparisons test. Table VI shows the rank sums, the mean rank, and the relative

Table VI

Summary for the Summation Method

	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Rank Sum	1354	1329	1416	1501	1309	1615	1486	1471
Mean Rank	4.245	4.166	4.439	4.705	4.103	5.063	4.657	4.612
Rel Rank	3	2	4	7	1	8	6	5

rank for each baseline.

The null hypothesis is that a strong measure of agreement exists between the baselines. Using the Kendall coefficient of concordance, W is found to equal 0.0155. This would tend to indicate strong disagreement between at least two of the baselines. The P-value for the Kendall coefficient is greater than .001.

Applying the multiple comparisons test with a 95% confidence level, the Averages of the Two Closest Quiet Days baseline is found to be significantly different from the Monthly Medians, the Lower Quartile, the Ten Quiet Day Means, and the Ten Quiet Day Medians baseline. Additionally, at the 90% confidence level, the Five Quiet Day Means baseline is found to be significantly different from the Ten Quiet Day Means baseline. At the 80% confidence level, in addition to the significantly different baselines already pointed out, the Lower Quartile baseline is found to be significantly different from the Five Quiet Day Means baseline and the Ten Quiet Day Means is found to be significantly different from the Averages of the Previous/Post Closest Non-disturbed Days baseline. At the 70% confidence level, additional significant difference can be found between the Ten Quiet Day Means baseline and the Averages of the Previous/Post Closest Days with $Kp<4$ baseline.

ANOVA. Assuming that the means of the individual methods are continuous and have a normal distribution, an

ANOVA test is applied to the individual means for each baseline over all eight methods. Table VII is the ANOVA table for the summation method.

Table VII

ANOVA of Summation Method

Source of Variation	d.f.	Sum of Squares	Mean Square	F
Treatments	7	SSTr = 5.9831	MSTr = 0.8547	$\frac{MSTr}{MSE} = 9.6837$
Error	56	SSE = 4.9428	MSE = 0.0883	
Total	63	SST = 10.926		

With a 99% confidence level, seven degrees of freedom for the numerator, and 56 degrees of freedom for the denominator, the upper-tail critical value for the F distribution is 2.984.

<u>Tukey's Procedure</u>. To determine if any of the baselines are significantly different, Tukey's procedure is applied. With an experimentwise error rate of .01, 8 numerator degrees of freedom, and 56 denominator degrees of freedom, the studentized range statistic, Q, is 5.278. The value needed between baselines for significant differences, w, is 0.5544. The baseline means are rank ordered below. Underlined baselines are those baselines which do not significantly differ from one another.

10QMn	Qrtl	Mnth	10QMd	Kp<4	Nond	5QMn	Av2Q
4.1056	4.1398	4.2699	4.4803	4.5829	4.6139	4.7114	5.0870

With a higher experimentwise error rate of .10, a greater delineation between significantly different baselines can be expected. With the same numerator and denominator degrees of freedom, the studentized range statistic, Q, is now 4.456. The value needed between baselines for significant differences, w, is now .4681. Once again, the underlined rank ordered means signify baselines that do not differ significantly. The results are presented below.

10QMn	Qrtl	Mnth	10QMd	Kp<4	Nond	5QMn	Av2Q
4.1056	4.1398	4.2699	4.4803	4.5829	4.6139	4.7114	5.0870

Duncan's Multiple Range Test. Another method of determining if there is any significant differences in baselines is the Duncan multiple range test. With 8 baselines to compare and an MSE of 0.0883, the standard error of the mean, s, is 0.1051. With 56 degrees of freedom for MSE and the desired confidence level, the values of standardized ranges, r, are determined. The number of means inclusive between ordered pairs range from 8 for the means at the extreme ends down to 2 for any two baseline means ranked next to each other. After the r values are determined, the LSR for each r is determined. The results for both an alpha of .01 and an alpha of .05 are presented in Table VII.

As in Tukey's procedure, the means are rank ordered. Starting at the extreme ends, the difference in baselines are

Table VIII

Values of r and LSR for Duncan's Test

Number of Means Between		8	7	6	5	4	3	2
alpha								
.01	r =	4.284	4.244	4.184	4.13	4.044	3.934	3.772
.05	r =	3.282	3.246	3.204	3.146	3.082	2.986	2.836
.01	LSR =	.4502	.446	.4397	.4341	.425	.4135	.3964
.05	LSR =	.3449	.3412	.3367	.3306	.3239	.3138	.2981

compared with the LSR for the appropriate confidence levels. If the difference in baselines is greater than the LSR, the baselines are determined to be significantly different. The results are shown in Table IX. Baselines that are signifi-

Table IX

Baseline Comparisons Using Duncan' Test

Means Between 8

Av2Q - 10QMn = .9814**

Means Between 7

Av2Q - Qrtl = .9472**
5QMn - 10QMn = .6058**

Means Between 6

Av2Q - Mnth = .8171**
5QMn - Qrtl = .5716**
Nond - 10QMn = .5083**

Means Between 5

Av2Q - 10QMd = .6067**
5QMn - Mnth = .4415**
Nond - Qrtl = .4741**
Kp<4 - 10QMn = .4773**

