IPS SCALING CONVENTIONS

By Phil Wilkinson

First Edition - March 1984

Second Edition March 1990

IPS Scaling Course First edition 1991

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1. SCALING IONOGRAMS.

The IPS scaling conventions were developed over many years and were eventually documented, as far as was possible, in 1982-84. The first edition of this report was the culmination of that effort. The second edition consolidated some scaling options, clarified parts of the text that were obscure (some remain) and included comments from people who read the text. Special thanks to Alan Rodger, Peter Davies, George Goldstone, and Paul Alekna for this assistance.

In 1991, some of the general material in the S*caling Conventions* was used to form a course on scaling ionograms. That material is now merged with the S*caling Conventions* to again make one document.

The material in the following major sections was used to produce the scaling rules in the IPS scaling stations. The scaling station has been developed to coax the scaler into developing good scaling habits. There are three themes::

- parameters should be scaled with reasonable values and limit values are checked to ensure this happens,
- where scaling letters are used, the scaler is queried if pairs of letters are unlikely for a parameter, and this is the subject of much of this report,
- the scaling of all parameters for an ionogram should be internally consistent.

This first section gives a general overview of scaling ionograms. It is not intended to be precise but rather introduces the scope of the exercise. The second section draws out, in greater detail, a number of scaling issues. The scaling letters are then introduced in the fourth section, followed by a section that describes flags. The fifth section discusses, in detail, scaling each of the parameters. These last two sections contain a good bit of information that a novice scaler does not need to be fully familiar with.

1.1 OVERVIEW

This section is an overview of the scaling details that will be covered in is note.

1.1.1 Basic Scaling

Scaling ionograms means many things. This overview notes the basic areas that should be second nature when looking at ionograms.

- The regions of the ionosphere and effects that are important
    - Normal regions: E, F1, F2 and sporadic E
    - Less familiar: E2, F0.5, F1.5, meteors
    - Notable conditions: spread F, absorption effects
    - Notorious effects: equipment failure, interference

Geometry of reflections
- think specular
- know the difference between thick and thin layers; retardation and blanketing,

- recognise examples of layers
- develop concepts of oblique returns; their recognition and elimination when scaling
- recognise unusual things; particle E, spurs, travelling disturbances

Resources

- UAG-23A; the bible of all scalers by Rawer and Piggott
- UAG-50; the High Latitude Supplement by Piggott
- INAG; an outlet for frustration for some, a link with all the other scalers for others
- Japanese scaling manual
- Scaling aids
- IPS High latitude notes
- IPS scaling notes - still under revision
- ionograms and your own common sense
    - Look at and scale (even mentally) lots of ionograms.

An important resource, once scaling becomes familiar, is examples of unusual ionograms and how they are scaled. As you scale, note any unusual ionograms for later discussion.

1.1.2 Nuts and Bolts of Scaling

A systematic approach is needed if one person's scaling is to have some chance of resembling another for the same awkward ionogram. Scaling conventions are the basis of this system and these conventions are expressed by scaling letters.

There are three themes.

- Accuracy of the scaling - qualifying letters
    - quantitative accuracy; E, D, U
    - unquantifiable errors; J, A, O, Z
    - unknown errors; I
- Reason for the loss of accuracy - descriptive letters
    - Gaps; A, B, C, G, L, R, S, W, Y
    - bumps; H, V
    - things; F, K, P, Q, X, Z
- Flags
    - which are things by another name and will become more obvious later.

1.1.3 The Parameter s

The features of the ionosphere considered important and easily recognised by a wide range of scalers from a single ionogram are the attributes of ionograms that are scaled. These are well known because of their simplicity, reproducibility and utility. The more complex an ionogram, the less likely it is that the scaled values will tell the full story - which can lead to frustration for good scalers.

Geoff King made the comment "nothing of interest in an ionogram is retained in the scaled values". As you come to enjoy scaling you will understand why this is not the bad news it appears to be.

The conventional parameters are: fmin, foE, foF1, foF2, foEs, fbEs, fxI, h'E, h'F, h'F2, h'Es, M(3000)F2, type of Es and at IPS we scale two more: range spread and frequency spread.

There are self consistent ways in which scaling letters can be used with the parameter s and these two items together offer a powerful, if incomplete, way of describing an ionogram.

1.1.4 Examples

As a novice scaler becomes more interested in understanding how ionograms are formed, some of the work mentioned below will become more accessible and interesting.

There are particular features which are best dealt with as units as they contain most, if not all, of the complexity of scaling. Understand these features and you have gone a long way towards understanding the complexities of the ionosphere.

- Spread F: a well known night time phenomenon. Look at Cummack, Bowman results. These are "small scale" irregularities.
- Troughs: a sub auroral feature - Bowman's work initially. These are large scale features.
- Travelling ionospheric disturbances - Munro, and many, many others. These are medium scale features.
- sporadic E - how to measure foEs, sometimes cited as the perfect example of scaling foolishness (it isn't).
- Ionospheric storms - how to recognise a small one is the key to forecasting them. These are global events.

Then there are distinctive aspects about the ionosphere in regions.

- high latitudes - particle effects (Es-K, B) and troughs and ridges of ionisation
- low latitudes - absorption, thick ionosphere and variability

1.1.5 Applications

The data is scaled to serve some purpose - an application. Generally, the scaling conventions were decided with communicators in mind and scientists as a secondary, but important, group. This needs to be appreciated.

1.2 The Objectives of the Course

At the end of the course everyone will be able to:

- recognise and scale all the conventional parameter s from an ionogram,
- use scaling letters effectively,
- recognise good and bad ionograms,
- use simple principles to clarify scaling of more complex ionograms,
- appreciate the variable sources affecting ionograms and how these relate to communication circuits,
- recognise large scale ionospheric processes and appreciate their likely global extent,
- be more confident in assessing ionospheric effects on communications systems.

Practical experience will be **essential** as scaling is mainly a "hands-on" exercise.

1.3 Supporting Physics Training Not Formally Developed

The following are some areas of physics that are not essential for developing competent scaling habits, but which make the task rather more interesting.

1.3.1 The Atmosphere and Ionosphere

- Develop concepts of an atmosphere and the natural coordinate system of atmospheres
    - density,
    - collisions,
    - hydrostatic equilibrium,
    - scale heights - a density based unit of height.
    - heating - temperature.
- And develop basic ideas of fluids and extend these to the ionosphere;
    - winds,
    - waves and tides,
- Having grasped how an atmosphere operates as a medium, look at how an ionosphere appears within it and what processes affect it.
    - Understand the sources of ionisation,
        - solar radiation,
        - energetic particles
        - and the important layer properties;
    - chemistry; recombination and attachment and how they change with altitude,

- dynamics; ambipolar diffusion, winds, electric fields - and why there is a nighttime ionosphere.

1.3.2 Ionospheric Effects on Radio Waves

Having an idea of what an ionosphere is and the forces that mold it, how does it affect things?

- What is a parabolic layer? How does it differ from a Chapman layer?
- How is propagation on a flat earth different from a curved earth?
- What do we expect an ionogram to look like, given an electron density profile?
- What is magnetoionic theory?
- What can we learn from treating an ionogram as an example of a short path oblique circuit?

Then the applications:

- ionospheric predictions,
- field strengths,
- ray tracing,
- fading, noise and signal quality

All these concepts are linked to the analysis of ionograms and some will be commented on in the course while some won't at this stage.

2. THE SCALING ENVIRONMENT

2.1 Introduction

It is difficult to describe a particular ionogram using just a few descriptive and qualifying letters attached to various parameters scaled from the ionogram. It is equally difficult to describe, in a few words, both the object and result of the application of the various scaling conventions advocated by URSI in UAG-23A. Consequently, different interpretations exist for the various scaling conventions within different station networks and within the same network at different times. The object of this report is to define the current manual scaling conventions used within IPS. These conventions should coincide with the rules proposed by URSI, but where doubts, or differences, exist they will be highlighted by discussions.

After a general discussion of aspects of scaling that are common to all parameters, each parameter is discussed separately. The object of these discussions is to explain the reasons for accepting or rejecting various combinations of qualifying and descriptive letter usage with each parameter. Recommended tables of acceptable scaling letter combinations for all parameters appear at the end of this report. These tables form the basis for validating the scaling of ionograms in the IPS computer scaling system.

Throughout this report it is assumed that the reader is familiar with the problems associated with scaling ionograms. Explanations given are intended to define current practices at IPS (together with some rationale for these practices). Consequently this report is not intended to be a training manual. Reference will frequently be made to other sources to emphasise a point. The prime references are UAG-23A and INAG bulletins.

In most places, where IPS conventions are likely to differ the difference is printed in *italics*.

2.2 General Points on Scaling

2.2.1 Scaling an ionogram

When a scaler first looks at an ionogram, various general principles come into focus. These are discussed here.

2.2.1.1 The general philosophy of IPS scaling

As section 0.2 of (UAG-23A, pp. 2-4) indicates, there are a variety of reasons for scaling ionograms and a variety of reasons for selecting parameters to scale. As shown in UAG-23A, the most workable ionogram scaling option for a worldwide network is to produce a simplified parametric description of the overhead ionosphere. At IPS this approach is adopted, although some emphasis is also placed on attempting to scale the ionogram in such a way that parameters describe the ionogram being scaled. There is no conflict between these two approaches (options a and b of section 0.22, UAG-23A) because IPS scaling stresses the importance of describing the overhead ionosphere. In other words, the parameters scaled refer to the ordinary wave vertical reflection, or principal trace, and oblique returns, multiples and other magnetoionic returns are used to clarify the principal trace.

This distinction becomes important when dealing with phenomena such as particle E - IPS has chosen to continue to distinguish between overhead particle E (Es - k) and oblique returns from a particle E cloud (Es - r). Had the 1980 URSI scaling option been adopted, and the Es-k and r types been treated as one type, the distinction associated with overhead traces would have become less distinct.

In effect, the scaler is required to use all available evidence on the ionogram, together with simple models of reflecting surfaces, to describe the observed overhead ionosphere. When conflict arises in the interpretation of this evidence, some skill is required by the scaler to deduce where the overhead trace should be and to place accuracy limits (see later in this section) on the estimates.

Problems associated with oblique returns can become extreme at higher latitudes, where ridges of ionisation close to a station dominate ionograms. At IPS, fxI is the only parameter scaled for studying these oblique returns.

2.2.2 What is overhead

There is no consensus opinion on overhead. At British Antarctic Survey, they discussed the issue at length and decided that anything within ±40° of the station zenith at Halley Bay is "overhead". However, this definition, they felt, could be dependent on the magnetic coordinates of a station.

At IPS, we have usually regarded overhead in terms of the multiples of a trace. Where the second order multiple is consistent with the primary trace, the overhead echo has been identified. During spread F, some sporadic E and TIDs this leads to minor problems at mid latitudes and rather larger problem at high latitudes. However, no more definitive advice has been suggested. (Note: TID = Travelling Ionospheric Disturbance: a neutral atmosphere gravity wave coupled to the ionised atmosphere causing local ionisation gradients).