Means Between 4

Av2Q - Kp<4 = .5041**
5QMn - 10QMd = .2311

Means Between 3

Av2Q - Nond = .4731**
5QMn - Kp<4 = .1285
Nond - 10QMd = .1336
Kp<4 - Mnth = .313
10Qmd - Qrtl = .3405*
Mnth - 10QMn = .1643

Means Between 2

Av2Q - 5QMn = .3756*
5QMn - Nond = .0975
Nond - Kp<4 = .031
Kp<4 - 10QMd = .1026
10QMd - Mnth = .2104
Mnth - Qrtl = .1301
Qrtl - 10QMn = .0342

Means Between 4

Nond - Mnth = .344 *
Kp<4 - Qrtl = .4741**
10QMd - 10QMn = .3747*

** Significant Differences at 95% and 90% C.L.
* Significant Differences at 90% C.L.

cantly different at a 99% confidence level are double-asterisked while those different at a 95% confidence level are either double or single asterisked.

Results of Comparison Rankings

Although no statistical significance can be attached to the following comparisons, the results are presented to give an idea of the effects each comparison may have on the overall rankings.

Comparison Using Method 9. Method 9 is a comparison with Method 8 to see if the order of the baselines change when the lower quartile baseline is removed. The results of the mean ranks and the relative ranks are presented in Table X for both method 8 with the lower quartile removed and the relative ranks shifted by one and for method 9.

Table X

Comparison of Method 8 and 9

Method		Mnth	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
8	Mean Rank	4.140	4.256	4.907	4.767	5.151	4.337	4.628
	Rel Rank	1	2	6	5	7	3	4
9	Mean Rank	3.651	3.651	4.279	4.139	4.523	3.756	4.0
	Rel Rank	1.5	1.5	6	5	7	3	4

Seasonal Method. The seasonal method is a comparison test to see if seasonal variation has any effect on the rankings. Twelve events were between January and March, eleven events were between April and June, thirteen events were between July and September, and eleven events were between October and December. The comparison of mean ranks and relative ranks for this method is presented in Table XI.

Table XI

Seasonal Method Comparisons

Season	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
				Mean Ranks				
Jan-Mar	4.0	4.083	5.167	5.25	4.083	5.042	4.042	4.333
Apr-Jun	3.727	3.545	4.455	6.091	4.0	4.455	4.909	4.818
Jul-Sep	5.0	4.538	3.692	3.308	3.769	5.462	5.346	4.885
Oct-Dec	4.545	4.364	4.545	3.818	3.727	4.909	5.045	5.045
				Rel Ranks				
Jan-Mar	1	3.5	7	8	3.5	6	2	5
Apr-Jun	2	1	4.5	8	3	4.5	7	6
Jul-Sep	6	4	2	1	3	8	7	5
Oct-Dec	4.5	3	4.5	2	1	6	7.5	7.5

Geomagnetic Method. The geomagnetic method is a comparison based on low and mid-latitude observatories to see what effects geomagnetism may have on the rankings. Ten events from method 3 were from low-latitude observatories and thirty seven events were from mid-latitude observatories. The comparison of mean ranks and relative ranks is presented in Table XII.

Table XII

Geomagnetic Comparisons

Latitude	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
				Mean Ranks				
Low	5.3	3.0	4.6	4.5	4.3	5.75	5.15	3.4
Mid	4.081	4.459	4.405	4.595	3.784	4.784	4.757	5.135
				Rel Ranks				
Low	7	1	5	4	3	8	6	2
Mid	2	4	3	5	1	7	6	8

Individual Observatory Method. The individual observatory method separates method 3 into individual observatories for which four or more events are available. The Boulder observatory had seven events while the Maui observatory had four events. Those observatories with five events were Chung-Li, Taiwan, Lannion, Tomsk, and Wallops Island. The comparison of mean ranks and relative ranks is presented in Table XIII.

Table XIII

Individual Observatory Comparisons

	Mean Ranks							
Observatory	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Chung-Li	5.8	2.6	4.2	5.2	4.6	4.9	4.7	4.0
Lannion	5.6	4.2	3.0	4.6	4.2	3.8	5.3	5.3
Tomsk	4.0	3.8	4.4	5.6	4.8	4.3	3.7	5.4
Wallops Is	6.2	4.8	3.8	3.2	3.6	6.7	4.0	3.7
Maui	4.75	3.75	5.25	2.75	3.25	7.5	5.5	3.25
Boulder	3.571	3.286	5.0	5.0	4.714	4.143	4.857	5.429
	Rel Ranks							
Chung-Li	8	1	3	7	4	6	5	2
Lannion	8	3.5	1	5	3.5	2	6.5	6.5
Tomsk	3	2	5	8	6	4	1	7
Wallops Is	7	6	4	1	2	8	5	3
Maui	5	4	6	1	2.5	8	7	2.5
Boulder	2	1	6.5	6.5	4	3	5	8

The Friedman test was applied to individual data sets for each of these methods but the null hypothesis of no difference between any of the baselines could not be rejected for any of the comparisons. The next chapter will draw conclusions from the analyzed data.