Routine scaling of ionograms consists of scaling the ionogram recorded on the hour. While extrapolation in time is frequently used to aid identification of the principal trace, at IPS interpolation is not used to replace an unusual hourly value atypical of ionospheric conditions on the hour. In UAG-23A, section 0.25, p3 this latter option appears to be stressed. If it were applied as stated, the scaler's task would become much more complex and interpretation of scaling rules more ambiguous. At IPS we scale "the ionogram on the hour" rather than "the ionosphere representative of the hour"

2.2.3 The parameters scaled

Fifteen ionospheric parameters are scaled from hourly ionograms at IPS; of these thirteen are standard parameters. They are the seven frequency parameters; fmin, foE, foEs, fbEs, foF1, foF2 and fxI, the four height parameters; h'E, h'Es, h'F and h'F2, M(3000)F2 and the type of sporadic E. All parameters are interpreted as described in sections 1.1 to 1.5 of UAG-23A. In addition, two local spread F parameters are scaled. These are range spread and frequency spread and are not considered in this report.

2.3 U E D - Accuracy of scaling (ref. sections 2.2, 2.4 and 2.5 of UAG-23A)

The qualifying letters D, E, U, I, J, O and Z are used to indicate how accurately an ionogram has been scaled. In this section the idea of accuracy is developed with special reference to D, E and U. The other letters are then introduced in later sub-sections. The qualifying letter A is not introduced until the discussion of fbEs since this is the only parameter it is scaled with.

Correct interpretation of the accuracy rules for scaling ionograms can give considerable trouble to scalers, partly because UAG-23A advocates at least two systems of accuracy explicitly and a third implicitly and partly because objective accuracy is less important than more qualitative judgments about the nature of the ionogram being scaled. This section discusses the possible interpretations of accuracy proposed in UAG-23A and outlines the preferred approach adopted by IPS.

2.3.1 Types of accuracy interpretation

There are three methods available to the scaler for interpreting the accuracy of a particular parameter.

2.3.1.1 Subjective assessment: measures of peculiarity

This mode allows more imaginative scaling. A good scaler may have greater freedom to speculate and formulate new interpretations if using qualitative limits, but it is too hard to maintain consistency between scalers.

Historically, this was the early approach adopted by many networks. While numerical accuracy could be assessed for simple ionograms, more complex ionograms were often difficult to interpret. The qualifying letter U was originally introduced to mean unusual and accounted subjectively for the expected (but unmeasurable) inaccuracies likely in the value scaled. Limits could then be set in a similar fashion although this does not appear to have been the case. Limits (E lower, D upper) have evidently always been objective and set currently at 20% of the observed boundary for the principal trace.

This approach is supported by analyses of scaling errors - subjective errors account for a far larger proportion of the total scaling error than pure objective errors. (Wilkinson, 1978)

2.3.1.2 Objective accuracy: measures of accuracy (UAG-23A, section 2.2)

The converse of subjective assessment is to adopt pure accuracy rules. This is achieved by defining δ such that;

$$\delta = \text{observed trace position - expected position}$$

where the expected position is found by inspection of the ionogram. Defined like this, accuracy has an absolute quality. Some flexibility can still be retained by remembering that the accuracy limits apply to **reasonable doubt**, but the accuracy limits (U, E, and D) are anchored to the last visible part of the principal echo being scaled.

This approach has its main advantage in ease of teaching and application. However, by making the limits objective, the meaning of **'reasonable doubt'** is compromised. As a result, many values are not scaled, replacement letters being used instead. In the presence of scatter traces (i.e. Spread F) this is a severe disadvantage.

2.3.1.3 Objective interpretation: measures of consistency (UAG-23A, fig 2.2b)

A blend of both approaches is obviously desirable. Some objective limits are required, but they should be applied to interpretation of the ionogram rather than be anchored to features on the ionogram. Accuracy now becomes a measure of the scalers consistency in interpreting the ionogram.

Scaling a parameter follows an iterative approach, extra information being assessed and reassessed as the final interpretation is refined. Roughly four steps can be identified:

(i) the principal trace (overhead ordinary ray) is identified. This may require some thought (iterations) for a complex ionogram.

(ii) extra information on the ionogram can then be incorporated to consolidate the identification of the principal trace (e.g. use O/X ray associations, multiples, oblique returns, extrapolation can be used with overlays).

(iii) time evolution of the ionograms from one frame to the next and with respect to normal (median) behaviour is used. (in scaling from film, tracings and tables of medians or predictions were often used to help in interpretation)

(iv) as a clearer picture of the pattern of the ionogram emerges, ranges of the various parameters will become clear and the final uncertainty will then be a summary of a refined interpretation.

Few ionograms require all four steps, **although it is good practice to think along these lines** while scaling.

Here, the accuracy limits assigned by a scaler will bracket the range of possible interpretations available for each parameter. This approach has the advantage of producing more scaled values where replacement letters might previously have appeared.

For instance, scaling foF2 in the presence of spread F might result in a value being scaled with only descriptive letter F whereas a simple application of measures of accuracy might otherwise require a replacement value to be used.

A problem can often occur when a scaler is certain about the bounds for a value and equally certain that the bounds are, say, just greater than 20% or 10%. It is then tempting to change an E or D to U or leave a U out completely. This becomes more frustrating when the same condition recurs frequently, (e.g. when scaling h'F at night in the presence of interference). By falling to temptation, the scaler is probably making the right decision for the wrong reasons. In such cases, careful inspection of the ionogram will usually give enough extra information to allow the increased accuracy to be legitimately scaled. If careful inspection does not give new grounds for changing the accuracy limit, and you still feel confident then 'reasonable doubt' may be invoked - but with care. Accuracy limits are not, in themselves, precise and problems such as this occur more out of misapplication and unfamiliarity than any other source.

There are two prime disadvantages of this method. First, accuracy can change from scaler to scaler dependent on their own assessment of their skill. As tests of scaler accuracy show, scalers generally adopt this approach, and it is only a disadvantage when a scaler is overzealous. Second, a much greater responsibility is placed on the scaler.

2.3.2 Accuracy interpretation adopted by IPS

There is still considerable debate over which of these approaches is most appropriate. The last case, *objective interpretation,* allows pure accuracy to be used while allowing some uncertainty to be acknowledged when the scaling is clear but the whole pattern of the ionogram suggests normal interpretation could be wrong. It is left to the discretion of the scaler to decide whether the pattern of the ionogram is so unusual that normal accuracy of interpretation is at fault. (It should be possible to explain most unusual patterns by careful inspection of ionograms, but other limiting factors may reduce the available information at the time).

IPS has adopted approaches *objective accuracy* and *objective interpretation.* While *objective interpretation* is preferred, novice scalers may prefer to adopt only stage *objective accuracy* until familiarity and experience with ionograms grows.

As a general rule, qualifying letter U takes the meaning - accurate between 4 to 10% in IPS scaling and is not used to qualify unusual patterns in ionograms unless the interpretation is believed compromised. Where ionograms are unusual, a descriptive letter is used to describe the nature of the unusualness. For ionograms that defy scalers completely, the descriptive letter N may be used. However, a scaling described by N is checked out at IPS Head Office and a more appropriate description of the ionogram will possibly be published in the final data.

2.3.3 Summary of the Accuracy of Ionogram Scaling

Five levels of accuracy are allowed using combinations of descriptive and qualifying letters to show the level of interpretive accuracy attained in scaling a parameter.

These ranges of accuracy are not pure objective limits. Subjective accuracy, described by a single descriptive letter, may encompass errors of large objective magnitude, as described earlier. Also, following the introduction of interpretive accuracy, it will be necessary to use some descriptive letters in ways specifically forbidden in UAG-23A, e.g. descriptive letter S on its own. Researchers using this scaled data will have to set the final objective limits for themselves.

The rules are outlined in the accompanying figure. This gives some guidance on how to scale an extrapolated trace - a common scaling problem.

As an example, refer to Fig. 3.1 on UAG-23A, p69, which shows, among other things, how to scale foE in the presence of a blanketing cusp type sporadic E layer. As pointed out, foE is extrapolated and if possible gives foE _A. In other words, blanketing may have affected the measurement of foE, but the interpretation is good. Following the extrapolation rules noted on p36 of UAG-23A, (using interpretive accuracy) the value of foE may also be estimated giving a value (foE)UA or a limit value (foE)DA. Neither of these need necessarily be taken from the cusp value so the (foE)UA value taken from the cusp must be biased low, making this a poor location to measure foE from.

The table shows the different levels of scaling accuracy. With good quality ionograms, quiet conditions in the ionosphere and confident scaling, most parameters will have no descriptive or qualifying letters.

Elsewhere in this report the term "full scaling" is mentioned. This refers to all the levels of scaling accuracy being available for the parameter. There are situations where accuracy limits are unlikely to apply because of the nature of the parameter being scaled. These situations are discussed latter in the report.

No Qualifying Letter - value is accurate to within 5%	No qualifying or descriptive letter is needed. Usually, this means the parameter was easy to scale and errors are smallest.
A Descriptive Letter is used - possible errors	When only a descriptive letter is required, the interpretation is sound, but possibly affected by scaling conditions. This appears to contradict UAG-23A, p34 where only two reasons are cited for using descriptive letters on their own - as replacement letters or when a phenomenon does not affect scaling accuracy. However, statistically, parameters scaled with descriptive letters used this way tend to be less accurate.
Qualifying Letter U - value between 4 and 10% accurate	The qualifying letter U is used when the interpretation is reasonably sound but inadequate information due either to a complex ionosphere or instrumental limitations (or combinations) now allows a range (4 to 10%) of possible values to fit the data.
Qualifying Letters E and D value is within 20% of this limit	The qualifying letter E or D gives a limit value for the parameter. This is an extension of the rules for U. Now too little unambiguous information exists for a well bounded range of values to be scaled. Instead, a range (10-20%) of values can be used to bracket where the parameter should lie and the clearest boundary of this bracket will be the limit value. For later use of the data, it is conventional, when a choice exists between using an upper (D) or lower (E) limit, to use the limit nearest average conditions. This eases the later calculation of medians as it tends to conserve back towards normal conditions, (i.e. value larger than usual, value smaller than usual).
Only a Descriptive Letter - a large error exists. This is called a **replacement** letter.	No value is scaled; the reason for a lack of values being described by a descriptive letter, often referred to as a replacement letter. This is a severe state and suggests a particularly difficult ionogram for scaling has been encountered. Even allowing for reasonable doubt, a bound cannot be placed within 20% of the likely position of the value. **While just any value is of little use, scalers should strive to obtain all possible information from an ionogram and use replacement letters as a last resort**. (This is particularly true of fxI scaling where a value is of great importance and it is almost worth suspending normal accuracy limits to obtain one. Think carefully before scaling a replacement letter for fxI.)

2.4 Extrapolation - a typical accuracy problem

Novice scalers should learn quickly how to extrapolate effectively. It is at the heart of scaling and is one of the major problems with automatic scaling programs - the human eye appears to be far better at extrapolating traces than a computer program.

Extrapolation refers to the systematic extension of the principal trace, in height and frequency, from regions where the principal trace is clearly visible to regions where it is invisible but where scaled parameters could be scaled if they were visible. Extrapolation is necessary if systematic errors in scaled values are to be avoided.

Consistent with the accuracy interpretation in the previous section, the error limit placed on a value deduced by extrapolation, and used to determine the qualification of the data, is the range between least possible and greatest possible extrapolation of the value being scaled not the range of the extrapolation (see figure 2.2b, p 36 UAG-23A).

Where the range of extrapolation exceeds 10%, and a limit value becomes appropriate, the limit used is that of the least possible, or greatest possible, extrapolation - whichever is appropriate. UAG-23A does not give complete guidance on this point.

Various aids are used to maintain objectivity in extrapolation. At IPS, the value of overlays for extrapolating both heights and frequencies is emphasised, although it is left to the discretion of individual scalers to decide whether such aids are used or not. IPS also supplies scalers with predictions of median ionospheric conditions to aid recognition of unusual events or, at high latitudes, to assist in identifying the different ionospheric layers.

2.5 Interpolation (Qualifying letter I, UAG-23A, p66)

Novice scalers can ignore interpolation.

Interpolation refers to parameter estimations made across time periods covered by several ionograms. UAG-23A advocates periods less than 2 hours should be used. At IPS interpolation is rarely, if ever, used.

Interpolation should be used to provide numerical values when a value is missing for some equipment reason (C), because of interference (S) or during a fadeout (B). It could be used to replace any ionospheric parameter that is unobservable, provided the parameter is not correlated with the phenomena preventing it from being seen. For instance, at mid latitudes Es and F region parameters are uncorrelated so interpolation can be used to deduce F region parameters blanketed by Es layers. However, at high latitudes sporadic E can be associated with F region ionisation troughs so blanketing could coincide with changes in the F region, and interpolation cannot be used. Interpolation must be applied carefully.

In general, interpolation should only be used for parameters that are slowly varying and obscured for one or at most two hourly ionograms. UAG-23A suggests interpolation must **not** be used:

- when the parameter is varying irregularly or rapidly.
- when the parameter is unobservable for periods greater than 2 hours.
- for fxI, fmin or any sporadic E parameter.
- when the reason for not observing the parameters would be described by D, E, F, G, L, N or W.

However, UAG-23A suggests interpolation should be used when retardation prevents a parameter being measured. As retardation can often be augmented by the regular diurnal changes in absorption, coupled with low equipment sensitivity, it may affect the same hours each day. *It is questionable whether interpolation should be used to replace these lost values as the 'smooth variation' may, be unknown*.

While interpolation is not to be used when the ionosphere is changing, UAG-23A allows interpolation during disturbances (often indicated by H or V) and during lacuna (Y). This appears to be a contradiction. When used carefully, interpolation can be a valuable aid for obtaining values for parameters where only replacement letters would otherwise appear. However, because UAG-23A has not stated clearly when to use interpolation, scalers are uncertain when it should be used, and probably few consider it. INAG should address this problem. Presumably interpolation with H, V or Y is allowed because these phenomena have a duration of less than an hour or so.

Interpolation can become particularly important for scaling IUWDS (now ISES) data for rapid data exchange. Here a value of foF2 is particularly important as often one value represents a measure of ionospheric conditions for a six hour period. For these data, interpolation could extend up to two or even three hours either side of the hour for which foF2 is measured. However, until there is international agreement on this, it won't be done.

2.6 J O Z - Magnetoionic Components

Novice scalers need to understand this section.

When a plane radio wave passes through the ionosphere it is split into two magnetoionic components called the ordinary and the extraordinary wave components. These two components travel along different paths in the same magnetic meridian plane with the extraordinary (or X) component being deviated equatorward of the ionospheric station while the ordinary (or O) component is deviated poleward. By studying both components carefully, the scaler can gain additional information from the ionogram. So; remember:

Ordinary (O) comes from the pole

Extraordinary (X) comes from the equator

In this section, the way this additional information is used is discussed.

Table of gyrofrequencies for Australian stations, Units are MHz.

Station	0 km	100 km	200 km	300 km	400 km
Brisbane	1.51	1.44	1.37	1.30	1.24
Canberra	1.66	1.58	1.50	1.43	1.36
Casey	1.81	1.73	1.64	1.57	1.49
Cocos	1.32	1.25	1.19	1.13	1.07
Darwin	1.30	1.23	1.18	1.12	1.07
Davis	1.57	1.50	1.43	1.37	1.31
Hobart	1.76	1.68	1.60	1.52	1.45
Macquarie Is	1.83	1.74	1.66	1.58	1.51
Mawson	1.44	1.38	1.32	1.26	1.21
Mundaring	1.65	1.57	1.49	1.42	1.36
Norfolk Is.	1.46	1.39	1.33	1.26	1.21
Pt. Mresby	1.21	1.154	1.09	1.04	0.99
Salisbury	1.68	1.60	1.52	1.45	1.38
Townsville	1.39	1.32	1.26	1.20	1.14
Vanimo	1.12	1.07	1.02	0.97	0.93

2.6.1 Estimating frequency parameters - Qualifying letters: J O Z.

It is possible to estimate the ordinary mode component using either the extraordinary or the Z component. When this is done the appropriate qualifying letter (J for use of extraordinary and Z for Z-component) is used together with a descriptive letter indicating the reason for not being able to use the ordinary component. The gyrofrequency and magnetoionic split are shown in the accompanying table.

Similarly, when scaling fxI (the only extraordinary component parameter scaled routinely at IPS), if the ordinary component is used to scale fxI the value is qualified by O.

Using magnetoionic components to obtain values, by addition or subtraction of the magnetoionic split, often ensures values are recorded. However, because the three magnetoionic components traverse different paths within the ionosphere, and have reflection points that are different both in the horizontal and vertical planes, errors associated with this approximation are unknown. Large errors are possible if there are ionisation gradients within the ionosphere close to the region defining a parameter.

Because of this, IPS considers it to be good practice to use the approximate position of the principal trace to aid in searching the ionogram for further evidence that will eliminate the need to use an approximation. If such a search reveals no additional information on the location of the principal trace, then the appropriate approximation (with unknown error) is used. It may be difficult, using automatic scaling systems, to both scale one magnetoionic component using another and also use the correct qualifiers, with the scaled value. While the qualifiers O, J and Z imply unknown error, in practice the errors will be less than or equal to the qualifier U.

2.6.2 Estimating height parameters

Because, for any point on an ionogram, for a fixed frequency, h'z < h'o < h'x, there would always be a bias of unknown magnitude associated with heights if they were deduced from other magnetoionic components.

In general, scaling methods that result in a bias of unknown amount are not used. In this particular case, however, the bias will be small for thin layers so h'xEs may be scaled for h'oEs. This is not an IPS scaling convention but is probably adopted here and at many networks when, for instance, foEs is less than fmin. The bias, or error, introduced is unknown, but small, so qualifying the height scaled by U would be satisfactory (describing the reason for not scaling h'oEs by the appropriate descriptive letter - e.g. S, if foEs < fmin). Note that no attempt can be made to correct h'xEs to give a better estimate of h'oEs.

This convenient approximation can only be used for thin reflecting layers such as flat, cusp, high and probably most low types of sporadic E. It should not be used for any thick layers (e.g. normal of particle E, F region).

In a sense, it is still better practice to qualify such heights by J rather than U as they are estimated from the extraordinary component and the errors are unknown.

2.7 Disturbances on ionograms

Novice scalers need to learn how to cope with disturbances in ionograms.

This section covers two points. The obvious one is to remind scalers how disturbances are recorded in the hourly tabulated data. The second point that the section outlines is how scaling copes with just one of many features seen on ionograms by scalers but, apparently, ignored by scientists using the scaled data since the features of the disturbance will not be recorded accurately. It is always worth raising the issue that you, when scaling, are seeing something frequently but are having to ignore it.

A disturbance usually means a large, transitory change in the horizontal ionisation gradient has occurred near the station. These are usually caused by travelling ionospheric disturbances, or TIDs.

2.7.1 Classification of disturbances

Disturbances affecting ionograms can be described by four different letters, listed in order of their effects on the ionosphere.

R defocusing, or weakening, of trace in a region of retardation.

V a clear forked trace on a critical frequency.

H a stratification, or when the general form of the ionogram changes.

Y large tilt.

Disturbances are only of interest when errors are likely to occur as a result of their presence. They are not flagged because hourly values undersample disturbances badly and because the ionosonde is a biased method of recording their presence, making statistics based on the scaling deceptive. Disturbances are always present on ionograms and can be detected as small changes in heights and critical frequencies. They are particularly evident in time lapse movie sequences of ionograms recorded every five minutes.

There may be some merit in discriminating between H and V, as at our 1982 conference Piggott gave the impression that V was more common in the Northern hemisphere. If this is so, then disturbances should be flagged and a statistical study carried out. However, I don't feel there would be much value in it as the principal difference between forked traces and stratification is the height of the disturbance above the ground in disturbance wavelengths. While the V trace could be caused by a less convex disturbance than the H trace, if both occur at the same height, the difference in occurrence probably results from a difference in layer heights rather than disturbance amplitudes.

If careful use were made of R, V, H and Y it might be possible to refine the scaling of disturbances on ionograms, making up a subjective set of classifications. This could prove useful for classifying days as more or less disturbed. While IPS is not currently using such classifications, some experimentation may be worthwhile, and the letters R, V, H and Y could be used to show increasingly greater effects of disturbances.

2.7.2 Accuracy rules associated with disturbances

Various conventions have been suggested in UAG-23A for ensuring the accuracy of measurements made during disturbed periods is estimated using reasonably consistent rules. Often an accurate measurement can be made in the presence of a disturbance, but some qualification of this measurement is desirable because evidence exists to show it may not be a good representation of the ionosphere for the hour. This requires careful interpretation to decide when "the ionogram" should be scaled and when "the hour" should be scaled.

At IPS, the ionogram is scaled and the adjacent ionograms may be used to give an estimate of possible errors. More weight is placed on consistency of interpretation within the one ionogram than on consistency between several ionograms.

Considerable care has to be taken in deciding how to deal with inconsistencies between multiples and the principal trace; a measure of differences in the overhead ionosphere, and differences between the magnetoionic components, a measure of spatial differences near the station. If the difference in the magnetoionic components is used as an accuracy criteria, then disturbances moving north-south are more likely to be qualified than those moving east-west as north-south disturbances are more likely to affect one or other of the magnetoionic components preferentially whereas east-west disturbances will affect both.

However, in the final analysis, it may not be worthwhile making large efforts to define the accuracy of parameters scaled during disturbances as the ionosphere is continually being affected by small scale disturbances whose accumulative effect can, for instance, be shown to produce a 5 to 7% errors in measured foF2 values.

2.7.3 Extrapolation and interpolation during disturbances

Interpolation is recommended to ensure a value is obtained for a parameter that may otherwise be lost because of a disturbance. This appears inappropriate at first sight, because interpolation will take place in time, across a sequence of disturbed ionograms. However, the intent here appears to be to extract the disturbance effect and interpolate over the rest. That appears more like the deceased letter T, rather than I. In general, then, interpolation during disturbances will be difficult as care has to be taken to ensure that the ionosphere is not so disturbed that interpolation loses meaning. If the ionosphere appears to be varying rapidly, don't interpolate.