Individual Rankings for Method 1

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	6	7	1	8	4	5	2.5	2.5
Dakar	770805	4	7	3	6	5	8	2	1
ChngL	771006	2	8	3	4	1	5	6.5	6.5
Bldr	771206	1	5	8	7	4	6	2.5	2.5
Tomsk	780108	4	5	1	6	3	7	2	8
ChngL	780203	6	2	7	1	3	5	8	4
ChngL	780208	2	6	7	8	1	4.5	3	4.5
ChCh	780211	8	7	1	3	2	5	5	5
Cnbra	780213	1	7	2	8	6	5	3.5	3.5
Maui	780221	1	8	7	2	4	3	5.5	5.5
Lnion	780306	8	3	2	1	4	6	6	6
NrfkI	780418	2	5	4	3	6	8	7	1
Bldr	780429	1	7	3	4	2	8	6	5
Kbrsk	780507	1	5	3	2	4	6	7.5	7.5
Lnion	780508	1	8	2	5	7	6	3.5	3.5
Bldr	780524	2	1	4	6	5	3	7	8
Bldr	780530	3	2	5	8	7	1	4	6
Cnbra	780622	2	6	7	8	5	1	3	4
Tomsk	780622	8	2	4	5	3	1	6.5	6.5
Vnbrg	780708	2	1	5	6	7	8	4	3
Bldr	780709	2	1	7	4	3	8	5	6
WlpsI	780710	6	8	3	7	2	1	4.5	4.5
Maui	780711	4	2	3	8	5	6	1	7
Kbrsk	780712	1	6	5	4	3	2	7.5	7.5

Appendix: Individual Rankings for First Eight Methods

This appendix contains the individual results of the rankings for each of the baselines using the first eight methods of determining the rankings. The remaining methods are rearrangements of the rankings for either method 3 or method 8 as explained in the text.

The following are the abbreviations and the full titles of the observatories that were used in the individual rankings:

Askbd	Ashkabad
Bldr	Boulder
Cnbra	Canberra
ChCh	Christchurch
ChngL	Chung-Li
Dakar	Dakar
Irkts	Irkutsk
Kbrsk	Khabarobsk
Lnion	Lannion
Lndau	Lindau
Maui	Maui
Mosc	Moscow
NrfkI	Norfolk Island
Tomsk	Tomsk
Vnbrg	Vandenberg AFB
WlpsI	Wallops Island

every fifteen minutes instead of every hour. In addition, ionograms for many observatories are taken every fifteen minutes but the foF2 values are only obtained from the ionograms on an hourly basis. To answer the question of what a proper cutoff point for fluence is for the hourly values, all events with all baselines above the event day foF2 and several events with fluences below 100 $ergs/cm^2$ should be correlated with available fifteen minute foF2 values to see if there is indeed an optimum fluence cutoff for hourly foF2 data.

The overall complexity of the problem suggests that the most fruitful area for further research is to find a baseline based on some parameter or index other than or in conjunction with Kp.

parameters of the F2 region with an acceptable accuracy.

Keeping simplicity in mind, the following areas are seen as areas for possible further research. The first area is an extension of this study using the same data. The available events should be randomly split into two data bases. Using one of these data bases and the three "better" baselines, the change in foF2 for each event day over each of these baselines should be calculated. Then a predictive model can be developed for each of the baseline/event days using techniques of multivariate analysis. The second data base would then be used as a sample to see if one of the predictive models does a better job of predicting than the other two models. This might provide the further delineation to find a "best" baseline that this study was unable to find.

The same study might also be continued with a larger data base spanning the entire eleven year cycle of solar activity. Several satellites exist that provide or have provided UV data. The basic problem is that some measure of equality between the satellite data would have to be determined. Some of the satellites provide high spectral resolution data while others like the SOLRAD satellite provide broadband data. At the least, a more complex form of integrating the data than a simple triangulation method would have to be employed to calculate fluence over a broad spectral bandpass.

A limited amount of foF2 data does exist that is taken highest value of fluence for the baselines rising above event day values was 200 ergs/cm^2. If we set the cutoff for fluence at 200 ergs/cm^2 thereby eliminating all events with all baselines above the event day values, we eliminate fourteen events including seven events with all baselines below the event day values. This changes the percentages to 0% events with baselines above daily values and 54.5% events with all baselines below daily values.

However, to maintain the largest possible data base, if we set the cutoff at 120 ergs/cm^2, we eliminate only seven events including two events with all baselines above and three events with all baselines below event day values. This changes the percentages to 5% (2) with all baselines above and 52.5% (22) with all baselines below the event day values. In other words, the UV burst for the smaller fluences may not last long enough or increase enough to cause the event day values of foF2 to rise above the baseline value for over an hour so that the difference in foF2 values is resolvable.

The overall problem is that no one fully understands all the cause and effect relationships of the F2 region yet. The region is so complex that no one factor such as Kp combined with past values of foF2 will allow an accurate prediction of future values of foF2 all of the time. If we had a full understanding of all the relationships, the effort would be simplified considerably. In the meantime, the search will continue for a simple but reliable way of predicting the having to be broken by using the closeness of values in the post hours of the burst. This is much simpler to match than methods 2 - 7 which rely on matching values over a four to eight hour period.

The surprising result of this study was that the methods which used averages of foF2 values on days close to the event day turned out to be the worst baselines. It was thought that because of the variability of the region, the closer days would be more likely to resemble the event day than a baseline based on several days. The exact opposite seems more likely. This brings up the question that if 30 days does a good job as a baseline, would 60 days do even better? The proven seasonal variability of the F2 region would seem to make this unlikely.