2.7.4 Summary

While this appears to be a tale of "don'ts" the recognition of disturbances and correct interpretation of their presence may prove to be valuable information the future 5A network can offer. For now, their recognition will give forecasters a clearer picture of the changes occurring in the ionosphere.

3. COMMON DESCRIPTIVE LETTER USAGE

While a novice scaler need not remember all the details in the following sections immediately, familiarity with the scaling letters is important. The following sections are intended to highlight areas where the use of descriptive letters has been open for discussion. It is not intended as a complete tutorial on each scaling letter - UAG 23A is far more comprehensive.

The various descriptive letters, used either as flags or to describe sources of error in estimating scaled parameters, have common meanings for all parameters. In general, IPS uses the descriptive letters in two ways

(a) to flag various phenomena as described in the next section, or

(b) to show the reason for a loss of accuracy in a scaled value.

This differs from the suggested reasons for letter usage (UAG-23A, p34), but is a more correct description of both the normal URSI scaling conventions and the accuracy interpretation IPS uses. This is because accuracy is always established first, then the scaler attributes flags to the appropriate parameter s and may, in so doing, overwrite the reason for a loss of accuracy.

In the following sub-sections each of the scaling letters is described briefly. In many cases, the discussion includes comments on definitions given in UAG-23A where these definitions have lead to problems in interpretation at IPS. These discussion points are retained here as they raise many small issues that require common sense. Scaling, frequently, is common sense.

Throughout the rest of the text the following conventions are adopted.

- Often a pair of scaling letters is mentioned in connection with a scaled value. This is written as _## where # refers to a scaling letter, e.g. _ES. The # is used whenever any reasonable scaling letter is appropriate.
- Sometimes (xxx)## is written where (xxx) is a parameter, say fmin, e.g. (fmin)ES.
- Sometimes, where it is obvious, only the scaling letters are referred to as ##, e.g. ES.
- When only one letter, a descriptive letter, is intended it is written as _#, e.g. _F, and no attempt is made to show the blank position for the qualifying letter.
- When no value is scaled, and the reason for this is tabulated by a single descriptive letter, the letter is referred to as a "replacement letter" because it replaces the missing value.

3.1 A - measurement affected by a lower thin layer

IPS uses A to describe any condition where a parameter is obscured either physically (blanketing) or by superposition of traces on an ionogram. Usually critical frequencies will not be measurable because of blanketing by sporadic E whereas height parameters may be scaled, but with reduced certainty as a result of another layer, or multiples of a layer, being superposed over the parameter being scaled.

3.2 B - measurement affected by non-deviative absorption

As introduced by UAG-23A, p72, B is used to indicate an increase in non-deviative absorption resulting in loss of accuracy when scaling parameters. The two sources of increased non-deviative absorption commonly encountered are fadeouts (which can result in a complete blackout) caused by solar flare X-ray emissions, and particle precipitation (normally restricted to auroral and sub auroral latitudes).

Fadeouts occur instantaneously and affect the entire sunlit hemisphere, the effects depending on the solar zenith angle and, to a limited extent, on station location. Data loss caused by fadeouts is rare and unlikely to affect median tabulations. However, since fadeouts affect all ionosondes in the sunlit hemisphere they offer useful corroborative evidence that the ionosonde timing is correct.

Energetic particle precipitation can also increase ionisation in the D region, often resulting in a complete loss of ionospheric records. These absorption events have reasonably well established diurnal properties, so ionospheric data may be preferentially lost at particular times of the day. This can then affect the final median tabulations for parameters.

As described in UAG-23A, p72, these are the only occasions when B should be used as a descriptive letter. However elsewhere (e.g. UAG-23A, p101), B is also used to describe the effects of differential absorption between the ordinary and extraordinary components. This may affect absorption in two contexts:

- absorption reduces the extraordinary component amplitude below the detection level for the ionosonde, while the ordinary component is still visible. This is a special case and will depend on frequency.

- when observations are made near the gyrofrequency, the extraordinary mode is not observed. This is really a special case of the first, but is now independent of equipment operation.

While B is a legitimate usage near the gyrofrequency it is questionable whether the scaling is as useful at any frequency where the extraordinary wave is not observed, or is observed to be different from the ordinary wave.

Absorption affects all the ionogram, the effect diminishes with increasing frequency and is greater for the extraordinary wave than the ordinary wave observed at the same frequency. Provided an ionosonde is operating correctly, and absorption is normal, there should be no need to use descriptive letter B.

When B is used to describe a loss of accuracy it implies absorption has increased substantially above normal conditions. When absorption is believed to be normal, but fmin is high enough to affect scaling of parameters, possibly descriptive letters R (deviative absorption) or C (equipment fault) are more appropriate. If, for instance, an ionosonde is designed without correct allowance for changing levels of solar activity, normal absorption may prevent foE from being observed. Here C may be more appropriate than B.

In the past, IPS has incorrectly tended to use B to explain any major diurnal increases in fmin above foE in addition to the correct usage, indicating major changes in absorption.

3.3 C - equipment failure

When C is used, it generally implies an avoidable fault has occurred preventing the accurate scaling of a parameter. Don’t be afraid of using C, but be sure the problem gets fixed. If you are scaling data from a station you are not immediately responsible for, bring any problems where C is required to the attention of people in Sydney (e.g. Paul Alekna and myself).

'Avoidable' can have a broad range of meanings, but at IPS the meaning is restricted to cover only those failures that could be avoided with the particular equipment currently being used. Thus, for example, when fmin is high at only one station in the IPS network, it is reasonable to suppose that the station equipment is faulty. Any scaling inaccuracies resulting from the high fmin should therefore be described by C rather than B. If further investigation reveals no reason for the high fmin, then (by agreement with IPS H/O) C may be superseded by some other descriptive letter. This is an admission that the ionosonde in question is operating as well as it can - such acceptance is not given lightly.

However, if fmin regularly exceeded foE near midday at most of the stations in a network then, presumably, the equipment is not sensitive enough to record the E region. Here, C is not appropriate. In other words, C is not used to describe the perceived poor operation of an ionosonde with respect to an arbitrary standard - a previous generation of ionosonde, for instance. This may be an important issue when 5A ionograms are scaled. (Written in 1983. Sadly, how prophetic!)

However, it is worth considering whether C should be used when ionosonde design results in parameters being poorly defined. Obviously it would be difficult to maintain adequate standards for reference, but if a full range of URSI ionogram parameters cannot be recorded because of some equipment limitation, it appears desirable to note the fact.

IPS does not scale C when ionograms are lost because of interference from local transmitters, rain or snow static. *This is not the usual convention.* Presumably these interference forms were included under C because they constitute poor equipment location and design. However, IPS experience at Mawson has shown local transmissions are far from avoidable, so S is preferable - and gives a catalogue of local interference data losses. Snow and rain static are possibly equipment faults associated with poor aerial earthing or proximity of high tension power lines. Only the former could be interpreted as a C condition.

3.4 D - upper frequency limit of ionosonde is exceeded

It is rare when ionograms exceed the upper limit of a modern ionosonde - but not impossible. When this event occurs, the parameter concerned is scaled _ DD for a frequency component. Obviously, if the upper limit is variable, the appropriate limit would be recorded although it is hard to imagine how this would occur normally and not be C. (see W for heights)

3.5 E - lower frequency limit of ionosonde

Various conventions are adopted when parameters fall below the lower frequency limit of the ionosonde. The conventions vary dependent on the parameter and it is convenient to tabulate them here. As the lower frequency limit for which ionospheric returns are observed is often set by interference, rather than the ionosonde, the same conventions are used.

Scale	Parameters	
E fmin #	fmin, foEs, fbEs, foF2, fxI	where # may be any character
#	M(3000)F2, h'Es, h'F	replacement letter
(nothing)	foE, foF1, h'E, h'F2	scale nothing

Note: there is no good reason why foE, foF1, h'E and h'F2 should not be scaled like M(3000)F2 etc. However, it is convenient not to and has been the convention at IPS in the past.

There are good arguments for not scaling ES on foE - it is how the result is observed but this may distort the medians near sunrise and sunset - a point that should be checked.

3.6 F - spreading echoes influenced the measurement

UAG-23A is not precise in its definition of F as an accuracy parameter. On p34, F is defined as 'measurements are affected by spread F', while p75 refers to 'the presence of spread echoes'. As F is also used to flag frequency spread, the dual usage becomes confusing.

When measurements of any parameters are influenced by spreading, descriptive letter F is used. Thus, F may appear on both height and frequency parameters. When used in this context, F is not indicating the presence of spread with clear limits, instead the limits will vary dependent on the level of accuracy. Furthermore, F is not necessarily the only reason for a loss of accuracy and may not be the major reason.

3.7 G - layer ionisation density is too low

A better definition of G is; layer ionisation is lower than an underlying thick layer, as G is commonly used to explain the absence of a parameter because of a lower thick layer (normal E when no sporadic E parameters are observed and often F1 layer for F2 parameters during a storm) prevent the layer from being observed. If there is no evidence of a lower thick layer, G is probably not the appropriate descriptive letter.

One particular exception to this rule was to scale G on any foEs value that was less than foE. These layers are not now scaled, removing the need for this rule except when fbEs is less than foE.

Where either G or W appears reasonable; favour G. This usually only applies to foF2.

3.8 H - measurement influenced by stratification

H is used in two contexts in UAG-23A; when multiple inflections or turning points are observed, or where the general form of heights, or critical, frequencies, is altered.

When applied to foF2 this takes on a distinct meaning; descriptive letter H describes clear transient stratifications near foF2. This distinction is further refined because both H and V can be used for describing these effects on foF2 and scalers must choose between the two.

However, the distinction is less precise for other parameters, for which H is used to describe any transient disturbed effects that may have affected the measurement.

It would be preferable for H to be used to highlight any scaled parameters that are affected by transient disturbances. 'Transient' can be defined as "having a duration of minutes to an hour or two at most". These disturbances should not be confused with ionospheric storms, although stable phenomena such as E2, F0.5 or F1.5 can be flagged using H. The usual reason for not scaling these layers is that they are of limited importance for radio propagation. Evidently, this is how the line has been drawn in the past and it seems practical. Little has been made of foF1.5 and E2 in the past.

3.9 K - measurement is obtained from particle-E (either Es-r or Es-k)

Descriptive letter K is used to show that the values are obtained from a particle E layer. Particle E is a thick layer within the ionosphere and may be observed overhead (Es-k) or obliquely (Es-r). These values should form a homogeneous group and their properties may affect median tabulations containing them.

3.10 L - insufficient cusp between layers

L is only used for the parameters foF1 and h'F2 and its discussion is postponed for now.

IPS does not use spread F type L.

3.11 M - mixed modes (no long used)

URSI have ceased to support the use of this descriptive letter. To the best of my knowledge, M has not been used at IPS.

3.12 N - interpretation is impossible

In the initial scaling of ionogram parameters, IPS allows N to be scaled anywhere as a descriptive letter. However, the parameters scaled this way are scaled again at IPS head office, so no published data should contain a descriptive letter N. So, N does not appear in the lookup tables.

In principle, ionograms where N is used are considered for future submission to INAG, making N a flag for "unusual ionogram". However, few, if any, really interesting ionograms have been found this way.

3.13 O - measurement refers to the ordinary component

IPS does not use this descriptive letter; why does URSI support it? When the ordinary component is scaled in an extraordinary tabulation the qualifying letter O is used together with the descriptive letter that best explains why the extraordinary component could not be scaled.

When the accuracy of the ordinary component is qualified, by U, E or D, then this level of accuracy supersedes O on the extraordinary component. This carries the implicit assumption that the errors in using the ordinary component to calculate the extraordinary component are less than 4%, or U.

3.14 P - man made perturbation (also spread flag)

IPS has not had much cause to use P. Things like atomic bombs, reentering satellite debris, rocket motor exhaust, barium clouds etc. can all affect the ionosphere, but it would be hard to unambiguously identify the source, even knowing the timing of events. Maybe it adds something to scaling to have the possibility of scaling P available, but I don't think this descriptive letter needs to be retained. Note: P is used as a flag on fxI to show a spur is controlling fxI.

3.15 Q - measurement influenced by range spread

Q, as defined (UAG-23A, p88), is not intended for describing a loss of accuracy. However (UAG-23A, p35), occasions can arise where it is a good descriptive letter for scaling inaccuracy. It is particularly valuable, for instance, at low latitudes when foF2 is ill-defined, or not defined at all, in the presence of equatorial spread. In this case, F cannot be used on foF2 because no frequency spread is present, so Q becomes essential for describing the accuracy of the foF2 value scaled.

Normally, however, inaccuracy of measurements resulting from spread returns is scaled as F. For parameters, such as h'F, F is superseded by the range spread flag Q when range spread exceeds 30 km.

Range spread greater than 30 km is recommended as a range spread flag threshold as this is consistent with past IPS usage. Such a convention is certainly equipment dependent so setting the threshold at twice the normal trace width has a lot to commend it.

3.16 R - influence of attenuation near critical frequency

There are a variety of ways R could be defined depending on the physical process assumed to be causing the attenuation.

UAG-23A discussed R in the context of deviative absorption causing the attenuation and stresses that "the attenuation must be associated with retardation". However, small undulations near the reflection point for a radio wave can produce focusing and defocusing effects that can further weaken ionospheric traces in regions of retardation. This point occasionally becomes important when interpreting fbEs.

If a strict definition of R is adopted, then R could not be used with any height parameters or sporadic E parameters because retardation would not be present.

UAG-23A also states that "R can only be used when there is evidence for the existence of a principal ray trace". Accepting this implies R could not be scaled for, say, foE when fmin > foE.

Evidently retardation (R) is a solar cycle dependent parameter, being used more often at solar maximum than solar minimum. This is because at solar maximum the ionosphere is thicker. The effect can be enhanced for ionosondes using narrow pulse widths. Thus, there is also an equipment reason for loss of definition of critical frequencies. While C might be appropriate, R is conventionally used because it is difficult to recognise the different effects on ionograms.

IPS has tended to relax these rules at times and R has been used as a descriptive letter, where C or B may be more appropriate. (See the discussion on when to scale C). For practical purposes, congenital equipment failures such as "too narrow a pulse width" are interpreted as R.

3.17 S - measurement influenced by interference or atmospherics

Use of S is straightforward except for two areas.

At IPS, S is can be used as a descriptive letter with no attached qualifying letters. This maintains consistency with the preferred accuracy convention adopted by IPS. While UAG-23A advocates the accuracy approach adopted by IPS, some scaling letters, such as S, are restricted in their usage.

As said previously, the general interpretation of local interference sources being classed as instrumental faults is not adopted by IPS except in special instances where the fault can be corrected by the IPS operator (principle of avoidable data loss).

3.18 T - value determined from a sequence (no longer used)

URSI and IPS no longer support the use of this descriptive letter and probably never did.

3.19 V - forked trace may influence measurements

It is far from clear to me why V exists as well as H. Because H is used to cover all disturbances, V is only used for small disturbances. About the only reason for distinguishing between V and H is that V can be recognised relatively easily on ionograms. Note: New Zealand do not allow V because careful inspection of such traces show they are very thin stratifications or satellite traces. Alan Rodger comments that this type of trace should be studied using a good directional ionosonde.

3.20 W - layer lies above the height range of the ionogram

This descriptive letter is used mainly with F2 parameters either at low latitudes, when the ionosphere is thicker than usual, or during ionospheric storms.

3.21 X - refers to the extraordinary component (also spread flag)

IPS does not use this scaling letter. Comments on descriptive letter O are appropriate here. Note: X is used on fxI as a flag for no spread is present.

3.22 Y - lacuna and severe tilts (also lacuna flag)

Descriptive letter Y is used in UAG-23A, and also by IPS, for three different conditions.

- gaps in ionograms
- severe tilts
- lacuna.

Of these, lacuna is identified as a unique ionospheric phenomenon and a variety of indicators exist for establishing whether it is present. This has been treated in detail in UAG-23A pp. 53-57 and pp. 93-95. I think that it would have been better to introduce a new scaling letter to describe this phenomenon once recognised. However, INAG chose to refine the meaning of Y in the handbook, thereby complicating its usage.

At IPS, Y is therefore a flag on foE, foF1 and h'F2 for lacuna. If other parameters are inaccurate because of lacuna, Y can be used as a descriptive letter on them, thereby refining the description of lacuna for the ionogram. In other words, once Y is used on a flag parameter, it gives greater significance to other Y descriptive letters scaled with that ionogram.

However, on parameters other than foE, foF1, and h'F2, Y may be used for lacuna, severe tilts or gaps in the trace, as interpretation dictates.

The meaning of 'severe' is a little hard to make objective although most scalers have a reasonable idea of how 'severe tilt' differs from 'disturbance'. I would prefer 'severe tilt' to mean that the whole F region is oblique - as might occur near a trough. At present there is no symbol available to represent this. It could prove useful on h'F and fbEs for instance.

An amazing number of articles and discussions have occurred around the use of Y. However it is rare when it can be used on IPS ionograms correctly.

3.23 Z - Z mode is present (a flag)

Z may be required as a descriptive letter associated with loss of accuracy. However, when the Z mode overlays other traces A is preferable, although the usage may not be conventional, (e.g., much like the A usage in _JA). Currently Z is only used as a flag.

4. Flagging Special Ionospheric Conditions - *an IPS Convention*

A novice needs to be familiar with flags, especially spread F flags. If scaling high latitude ionograms, understanding particle E is essential. Scaling Y and Z can be learned as it is encountered.

4.1 An introduction to flags

A flag is a descriptive letter, used with a particular parameter, which describes some ionospheric phenomenon. The phenomenon could affect the accuracy of the parameter scaled but it need not do so. This convention is only stated explicitly for a few select features on ionograms (e.g. spread F) and implicitly for a range of others (e.g. lacuna). The mixture of conventions makes it difficult to interpret the data for analysis.

For a flag to be useful it should have the highest priority of all letters scaled for the parameter to which it belongs. This is an important concept and it is not stated explicitly in UAG-23A.

Thus, the normal explanation of accuracy limitations is superseded by the flag. The best way to achieve this is;

- scale the ionogram and interpret accuracy in the normal way citing the appropriate scaling letter for any loss of accuracy,
- then check to see if a flag is appropriate and if it is, scale it, overwriting the previous descriptive letter in the process;
- the descriptive letter now probably bears no relationship to the qualifier.

As an example: an ionogram is scaled where the F2 trace is clean, but both components are obscured by a combination of high interference and retardation near the critical frequencies. In this particular case fxI can be measured but with reduced accuracy, say qualified by U. The reason for the reduced accuracy is either interference, S, or retardation, R, whichever appears most appropriate. So normal accuracy scaling gives an fxI value, _US. Next, the flags appropriate to fxI are checked. As there is no spread on fxI, X is scaled and supersedes S. The final scaling _ UX.

There may be several flags appropriate for scaling with a parameter. If so, a clearly defined hierarchy must be defined. Later this will be done.

UAG-23A and INAG do not advocate flags. Instead, possible flags are indicated and it is left to the individual networks to decide whether to use them and if so, what hierarchy they will choose. To ensure consistency between networks, the various possible hierarchies should be discussed by INAG so that networks are fully aware of the choices they are making. Past choices should also be acknowledged so past data is made more amenable to analysis.

It is important to realise that:

- a flag may be the only indication researchers have that a particular phenomenon has occurred. Because of this, precise use of flags is vital.
- flags bear no relationship to reasons for a loss of accuracy.
- networks should define which flags they are currently using and what hierarchy they use when more than one flag applies to a parameter. (Ideally such a hierarchy should be published along with scaled data.)
- flags apply to the hourly ionogram being scaled. For special transient phenomena, such as lacuna, possibly flags could apply to all ionograms recorded within 30 minutes of the hour. IPS does not do this.

4.2 Spread F flags; F, Q, P and X

There are five spread F flags - F, L, P, Q and X. These flags should not be confused with spread-F types, or spread-F typing, which are referred to in UAG-23 and INAG in various places. Spread F typing is applied in a similar way to sporadic-E typing. The various types of spread F present on an ionogram are identified and inserted in a spread F type table. Examples of these tables appear in INAG-42. As most of the spread types can be derived from the flags scaled on IPS data, IPS does not produce separate tables. Because IPS is not using spread F tables, there is no need for the optional spread F flag L. This is, as defined, shorthand for range and frequency spread both being present. If a type table were produced, then L would be used when foF2 was described by F and h'F by Q.

4.2.1 F - frequency spread

Whenever the frequency range of spread exceeds or is equal to 0.3 MHz F is scaled on foF2. The alternative definition is that spread is present when the recorded trace is double the normal pulse width. Many (BAS) believe this definition is less sensitive to the type of ionosonde being used. The same is true for the 30 km threshold for using Q. (spread χ 0.3 MHz.)

4.2.2 Q - range spread

Whenever range spread exceeds 30 km in virtual height, Q is scaled on h'F2, h'F, h'E and h'Es. An alternative definition of spread extent in terms of the pulse width has not been used as it is inconsistent in the past IPS scaling conventions. (Spread β 30 km)

4.2.3 P - spur

When a trace is recorded from an oblique reflecting region, usually at a much higher frequency than the overhead F layer, and fxI is scaled from it, then the flag P is scaled on fxI. Although this phenomena will normally be accompanied by spreading, it need not be. (The phenomena scaled is usually called a spur because of what it looks like on an ionogram, not what it is physically.) Note that as defined, UAG-23A, p58, anything that doesn't fit the Q classification, but is "spready", can be classified as P. As defined in UAG-23A, p58, P does not allow for two cases that could affect IPS results.

- P is only scaled on fxI if fxI is scaled from a spur. This is probably the normal convention, but it is not clear from the definition. A spur may be clear on an ionogram, but fxI is not scaled from it. In this case no P is scaled.
- It clear that the presence of a spur necessarily implies spreading is also occurring. IPS would not require spreading to be present for a spur to be scaled as P.

P is not scaled from E region returns. This is sometimes difficult to determine at high latitudes where oblique Es layers can appear at F region heights. With experience, this does not pose major difficulties and becomes one of the challenges of scaling.