An assumption that may be questioned is requiring the baseline to remain under the hourly values of the event day over the time of the burst. The author feels that this was a valid assumption. The cutoff value for fluence of 100 ergs/ cm^2 is the more likely assumption to be questioned.

In examining the positioning of the baselines, 53.2% (25 events) of the events had all eight of the baselines below the hourly values of the event day. In contrast, 8.5% (4 events) of the events had all eight of the baselines rise above the hourly values of the event day. The other 38.3% (18 events) of the events had a mixture of baselines above and baselines below the hourly values of the event day. The

VI. Discussion and Recommendations

One of the topics not discussed in this study is which of the methods of determining rankings is the best method. The method of ranking is best determined by the type of study that the individual is conducting. If this study was extended into the actual effects of solar UV irradiance on the F2 region, the author would select method 1 for determining rankings for the following reason. Solar flares are one of the causes of ionospheric storms. One way of classifying these ionospheric storms is into positive storms and negative storms with negative storms being the most likely. One of the predominant effects of negative storms is a relatively sharp increase in foF2, in essence what this study was based on, followed by a decrease below normal foF2 values (Manley, 1981:77-78). These effects were obvious in several of the events that were studied although no statistics were kept on how many events showed the effects. However, if these effects do show up regularly, then methods 2 - 7, which attempt to match both the pre- and post-burst foF2, would be affected by negative storms. Method 1, which matches only the pre-burst values, would not be affected by negative storms if we assume that the start of the storm coincides with the start of the UV burst.

In addition, method 1 is based on matching one to three hours of foF2 values prior to the UV burst with a few ties rankings the most depending on geomagnetic latitude. However the low number of events for the low latitude observatories make it difficult to make any good assessments.

The position of the observatory itself would appear to have an effect on the rankings. In some cases a complete changing of the ranks can be noted. The Ten Quiet Day Means baseline seems most resilient to this effect. As in the geomagnetic method, the small number of events makes it difficult to imply any accurate assessment.

statement that can be made with a 95% confidence level is that the Averages of the Two Closest Quiet Days is the worst of the eight baselines.

The conclusions to be made from the remaining methods have no statistical backing to them. The conclusions are derived entirely from the rearrangement of relative rankings based on means. In method 9, it would appear that no distinction can be made on the effects of the Lower Quartile baseline depending on whether all baselines lie above or below the daily values of foF2. Had there been a distinction, the removal of the Lower Quartile baseline should have affected the relative rankings of the other seven baselines. The only effect shown is that the first two baselines are tied in Method 9 instead of being ranked a relative 1-2 as they were in method 8.

The seasonal method of comparing the rankings of method 3 does seem to show some effects. None of the baselines maintain a consistent ranking throughout all four seasons. The Ten Quiet Day Means and the Lower Quartile baselines do show consistency in being better than the other baselines in not showing a seasonal effect.

The geomagnetic method of comparing the rankings of method 3 also shows an apparent effect . Some of the baselines seem to be more affected then others. In particular, the Monthly Medians and the Averages of the Previous/Post Closest Days with Kp<4 baselines appear to change their

Table XVII

Summary of Statistically Better/Worse Baselines Using Duncan's Multiple Range Test on the Summation Method for Determining Rankings

Confidence Level	Better Baseline(s)	Worse Baseline(s)
99%	10QMn Qrtl Mnth 10QMd Kp<4 Nond	Av2Q
	10QMn Qrtl Mnth	5QMn
	10QMn Qrtl	Nond Kp<4
95%	10QMn Qrtl	10QMd
	Mnth 5QMn	Nond Av2Q

multiple range test for both a 99% and a 95% confidence level is summarized in Table XVII. As in the previous tests, the conclusion is that no overall "best" baseline exists among these eight baselines. Although it cannot be said with statistical conclusiveness, it would appear that the number of better baselines is narrowed to three. If the Monthly Medians baseline was significantly different from the Ten Quiet Day Medians and the Averages of the Previous/Post Closest Days with Kp<4 baselines, this statement could be made with at least a 95% confidence level. However, the only

Table XVI

Summary of Statistically Better/Worse Baselines
Using Tukey's Procedure on the
Summation Method for Determining Rankings

Experimentwise Error Rate	Better Baseline(s)	Worse Baseline(s)
1%	10QMn Qrtl Mnth 10QMd	Av2Q
	10QMn Qrtl	5QMn
5%	10QMn Qrtl	Nond
	10QMn	Kp<4
	Kp<4 Nond	Av2Q

baselines is summarized in Table XVI. The only improvement over nonparametric statistics is the inclusion of a significant difference between the Lower Quartile baseline and the Averages of the Previous/Post Closest Non-disturbed Days baseline and the inclusion of a significant difference between the Averages of the Previous/Post Closest Days with Kp<4 and the Averages of the Previous/Post Closest Non-disturbed Days baselines and the Averages of the Two Closest Quiet Days baseline. In addition, there is an improvement in the statistical confidence that can be put into the differentiations that were previously made.

The comparison of baselines as deduced from Duncan's

Table XV

Summary of Statistically Better/Worse Baselines
Using the Method of Comparisons on the
Summation Method for Determining Rankings

Confidence Level	Better Baseline(s)	Worse Baseline(s)
95%	10QMn	
	Qrtl	Av2Q
	Mnth	
	10QMd	
90%	10QMn	5QMn
80%	Qrtl	5QMn
	10QMn	Nond
70%	10QMn	Kp<4

that they are statistically different from all of the remaining baselines. These baselines are the Ten Quiet Day Means, the Lower Quartile, the Monthly Medians, and the Ten Quiet Day Medians.

In an effort to see if a "best" baseline exists or at least if the four previously mentioned baselines can be statistically proven to be better than the remaining four baselines, the assumptions of continuity and normality are made so that an extension to the use of parametric statistics can be made. The interpretation of the results of the ANOVA is that with 99% certainty, differences do exist between the baselines.

With both a 1% and a 5% experimentwise error rate, the interpretation of Tukey's procedure to differentiate between

Quiet Day Medians, the Ten Quiet Day Means, or the Monthly Medians baselines being statistically better than any of the remaining baselines. In addition, no statistical inferences can be made about differences between any of the baselines for the remaining seven methods of determining rankings for the baselines. The early conclusion then is that no "best" baseline exists statistically using the individual methods of determining baselines. The Ten Quiet Day Medians, the Ten Quiet Day Means, and the Monthly Medians baselines might be called the better three baselines when using method 1 but these three baselines cannot be statistically proven to be different from all of the remaining five baselines.

In an effort to see if a statistically "best" baseline does exist, the results of the individual methods of determining baselines are combined. Using nonparametric methods of statistical analysis, the conclusion from the low Kendall coefficient of concordance with a greater than 99.9% level of confidence is that two or more of the baselines are significantly different.

Using the multiple comparisons test, Table XV summarizes the proper interpretation of the results for the summation method with the better baselines shown on the left.

As in the individual methods, the overall conclusion is that no "best" method can be statistically inferred from the summation method. Four baselines seem to be better baselines although it cannot be proven with nonparametric statistics

V. Conclusions

In examining the results of the statistical analysis of the individual methods of determining baselines, only method 1 supports a conclusion that there is a difference between the baselines. Table XIV summarizes the proper interpretation of the results for the multiple comparisons test. The baselines that are statistically better are shown on the left side. In Table XIV and the tables that follow, the results of the comparison of baselines at a lower confidence level includes the results shown only at the higher confidence level.

No statistical inferences can be made about the Ten

Table XIV

Summary of Statistically Better/Worse Baselines
Method 1 for Determining Rankings

Confidence Level	Better Baseline(s)	Worse Baseline(s)
95%	10QMd	Av2Q Kp<4
90%	10QMd	Nond
85%	10QMn	Kp<4
70%	10QMn	Av2Q
	Mnth	Av2Q Kp<4
	10QMd	Qrtl

Individual Rankings for Method 1 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Bldr	780721	5	6	8	7	3	4	1.5	1.5
Lndau	780729	6	7	1	2	3	8	4.5	4.5
Askbd	780904	4	1	5	3	2	6	7.5	7.5
Lnion	780916	4	8	2	1	3	6	6	6
WlpsI	780924	1	4	2	5	3	8	6.5	6.5
WlpsI	781006	5	6	1	3	2	4	7.5	7.5
Lnion	781110	1	5	4	3	2	6	7.5	7.5
Irkts	787729	8	7	1	3	2	5	5	5
Cnbra	781130	3	5	1	8	2	4	6.5	6.5
ChngL	781210	5	4	1	2	3	7	7	7
ChCh	781213	6	4	3	5	7	8	1.5	1.5
Maui	781224	5	2	6	4	1	3	7.5	7.5
Bldr	790113	5	4	3	2	1	7	7	7
Tomsk	790205	8	1	6	7	5	3.5	2	3.2
WlpsI	790218	2	5	1	3	4	6.5	8	6.5
Tomsk	790225	5	1	3	4	2	6	7	8
Lndau	790309	4	8	1	5	2	3	6.5	6.5
Maui	790517	5	6	2	3	4	1	7	8
ChngL	790604	3	2	1	8	7	4	4	4
Tomsk	790908	7	8	5	1	6	3	3	3
WlpsI	790911	5	8	1	4	6	7	2.5	2.5
Askbd	791017	1	5	6	2	7	8	3.5	3.5
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Rank Sum		176	226	161	209	173	236.5	232	239.2

Individual Rankings for Method 2

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
Dakar	770805	5	2	4	8	7	3	6	1
ChngL	771006	4	3	1	5	2	6	7.5	7.5
Lnion	771008	5	6	3	2	4	1	7.5	7.5
Bldr	771206	4	5	8	7	6	3	1.5	1.5
Tomsk	780108	3	4	2	8	1	6	5	7
ChngL	780203	4	1	5	7	6	8	3	2
ChngL	780208	8	3	6	1	2	4.5	7	4.5
ChCh	780211	5	8	6	7	4	2	2	2
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
Maui	780221	3	4	7	5	6	8	1.5	1.5
Lnion	780306	8	4	6	7	5	2	2	2
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	6	5	1	4
Kbrsk	780507	4	1	3	5	2	8	6.5	6.5
Lnion	780508	7	1	2	8	5	6	3.5	3.5
Bldr	780524	1	3	4	6	2	5	7	8
Bldr	780530	2	4	6	8	7	1	5	3
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	2	1	8	3.5	3.5
Maui	780711	6	5	3	1	4	7	8	2