4.2.3.1 X-no spread

At IPS we have scaled the descriptive letter X on fxI when spreading was less than 0.3 MHz. This was a local rule that IPS changed in 1983.

As described in UAG-23A, fxI, and descriptive letter X, were introduced as an experiment. Neither parameter nor descriptive letter was clearly defined. As fxI is now accepted as a routine parameter it is appropriate that both fxI and the use of X on fxI should be defined carefully.

In other words, fxI is scaled for every hour of the day and X is scaled when no spread is present on the F2 trace. This is a minimum assumption definition.

IPS has altered its scaling of X to allow for this. In other words, when frequency spread is scaled as 1 (FS = 1 an IPS local parameter), fxI will have no descriptive letter X and foF2 will have no descriptive letter F. This, together with the conventional URSI parameters supplies more information on spread F.

This definition makes X a functional daytime parameter, as occasional minor daytime spread will now be flagged by the absence of X on fxI.

4.3 Particle E overhead, Es-k

Conventions introduced here are intended to simplify scaling. However, they are not necessarily accepted internationally. Furthermore, URSI proposed voluntary adoption of an amalgamation of Es-k and Es-r into the one Es-r type. IPS has decided not to adopt this suggestion. Rather than weaken the definition of Es-k, it is to be strengthened by requiring Es-k to be scaled as the second type of sporadic E if overhead particle E is present though not controlling foEs. This becomes the only firm rule for flagging the presence of particle E. From experience, it is rare when particle E does not control foE, so these restrictions shouldn't matter.

IPS does not use descriptive letter K as a flag for particle E. However, when measurements are made from particle E, then the descriptive letter, K, has a high priority as the particle layer affects the final statistics for the parameter being recorded. This apparent contradiction is because of flags are not associated with values. The descriptive letter K signifies that the associated value was scaled from particle E.

IPS considers particle E is a common name for thick layers of ionisation formed in the E region by particle precipitation. When seen obliquely this is Es-r and when seen overhead it is Es-k. While all parameters scaled for either Es-r or Es-k are described by K, only Es-k is tabulated in foE and h'E tables. This definition implies the scaler knows when particles are present. However, the same definitions should be applied to any thick non-solar layer. This possibility is not emphasised because it is intended that the scaler try and identify particle layers and distinguish them from other types of layer. The other strong variable is time variability.

Piggott has shown that intermediate F layers can be seen at Mawson, further complicating this discussion. This type of layer is discussed under foF1, where it should be scaled when seen.

Thus, when overhead particle E is present, the top frequency for particle E is scaled in the foE table and the height of the layer is scaled in the h'E table. Both foE and h'E are always described by K, irrespective of the cause for errors in measuring foE and h'E, because particle E may alter the final median table evaluations of foE in a systematic way.

If the overhead particle E penetration frequency is greater than for any other sporadic E type present, then the Es-k layer is also scaled as foEs. The sporadic-E blanketing frequency and layer height must be scaled from the layer giving foEs, so fbEs and h'Es are both scaled from the particle-E layer. Again, descriptive letter K is scaled on foEs, fbEs and h'Es because the particle E may alter the final median evaluations.

In other words;

the penetration frequency of the overhead particle E layer = foE _ K = foEs _ K = fbEs _ K

and, the height of the particle E layer = h'E _ K = h'Es _ K

However, when Es-r controls foEs, the value is scaled as foEs _K and h'Es _K. fbEs, here, is not scaled with a K because Es-r, being oblique, cannot blanket. This is contentious and only gains acceptability when all scaled parameters can be treated together. It is used so that those occasions when particle E shows no multiple won't get placed, automatically, in the retardation -Es bin. Note that IPS now accepts that in normal circumstances Es-r cannot blanket. However, blanketing may be observed in association with Es-r and should always be scaled. Provided all scaling conventions are followed, any inconsistencies can be removed at an analysis stage. When blanketing accompanies Es-r then Es-K is present, but possibly it is due to a lower flux of particles.

Notice that the median evaluations can be affected by particle E because particle E is associated with various auroral forms that can have specific repetitive diurnal behaviors that can affect parameters in the same way at the same (magnetic) time each day.

4.4 l - Low type sporadic E

IPS has a local convention of scaling low type Es as the second type of sporadic E, or the first if no other type is present, if fmin is measured from the low Es layer.

This local convention was introduced to improve absorption information from fmin. Obviously equipment limitations and broadcast interference will still affect fmin.

If Es-k is present, but does not control foEs, then Es-k is scaled as the second Es type and the low layer is then scaled as the third type. Up to three sporadic-E types can be recorded and tabulated.

4.5 Y - Lacuna

At present, it appears rare at all latitudes when a clear example of lacuna is observed on 4B ionograms. However, lacuna conditions are important, as shown in the literature and INAG, so a clear convention for flagging its occurrence is needed. For this purpose, Y should be the descriptive letter used whenever a parameter is either not scaled, or scaling is affected by lacuna.

To ensure that the condition is always flagged, Y has the highest priority of all scaling letters on foE, foF1, and M(3000)F2, thus;

- lacuna affects the E region, scale Y on foE.
- lacuna affects the F1 region, scale Y on foF1.
- lacuna affects the F2 region, scale Y on M(3000)F2.

Lacuna is flagged on M(3000)F2 rather than foF2, because Y could have two meanings when applied to foF2, making the identification ambiguous.

Notice the distinction between using descriptive letter Y to show that a parameter is affected by the lacuna condition and using Y to flag lacuna in various regions of the ionosphere. As a flag, Y has an unambiguous meaning, highest priority of all scaling letters for that parameter and is not related to the accuracy qualification for the parameter. For other parameters, Y is appropriate if scaling accuracy is affected by the lacuna condition.

Unlike particle E, and the use of descriptive letter K, lacuna does not alter most parameters, it obscures them. Thus limit values are likely to be affected, but scaled values are not. Its effects on median tables should be less significant, even though lacuna can have clear diurnal and seasonal patterns of occurrence.

The only parameter likely to be affected is fbEs, where a lacuna could affect the measurement of fbEs. Some effort has been taken defining flags for lacuna because of discussions in the past about whether gaps in traces are lacuna or not. However, lacuna is rare at Australian sites and gaps in traces can almost always be explained in other terms.

4.5.1 s - Slant type sporadic E

Slant type sporadic E is also considered a fundamental indicator of lacuna. However, it is also seen at most of the Australian midlatitude ionospheric stations. While it is always scaled, if present, it is not a flag for anything and has a lower priority than the Es layer controlling foEs, Es-k and Es-l. In other words, at present Es-s may be present on an ionogram but could still be the fourth type of sporadic E scaled. It is not used for foEs, fbEs and h'Es scaling.

4.5.2 Z - the Z-mode

UAG-23A p97 is not completely clear about which parameters Z should be recorded on. It starts by saying 'The critical frequency or height parameter is described by Z.....' and in paragraph 6 states, 'The letter Z should be recorded as a descriptive letter with the frequency parameter of the appropriate layer'. It happens to be convenient to define Z as a flag for either frequency or height parameters as this can resolve problems of hierarchies of letters. In particular, it can resolve the problem of where to record Z when the F2 region is showing spreading. In this respect, the qualifying letter Z cannot be used as a flag as it may mean using an estimate of foF2 that is more uncertain than can normally be scaled from the ionogram.

Conventions IPS follow;

fmin	when fmin is scaled from the Z trace, use the descriptive letter Z on fmin.
h'E	When the Z mode is present in the E region, h'E is described by Z (see UAG-23A, p54-56, where Z is flagged on h'E, not foE) so foE is clear to show lacuna is present with Y. Note: IPS currently scales Q on h'E as a range spread flag. This could clash with scaling Z on h'E. The local convention to handle this condition is, if Q is required on h'E, then scale Z on foE.
foEs	When the Z mode is observed in association with an Es layer, foEs is described by Z. This will probably only apply to particle E layers. Z has the highest priority of all descriptive letters used with foEs, including K.
foF1	When the Z mode is present in the F1 region, foF1 is described by Z. However, if F1 lacuna is present Y takes precedence. As a local rule, if lacuna is present and the F1 Z mode can still be observed, then scale Z on h'F.
M(3000)F2	When the Z mode is present in the F2 region, M(3000)F2 is described by Z. This is unconventional. However, both foF2 and h'F are used for spread F flagging, fxI has spread parameters X and P scaled on it and h'F2 is usually a daytime parameter. That leaves M(3000)F2, which has no other flags attached to it.

Z is only scaled as a flag on these parameters. As the Z mode cannot be a source of inaccuracy it should not appear on any other parameters. When the Z mode is used to deduce another magnetoionic component, that value is always qualified by Z.

These flags are introduced because Z is seen infrequently at IPS stations so its occurrence may be of interest. If it is seen regularly then flagging would be pointless - e.g. at Scott Base.

4.6 When are flags not flags

The direct answer is, when they are not being used with parameters for which they are defined as flags.

It requires only a little thought to remember that F, for instance, when used as a descriptive letter with M(3000)F2 is indicating that M(3000)F2 is in error as a result of trace spreading. While use of F with other parameters than foF2 gives a richer description of the ionogram being scaled, it is not necessarily unambiguous information.

Thus letters used as flags revert to accuracy descriptive letters when they appear on other parameters.

4.7 Summary of IPS flags

The flags used by IPS and considered in these sub-sections can be summarized in the following table.

Flag	**Parameter**	**Phenomenon flagged**
F	foF2	Frequency spread > 0.2 MHz or ≥ 0.3 MHz (accuracy 0.1 MHz)
k	Es type	Particle E
l	Es type	low type Es
P	fxI	spur

Q	h’F2, h’F, h’E, h’Es	range spread > 30 km
X	fxI	no spread
Y	foE, foF1, M(3000)F2	lacuna
Z	fmin	fmin evaluated from Z mode
Z	h'E(foE), foEs, foF1(h'F), M(3000)F2	Z mode observed in E, Es, F1 and F2 region

5. Scaled parameters

5.1 fmin, lowest frequency at which echoes are observed

fmin is the lowest frequency at which echo traces are observed on the ionogram.

5.1.1 General comments

fmin is scaled with two competing purposes in mind

- the primary purpose is as a measure of the ionosonde performance,
- the secondary purpose is to estimate the amount of absorption present.

The primary requirement is to estimate ionosonde low frequency sensitivity, so fmin is always scaled as the lowest observed frequency for which echoes are returned from the ionosphere. All the scaling conventions adopted by IPS, and advocated in UAG-23A, are therefore used.

fmin is also affected by absorption - the minimum limit on fmin, set by equipment factors, being enhanced by diurnal variations in solar controlled absorption, and sporadically further enhanced by solar flare emissions and particle precipitation. There are better possibilities for estimating absorption. The minimum frequency from the second multiple is more sensitive to absorption, but for our ionosondes (4B) this would only be useful for a few hours around sunrise and sunset. A digital ionosonde (5A?), could record amplitudes at a constant frequency, but it will probably be of dubious value.