Individual Rankings for Method 2 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Kbrsk	780712	1	6	3	4	2	5	7.5	7.5
Bldr	780721	5	2	3	4	6	1	7.5	7.5
Lndau	780729	7	8	4	1	3	2	5.5	5.5
Askbd	780904	4	1	6	2	3	5	7.5	7.5
Lnion	780916	2	8	1	4	3	6	6	6
WlpsI	780924	7	2	1	6	5	8	3.5	3.5
WlpsI	781006	8	4	6	3	7	5	1.5	1.5
Lnion	781110	6	1	5	2	3	4	7.5	7.5
Irkts	787729	1	4	5	2	3	7	7	7
Cnbra	781130	1	5	3	8	2	4	6.5	6.5
ChngL	781210	5	4	8	6	7	2	2	2
ChCh	781213	6	7	1	3	2	8	4.5	4.5
Maui	781224	8	1	4	2	3	7	5.5	5.5
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
WlpsI	790218	2	3	5	1	4	6.5	8	6.5
Tomsk	790225	1	2	4	5	3	6	7	8
Lndau	790309	2	8	3	7	6	1	4.5	4.5
Maui	790517	2	5	6	3	1	8	7	4
ChngL	790604	8	2	1	7	6	4	4	4
Tomsk	790908	8	6	2	1	7	4	4	4
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
Askbd	791017	1	7	6	2	3	8	4.5	4.5
Rank Sum		200	191	209	215	193	232.5	228.5	223

Individual Rankings for Method 3

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
Dakar	770805	5	2	4	8	7	3	6	1
ChngL	771006	4	3	1	5	2	6	7.5	7.5
Lnion	771008	5	6	3	2	4	1	7.5	7.5
Bldr	771206	4	5	8	7	6	3	1.5	1.5
Tomsk	780108	4	5	2	8	1	6	3	7
ChngL	780203	4	1	5	7	6	8	3	2
ChngL	780208	8	3	6	1	2	4.5	7	4.5
ChCh	780211	5	8	6	7	1	3	3	3
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
Maui	780221	3	4	7	5	6	8	1.5	1.5
Lnion	780306	8	4	5	7	6	2	2	2
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	5	6	1	4
Kbrsk	780507	5	1	2	4	3	8	6.5	6.5
Lnion	780508	7	2	1	8	5	6	3.5	3.5
Bldr	780524	1	3	4	6	2	5	7	8
Bldr	780530	2	4	6	8	7	1	5	3
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	4	1	8	2.5	2.5
Maui	780711	6	5	4	1	3	7	8	2

Individual Rankings for Method 3 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Kbrsk	780712	1	6	4	3	2	5	7.5	7.5
Bldr	780721	5	2	3	4	6	1	7.5	7.5
Lndau	780729	8	7	4	1	2	3	5.5	5.5
Askbd	780904	4	1	6	2	3	5	7.5	7.5
Lnion	780916	2	8	1	4	3	6	6	6
WlpsI	780924	7	3	2	6	1	8	4.5	4.5
WlpsI	781006	8	5	6	3	7	4	1.5	1.5
Lnion	781110	6	1	5	2	3	4	7.5	7.5
Irkts	781129	1	4	5	2	3	7	7	7
Cnbra	781130	2	5	3	8	1	4	6.5	6.5
ChngL	781210	5	4	8	6	7	2	2	2
ChCh	781213	6	7	1	3	2	8	4.5	4.5
Maui	781224	8	1	4	2	3	7	5.5	5.5
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
WlpsI	790218	2	3	5	1	4	6.5	8	6.5
Tomsk	790225	1	2	4	5	3	6	7	8
Lndau	790309	2	8	3	7	6	1	4.5	4.5
Maui	790517	2	5	6	3	1	8	7	4
ChngL	790604	8	2	1	7	6	4	4	4
Tomsk	790908	8	7	2	1	6	4	4	4
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
Askbd	791017	1	7	6	2	3	8	4.5	4.5
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Rank Sum		204	195	209	215	183	234.5	227.5	224

Individual Rankings for Method 4

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
Dakar	770805	5	2	4	8	7	3	6	1
ChngL	771006	4	3	1	5	2	6	7.5	7.5
Blaer	771206	4	5	8	7	6	3	1.5	1.5
ChngL	780203	4	1	5	7	6	8	3	2
ChCh	780211	5	8	6	7	1	3	3	3
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
Maui	780221	3	4	7	5	6	8	1.5	1.5
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	5	6	1	4
Kbrsk	780507	5	1	2	4	3	8	6.5	6.5
Lnion	780508	7	2	1	8	5	6	3.5	3.5
Bldr	780524	1	3	4	6	2	5	7	8
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	4	1	8	2.5	2.5
Maui	780711	6	5	4	1	3	7	8	2
Bldr	780721	5	2	3	4	6	1	7.5	7.5
Lndau	780729	8	7	4	1	2	3	5.5	5.5
WlpsI	780924	7	3	2	6	1	8	4.5	4.5
WlpsI	781006	8	5	6	3	7	4	1.5	1.5
Irkts	781129	1	4	5	2	3	7	7	7

Individual Rankings for Method 4 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
ChngL	781210	5	4	8	6	7	2	2	2
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
Maui	790517	2	5	6	3	1	8	7	4
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
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Rank Sum		126	115	142	142	118	151.5	126	123.5

Individual Rankings for Method 5

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
ChngL	771006	4	3	1	5	2	6	7.5	7.5
ChngL	780203	4	1	5	7	6	8	3	2
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	5	6	1	4
Lnion	780508	7	2	1	8	5	6	3.5	3.5
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	4	1	8	2.5	2.5
Maui	780711	6	5	4	1	3	7	8	2
Bldr	780721	5	2	3	4	6	1	7.5	7.5
Lndau	780729	8	7	4	1	2	3	5.5	5.5
WlpsI	780924	7	3	2	6	1	8	4.5	4.5
WlpsI	781006	8	5	6	3	7	4	1.5	1.5
Irkts	781129	1	4	5	2	3	7	7	7
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
Rank Sum		96	83	97	96	85	111.5	91.5	96

Individual Rankings for Method 6

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
Dakar	770805	5	2	4	8	7	3	6	1
ChngL	771006	4	3	1	5	2	6	7.5	7.5
Lnion	771008	7	8	3	2	6	1	4.5	4.5
Bldr	771206	4	5	8	7	6	3	1.5	1.5
Tomsk	780108	7	8	5	3	4	1	6	2
ChngL	780203	4	1	5	7	6	8	3	2
ChngL	780208	7	3	6	1	2	4.5	8	4.5
ChCh	780211	5	8	6	7	1	3	3	3
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
Maui	780221	3	4	7	5	6	8	1.5	1.5
Lnion	780306	1	5	6	8	7	3	3	3
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	5	6	1	4
Kbrsk	780507	5	1	2	4	3	8	6.5	6.5
Lnion	780508	7	2	1	8	5	6	3.5	3.5
Bldr	780524	1	3	4	6	2	5	7	8
Bldr	780530	1	4	6	8	7	3	5	2
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	4	1	8	2.5	2.5
Maui	780711	6	5	4	1	3	7	8	2

Individual Rankings for Method 6 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Kbrsk	780712	1	6	4	3	2	5	7.5	7.5
Bldr	780721	5	2	3	4	6	1	7.5	7.5
Lndau	780729	8	7	4	1	2	3	5.5	5.5
Askbd	780904	4	1	6	2	3	5	7.5	7.5
Lnion	780916	2	4	1	5	3	7	7	7
WlpsI	780924	7	3	2	6	1	8	4.5	4.5
WlpsI	781006	8	5	6	3	7	4	1.5	1.5
Lnion	781110	6	1	5	2	3	4	7.5	7.5
Irkts	781129	1	4	5	2	3	7	7	7
Cnbra	781130	2	5	3	8	1	4	6.5	6.5
ChngL	781210	5	4	8	6	7	2	2	2
ChCh	781213	6	7	1	3	2	8	4.5	4.5
Maui	781224	8	1	4	2	3	7	5.5	5.5
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
WlpsI	790218	5	6	8	4	7	1.5	3	1.5
Tomsk	790225	3	4	6	7	5	8	1	2
Lndau	790309	2	3	4	8	7	1	5.5	5.5
Maui	790517	2	5	6	3	1	8	7	4
ChngL	790604	8	2	1	7	6	4	4	4
Tomsk	790908	8	3	4	1	2	6	6	6
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
Askbd	791017	4	7	6	5	1	8	2.5	2.5
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Rank Sum		208	193	221	221	189	232.5	220.5	207

Individual Rankings for Method 7

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	2	6	5	4	3	1	7.5	7.5
Dakar	770805	5	2	4	8	7	3	6	1
ChngL	771006	4	3	1	5	2	6	7.5	7.5
Bldr	771206	4	5	8	7	6	3	1.5	1.5
Tomsk	780108	7	8	5	3	4	1	6	2
ChngL	780203	4	1	5	7	6	8	3	2
ChngL	780208	7	3	6	1	2	4.5	8	4.5
ChCh	780211	5	8	6	7	1	3	3	3
Cnbra	780213	1	4	8	7	6	5	2.5	2.5
Maui	780221	3	4	7	5	6	8	1.5	1.5
Lnion	780306	1	5	6	8	7	3	3	3
NrfkI	780418	3	7	4	6	2	8	5	1
Bldr	780429	3	2	7	8	5	6	1	4
Kbrsk	780507	5	1	2	4	3	8	6.5	6.5
Lnion	780508	7	2	1	8	5	6	3.5	3.5
Bldr	780524	1	3	4	6	2	5	7	8
Bldr	780530	1	4	6	8	7	3	5	2
Cnbra	780622	3	5	7	6	2	1	4	8
Tomsk	780622	5	2	6	7	8	1	3.5	3.5
Vnbrg	780708	3	2	8	6	5	7	1	4
Bldr	780709	2	3	4	1	5	7	6	8
WlpsI	780710	6	7	5	4	1	8	2.5	2.5
Maui	780711	6	5	4	1	3	7	8	2
Bldr	780721	5	2	3	4	6	1	7.5	7.5