IPS has decided to scale low type Es in the sporadic-E type table as a flag, indicating fmin is measured from a low Es layer. This is the only rule IPS has introduced to improve the use of fmin as an absorption parameter and it is currently under review. Intermittent traces are often seen in the vicinity of fmin. These are often associated with low type Es, so fmin is still scaled from the lowest frequency and the presence of a low type is indicated in the type column.

Various alternatives could have been added; e.g. descriptive letter A, to indicate fmin was not scaled from the normal E region. However, these require quite difficult judgments on the part of the scaler, and considering the effect of ionosonde sensitivity on fmin, the additional scaling effort may be wasted. They are not used.

In general, while two processes are being monitored, when a conflict arises between measuring one or other process more accurately, it is resolved by remembering that fmin is neither a good measure of absorption nor a good estimate of equipment sensitivity, it is merely convenient and equipment comes first.

5.1.2 Qualifying letter usage

Accuracy estimates for fmin depend on the use to be made of fmin.

As IPS uses fmin as an equipment monitor, the definition quoted at the beginning of the section requires fmin to be scaled from an observable ionospheric return. This will almost always be an exact measurement, although qualifier U may occasionally be required for faint or obscured returns. However, it is conventional to accept that if returns are lost for non-ionospheric and non-equipment reasons, then the equipment would not be fairly represented by the observed value and the qualifier E is used to show that returns could be observed if the obscuring source (usually broadcast interference) was removed. E is also used when returns are observed down to the lower limit of the ionosonde. The qualifier D, however, will never be required because the value scaled must be an ionospheric return.

If absorption monitoring were the prime objective in measuring fmin, then maybe more use could be made of the accuracy qualifications to estimate where fmin should lie, but IPS does not do this.

No interpolation is allowed with fmin by IPS or URSI. This is consistent with the primary equipment monitoring objective of fmin but inconsistent if absorption monitoring is regarded as important.

5.1.3 Flag used with fmin

If fmin is measured from the Z mode, the value is always described by Z. This is the only flag used with fmin. The values so flagged would not be used for absorption studies.

5.1.4 Descriptive letter usage

Descriptive and qualifying letter usage for fmin are shown in the accompanying lookup table. Specific letter usage are discussed in the following subsections.

_EE	lower limit of the ionosonde
_ES	broadcast interference
_EC	the equipment is malfunctioning

5.1.4.1 B - absorption

As fmin is primarily an equipment sensitivity monitor, when scaled values are affected by significant increases in absorption, greater than the normal diurnal changes observed, the descriptive letter B is added. The two occasions when this is usually required are fadeouts and particle precipitation. Both are reasonably easily identifiable events. Replacement B is only scaled when no ionospheric traces are present.

B is not used to describe fmin when fmin is regularly greater than foE near midday although B is acceptable if foE is lost on less than 25% of the days in a month. *This is a local convention*. When fmin is greater than foF1, or greater than foE on more than 25% of the days of a month, descriptive letter C should be used. While absorption is affecting fmin, the equipment is obviously operating poorly and is the main reason for the poor measurement (a correctly operating ionosonde should record foE near midday at solar maximum every day of the year). Replacement B would never be used in this case.

This observation is certainly true at middle and low latitudes, but at high latitudes particle precipitation will make B more appropriate than C.

The descriptive letter B, unaccompanied by any qualifier, can be used if, in the scalers estimation, absorption is greater than usual even though fmin has changed little from previous days. The descriptive letter B would be used for occasions when the traces are weakened or it could also be used for scalers to draw attention to unusual circumstances such as after-effects of ionospheric storms or anomalous winter absorption increases. *This is a local convention used to enhance fmin* by allowing the scaler to identify periods where absorption appears more important. Some of the conventions, especially this last one, are subjective and will be re-assessed.

5.1.4.2 C - equipment problems"

Where equipment is operating below optimum, resulting in high fmin values during the day, the descriptive letter C is used with fmin (see previous discussion on B). In particular, when fmin is regularly higher than foE then fmin _C is scaled. Replacement C is only scaled if no ionospheric traces are observed.

However, where fmin is enhanced, or limited, by equipment design features (such as a low pass filter) then the fmin value is described by the reason for the feature, not by C. In other words, the ionosonde was designed to minimise the effects of unavoidable external effects (e.g. a local high power HF transmitter). Where doubt exists on this point, consult IPS Head Office.

As fmin is primarily an equipment parameter; it is debatable whether fmin _C or (fmin) EC should be scaled for extreme values of fmin. At IPS, when equipment is operating poorly for moderate periods (more than two or three weeks), then descriptive letter C alone is more appropriate as there is probably no doubt about where fmin is. (C is a sort of "I'm fixing it" flag). Descriptive letter C may also be used if ionosonde sensitivity is reduced by an unknown amount - e.g. aerial problem, underdeveloped film.

For absorption studies, any fmin values described by C would be excluded irrespective of qualification.

5.1.4.3 E - ionosonde lower limit

When fmin drops below the lower limit of the ionosonde, (fmin) EE is the conventional scaling used.

5.1.4.4 H - disturbances affecting measurement

Infrequently, the lowest frequency observed can return from the second reflection rather than the first. If only the first reflection is scaled then the equipment sensitivity is not fairly represented, but absorption studies are improved. One possible solution would be to scale the second reflection using descriptive letter H on fmin to indicate an unusual measurement. However, this condition can often occur at night where interference is still probably the primary limitation on fmin.

At IPS, we assume this condition does not occur frequently enough affect fmin and therefore fmin is always scaled from the first return and H is added. *This is a local scaling convention*.

5.1.4.5 R - retardation

UAG-23A, p72, recommends that when fmin approaches foE, and nondeviative absorption is progressively enhanced by deviative absorption, then the scaled value should be recorded as (fmin) UR. As it is not possible to know how much fmin is being enhanced by deviative absorption, U cannot have a true accuracy meaning. Therefore the scaling fmin _R is preferred at IPS.

While deviative absorption will affect estimates of equipment response, B or C are always used if fmin exceeds foE.

5.1.4.6 S - interference

S is scaled as an unqualified descriptive letter when ionosonde sensitivity has been reduced as a result of strong interference. *This is a local convention* and is preferred to the use of C because statistical studies of S may give information on the source of the interference. Typically, local transmissions at Mawson prevented ionograms from being recorded by desensitising the 4B receiver.

5.2 foE, the critical frequency of the normal E region

foE is the ordinary wave critical frequency corresponding to the lowest thick layer in the E region which causes a discontinuity in the height of the E trace.

5.2.1 General Comments

There are many reasons for scaling foE, yet it is one of the first parameters suggested for elimination when a reduced set of ionogram parameter s is discussed. Some reasons for scaling it are:

- it is important as a daily replacement value for the sporadic-E parameters foEs and fbEs.
- at some locations particle E can enhance foE and might go undetected if foE was not scaled.
- foE is an excellent time indicator. If you doubt the local time on an ionogram, foE will usually give an estimate of time within an hour.

It can be more difficult to scale foE than other parameters because a wide variety of effects - obscuration by Es layers, absorption, retardation, lacuna, particle precipitation - can all affect it. This range of effects possibly makes normal E-region parameters useful, as it ensures practice with nearly all the usual scaling variables. This has particular advantages during scaler training, because the location of foE can always be known reasonably accurately in advance, from predictions or running medians of foE, leaving the scaler to deal almost entirely with the processes affecting the accuracy of measurements.

However, because foE is so predictable, special efforts are required in scaling it accurately. Researchers are only aware of the many competing processes affecting foE because scalers recorded foE carefully. For instance, small shifts in the maximum value of foE can be deduced from hourly values, giving information on movements of the Sq focus. This type of study is impossible if too much reliance is placed on predicted values of foE.

Scaling foE near sunrise is more difficult because a variety of processes often produce unusual E-region layer shapes compared with those observed near midday. As a general rule, IPS scale foE from the cusp that is largest and lowest in frequency, or where the first break in the ionospheric trace is seen (Piggott, INAG-35, p6). In other words, when it becomes difficult to decide which cusp is most important, then the layer as a whole is judged and the cusp is picked out for the layer that is expected to control the maximum frequency propagated by the E layer. *It should be possible to make a family of M-sliders to quantify this rule*.

Care is also needed when an E2 layer is present. Occasionally, E2 will appear before layer sunrise at normal E-region heights and can be mistaken for the normal E region. *When E2 is present, use descriptive letter H on foE*.

Both during early morning, and near sunset, the E region reflection may not be observed but its presence can be deduced from the turnup in the F-layer ordinary wave reflection. This effect must not be confused with turnup in the extraordinary component as it approaches the gyrofrequency, which is between 1.0 MHz to 1.7 MHz for IPS stations, (see earlier Table). It is also possible that the turnup is an E2 layer.

Scaling foE from the X component is difficult when near the interference limit. This is especially true for the extraordinary component because the interference limit is near the gyrofrequency. A good practice is only scale foE from the X ray if some turnup in the O ray also is present.

5.2.2 Qualifying letter usage

Scaling letters are used to indicate the full range of accuracy possible. Exceptions are discussed with the appropriate descriptive letters.

Where a choice exists between using limits D or E, the limit that is closest to the expected foE value is used. This ensures the final medians represent normal conditions.

Interpolation is allowed, although it should be restricted to, at most, the few hours either side of the ionogram being scaled. Predictions and running means of foE may be used to estimate where foE should be, but cannot be used for interpolation. It should only be used in fadeouts.

Both Z mode and extraordinary components can be used to deduce foE.

5.2.3 Flag used with foE

Generally local rules apply. Lacuna (Y) and the Z mode (Z) can both be flagged on foE. However, the Z mode is only flagged on foE if h'E is scaled with a Q. In the very unlikely event that Q, Z and Y are all possible, Y takes precedence, but save the ionogram.

5.2.4 Descriptive letter usage

5.2.4.1 A - blanketing

While foE may be deduced from either magnetoionic component, some care may be required because mode coupling will be possible and because all components would most likely be blanketed together. When a cusp Es layer blankets foE, the Z mode, if present, may be used and scaled as (foE)ZA.

5.2.4.2 B - absorption

(foE) DB is excluded, as it has no meaning.

(foE) JB is considered most unlikely as absorption will affect the extraordinary more than the ordinary component. If the F trace extraordinary ray were used, (foE)UB would probably be a more likely estimate of the errors involved.

Interpolation is only used to obtain an foE value during a fadeout. If particle precipitation is present, foE could be enhanced in a variable fashion, (Es-k), making interpolated values unreliable.

5.2.4.3 D - upper frequency limit

This was more common when band changes were used in older ionosondes. If a band was missing, D was a more complete description than C. IPS have no use for this scaling.

5.2.4.4 E - lower frequency limit

If foE falls below the lower limit of the ionosonde, it may still be possible to deduce a value using the turnup in the ordinary wave return from the F region. Either (foE) UE or EE could be used. Remember that when the layer cannot be seen, then the turnup may not be due to the normal E region. Usually this will be apparent from a sequence.

When foE drops lower than this in frequency, no value is scaled and no replacement letter is required.

It is unlikely, that JE could ever be used with current IPS ionosondes because of the proximity of the gyrofrequency to the ionosonde lower frequency limit. In these cases extraordinary wave turnup will almost certainly be associated with the gyrofrequency.