Individual Rankings for Method 7 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Lndau	780729	8	7	4	1	2	3	5.5	5.5
Lnion	780916	2	4	1	5	3	7	7	7
WlpsI	780924	7	3	2	6	1	8	4.5	4.5
WlpsI	781006	8	5	6	3	7	4	1.5	1.5
Irkts	781129	1	4	5	2	3	7	7	7
ChngL	781210	5	4	8	6	7	2	2	2
Bldr	790113	8	4	3	1	2	6	6	6
Tomsk	790205	2	3	8	7	6	4.5	1	4.5
WlpsI	790218	5	6	8	4	7	1.5	3	1.5
Tomsk	790225	3	4	6	7	5	8	1	2
Lndau	790309	2	3	4	8	7	1	5.5	5.5
Maui	790517	2	5	6	3	1	8	7	4
Tomsk	790908	8	3	4	1	2	6	6	6
WlpsI	790911	8	6	1	2	5	7	3.5	3.5
Askbd	791017	4	7	6	5	1	8	2.5	2.5
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Rank Sum		166	162	194	192	163	194.5	173	159.5

Individual Rankings for Method 8

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Mosc	770412	5	1	8	7	6	4	2.5	2.5
Dakar	770805	2	6	1	4	3	7	5	8
ChngL	771006	5	1	4	7	6	8	2.5	2.5
Lnion	771008	6	8	1	7	3	2	4.5	4.5
Bldr	771206	4	5	6	8	7	3	1.5	1.5
Tomsk	780108	1	6	4	5	3	2	8	7
ChngL	780203	4	1	8	7	5	6	2	3
ChngL	780208	2	3	1	8	4	5.5	7	5.5
ChCh	780211	1	2	7	8	3	5	5	5
Cnbra	780213	1	4	5	3	2	8	6.5	6.5
Maui	780221	4	2	1	5	3	6	7.5	7.5
Lnion	780306	4	5	1	3	2	7	7	7
NrfkI	780418	5	1	6	3	7	4	2	8
Bldr	780429	3	6	1	8	2	4	5	7
Kbrsk	780507	6	8	4	3	5	7	1.5	1.5
Lnion	780508	1	3	4	2	5	6	7.5	7.5
Bldr	780524	3	1	6	7	8	5	4	2
Bldr	780530	4	1	5	6	8	7	2	3
Cnbra	780622	3	6	8	7	4	5	2	1
Tomsk	780622	5	8	4	3	1	2	6.5	6.5
Vnbrg	780708	7	1	4	3	5	8	2	6
Bldr	780709	4	5	2	1	6	7	3	8
WlpsI	780710	2	1	5	7	6	8	3.5	3.5
Maui	780711	3	1	2	4	5	8	7	6

Individual Rankings for Method 8 (cont)

Statn	Date	Mnth	Qrtl	10QMd	5QMn	10QMn	Av2Q	Nond	Kp<4
Bldr	780721	4	3	6	5	8	7	1.5	1.5
Lndau	780729	6	8	2	1	3	7	4.5	4.5
Askbd	780904	5	3	4	8	6	7	1.5	1.5
Lnion	780916	3	4	2	5	1	7	7	7
WlpsI	780924	7	8	6	4	5	1	2.5	2.5
WlpsI	781006	8	3	6	5	7	4	1.5	1.5
Irkts	787729	8	1	6	5	7	3	3	3
ChngL	781210	5	1	2	3	4	7	7	7
Maui	781224	6	2	4	3	5	1	7.5	7.5
Bldr	790113	8	5	7	4	6	2	2	2
Tomsk	790205	5	1	7	8	6	2.5	4	2.5
WlpsI	790218	1	7	2	3	6	4.5	8	4.5
Tomsk	790225	4	1	6	8	5	7	2	3
Lndau	790309	4	7	1	8	2	3	5.5	5.5
Maui	790517	2	5	6	7	8	1	3	4
ChngL	790604	2	1	5	4	3	7	7	7
Tomsk	790908	1	4	5	2	3	7	7	7
WlpsI	790911	8	6	3	1	7	2	4.5	4.5
Askbd	791017	6	8	5	1	4	7	2.5	2.5
Rank Sum		178	164	183	211	205	221.5	186.5	199

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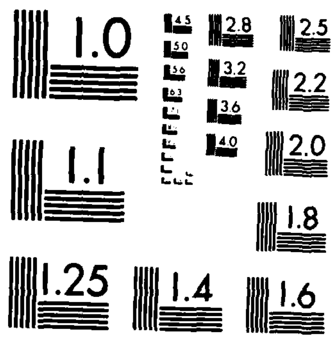

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Title: A COMPARISON OF FOF2 BASELINES FOR USE IN STUDYING THE EFFECTS OF SOLAR ULTRAVIOLET IRRADIANCE ON THE F2 REGION OF THE IONOSPHERE

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This study determined if one or more representations of a baseline foF2 are statistically more accurate than others in representing a background foF2 for studying the effects of solar UV irradiance on the F2 region of the ionosphere. Event days for comparing baselines were determined from satellite recorded UV bursts. Observations from an ionosonde close to local noon at the time of the UV burst were used for foF2 values. Eight baselines were rank ordered against the hourly foF2 values for the event day using eight methods of comparison.

The rankings were statistically analyzed using both parametric and nonparametric methods. Using parametric methods, only one baseline was found to be statistically worse than the others. Using nonparametric methods, baselines based on the lower quartile median and the means of the hourly values of the ten quietest days of the month using the Kp scale were found to be statistically better than four of the baselines. However, no statistical difference could be found between these two baselines and the currently accepted baseline of the monthly median values of foF2.

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