5.2.4.5 F - spread affects accuracy

Spreading in the E region may affect the accuracy of foE, but it won't usually be severe enough to prevent a reasonably accurate foE value being scaled.

If spread is severe, it could be due to particle E, and if so K would take precedence - sequences, coupled with prior knowledge of where foE normally appears, will help here.

At mid-latitudes, foE can become spread because of local ionisation instabilities. While IPS have introduced Q to flag this on h'E, F on foE may also refine the description of the ionogram.

5.2.4.6 H - disturbances

Descriptive letter H is scaled when the normal E region trace shows a cusp not normally scaled at a station. UAG-23A indicates that H is applicable in all such cases, even when scaling is accurate, because a potential source of error has been introduced. The extent of this error may be interpreted using differences between multiples and between the O and X mode, in which case qualifying letters U and, possibly E or D may be required. However large disturbances causing foE to be in error by over 0.2 MHz will be unusual and possibly worth noting. If a disturbance is large enough for interpolation to be required for foE, the event is most unusual.

5.2.4.7 K - particle E

Whenever foE is scaled from particle E, the value is always described by K. Should lacuna be present, Y supersedes K, but the presence of particle E is still known from the Es type table.

Replacement K is not allowed as K cannot be a reason for not scaling foE.

Interpolation is not allowed because particle E is an irregular sporadic E-layer. However, considering the value of measuring particle E, if interpolation is likely to be the only way a value is recorded, it may be worth reconsidering this point.

5.2.4.8 R - deviative absorption

R is used strictly to show the effects of deviative absorption. If fmin exceeds foE on more than 10 days in a month, R should not be used as B or C are more appropriate. For R to be used with foE, there must be some evidence of increasing attenuation in association with an increase in retardation. Provided this is observed, then all levels of accuracy are allowed, although replacement R is considered unusual. Interpolation should be possible.

If deviative absorption is high, the X component is also affected.

5.2.4.9 Y - lacuna (a flag)

ZY and JY are both considered unusual. However, they retain the weight 6 for a flag, and this supersedes all other weights. Interpolation is allowed because I think lacuna obscures foE but does not alter it in any way.

Y cannot be used to describe large gaps near foE because Y is the lacuna flag for foE. Such gaps must now be described by R, B, or H whichever is appropriate. If cases arise where this approach leads to a poor description of the ionogram then the rules may have to be reassessed.

5.3 h'E, height of the normal E region

h’E is the minimum virtual height of the normal E layer.

5.3.1 General Comments

Comments made about foE apply here also, although h'E is significantly easier to scale than foE. At IPS, the main value of h'E is that the range spread and Z mode flags are scaled on it.

5.3.2 Qualifying letter usage

The upper limit, D, is rarely used with h'E as the normal E region is the lowest ionospheric layer observed on an ionogram. Any loss of accuracy will mean the part of a trace observed must be greater than h'E, so E is the only limit possible.

Because h'E is a thick layer it should not be estimated from other magnetoionic components. However, in most cases the difference in virtual height for the ordinary and extraordinary components is usually within scaling accuracy and could therefore be used.

5.3.3 Flag used with h’E

Both range spread, Q, and the presence of an E region Z mode are flagged on h'E. If both are present, Q has priority on h'E and Z is then scaled on foE. This is done because Q is a local parameter and Z is an URSI parameter so the latter is preserved even if the method is unusual. (See F, below, for a possible additional flag).

5.3.4 Descriptive letter usage

5.3.4.1 B - blanketing

Perhaps DA seems reasonable, using the argument that the layer is thin so E must be just above the h'Es value.

5.3.4.2 E - lower frequency limit of ionosonde

EE and UE may both be appropriate when foE is just above the lower limit of the ionosonde. Replacement E is used when foE is deduced from the F region turnup and no E region is observed, so no h’E can be scaled or estimated.

5.3.4.3 F - spread affects measurement

It will generally be hard to assess how much effect spread has on height measurements, such as h'E, although its presence may constitute a source of unknown error. While descriptive letter F is regarded as normal, examples where accuracy limits can be placed will be unusual. Replacement F is not allowed and it would probably be superseded by Q.

It is worth scaling F as a range spread flag on h'E when spreading doesn't exceed 30 km, thereby keeping Q within URSI bounds while gaining extra information on the spreading in the E region. *This is a local rule.*

5.3.4.4 G - insufficient ionisation in the layer

There is no need for descriptive letter G with h'E.

G is used to show h'Es for cusp and, in particular, high type Es layers are inaccurate. If there were more ionisation in the sporadic E layer, then the effects of retardation associated with the lower, thick, E layer would not produce errors in the height. However, similar reasoning does not hold for h'E as there is no lower thick layer. Any lower thin layers can obscure higher layers, but they cannot produce biased (by retardation) heights in the layers.

5.3.4.5 H - disturbance

Disturbances are unlikely to affect, h'E, and if they do it is most unlikely that enough information will be available on the ionogram to assess the accuracy.

5.3.4.6 K - particle E

Whenever h'E is scaled from a particle-E layer, the value is always described by K. Should range spread, or a Z mode, also be present, Q or Z supersede K. (See foE, descriptive letter K, for other comments.)

5.3.4.7 Q - range spread (a flag)

Replacement Q should be an unusual condition and interpolation cannot be allowed to obtain a value lost because of spread.

5.3.4.8 R - retardation

If fmin is high, then h'E may be affected by retardation, but it is not obviously the primary reason for loss of accuracy, i.e. loss of ionosonde sensitivity or higher than normal absorption may be more appropriate. During solar maximum fmin may increase enough to be affected by deviative absorption, in which case R would be used. Retardation is considered a secondary effect and is used to describe h'E when fmin increases significantly for less than 25% of the days in a month.

If fmin < foE and h'E is usually affected by retardation, B is appropriate. If fmin > foE, usually h'E is replaced by C. However, if h'E is only rarely affected by retardation, R could be scaled. Similarly, if fmin > foE is rare, replacement R could be used.

However, all this places a reasonable load on the scaler for a limited return. An acceptable alternative is to use descriptive letter B for all cases except when fmin > foE, in which case replacement C is used. Consequently no cases exist where R is required.

5.3.4.9 Y - gaps, tilts or lacuna

All the following processes mentioned are questionable scaling outcomes:

- Gaps affecting h'E, as occur in association with low type Es are described by B - a better physical description of the measurement problem than Y.
- Large scale tilts are unlikely to affect the E region as chemical processes are fast here and will rapidly eliminate any steep gradients.
- Lacuna is an upper E region phenomena unlikely to penetrate to low E-region heights and therefore unlikely to affect h'E.

No scaling outcomes are accepted.

5.4 foEs, the top frequency recorded from sporadic E

foEs is the ordinary wave top frequency corresponding to the highest frequency at which a mainly continuous Es trace is observed.

5.4.1 General Comments

All sporadic-E parameters (foEs, fbEs and h'Es) are scaled from the same sporadic E layer; that is the sporadic E ordinary mode layer with the greatest critical frequency, foEs. Thus foEs is the maximum foEs value observed on the hourly ionogram.

Neither foEs nor fbEs are scaled from a low type Es layer unless foEs>foE and l-Es is the maximum foEs for the ionogram.

In the past, IPS scalers have not always followed this rule, and have scaled foEs from a layer that is present in a developing sequence. This approach has significant advantages if sequential layers can always be identified. However, as IPS has at least a solar cycle of such data (1974-84), the more specific rule will now be strictly applied.

Note: If it is assumed that sporadic E layers form close to 100 km then the layer with the maximum foEs is the layer controlling the maximum frequency propagated by sporadic E. (An E-region slider could also be used for foEs, but it is not.)

5.4.2 Qualifying letter usage

All levels of accuracy are allowed with foEs and any exclusions are discussed with the appropriate descriptive letters.

Interpolation is not allowed.

foEs is often calculated from fxEs, using the magnetoionic split appropriate for 100 km.

If the Z mode is formed in thin layers it will be obscured, but it is observed for thick layers, such as particle E, in which case ZK is the only scaling allowed. If a Z mode is seen, it could also control fmin.

5.4.3 Flags used with foEs

The Z mode is flagged on foEs, but this will probably only duplicate the flag on h'E when a particle-E layer shows a Z mode.

5.4.4 Descriptive letter usage

5.4.4.1 A - blanketing

JA is commonly used when foEs is deduced from fxEs, but no other use for descriptive letter A is appropriate.

5.4.4.2 B - absorption

Absorption can effect foEs in two ways:

- reduce fxEs with respect to foEs even to the extent that fxEs is not seen (as the extraordinary mode is absorbed more than the ordinary mode.)
- some types of sporadic E are gain sensitive so the top frequency foEs may be reduced or eliminated. This may affect spread Es which is not treated as a separate class of Es.

These are both matters of intensity, more absorption, more effect. As we may know absorption is affecting results, it will be desirable to note this, but it will rarely be possible to determine how effective it is.

Only descriptive letter B and replacement B are allowed as the loss of accuracy will be unknown.

During daylight hours, if no sporadic E-layer, or E region is observed a limit value (fmin) EB is scaled for foEs.

5.4.4.3 D - upper frequency limit of ionosonde

When foEs exceeds the upper limit of the ionosonde, (limit) DD is scaled. The descriptive letter D is not otherwise used with foEs.

5.4.4.4 E - lower frequency limit of ionosonde

When no sporadic-E layers are seen, and fmin is scaled EE, foEs is scaled (fmin) EE.

While foEs may be deduced from fxEs in these circumstances, for IPS ionosondes, the X component will probably be too close to the gyro frequency to be observed.

5.4.4.5 F - spread affecting the measurement

While not scaled on foEs, F is appropriate at times. When the sporadic E layer looks spread, and Q is appropriate on h'Es, it is possible that the foEs value deduced from the layer depends on equipment sensitivity. If so, F on foEs is an appropriate way of indicating a possible error.

5.4.4.6 G - insufficient ionisation

When no sporadic-E layer is observed above foE, foEs is scaled as (foE) EG - meaning that any sporadic-E layer that is present has a critical frequency lower than foE.

When foE cannot be scaled accurately, and only a replacement letter is tabulated, foEs can be scaled as replacement letter G. However, if doubt exists whether a sporadic-E layer is present or not, the alternatives are to scale (fmin) EG when fmin > foE, or (f) EG where f < foE but foE is not observable, f being the last observed reflection from lower E region. The last option is unusual.

5.4.4.7 H - disturbance

Disturbances can affect foEs, but it seems unusual. When a large disturbance occurs it may even cause the sporadic E layer before it distorts it.

5.4.4.8 K - particle E

When foEs is controlled by particle E, foEs is always described by K, and K has priority over all other scaling letters including Z.

Replacement K is not allowed, as particle E cannot be the reason for not scaling the layer.

5.4.4.9 Y - (not used)

This should not be used when lacuna obscures where foEs could be, as there will generally be insufficient information available to tell with certainty whether a sporadic-E layer is present or not. In these cases G is scaled.

5.5 fbEs, the blanketing frequency associated with foEs

fbEs is the lowest ordinary wave frequency at which the Es layer begins to become transparent.

5.5.1 General Comments

fbEs is scaled from the same sporadic-E layer that foEs is scaled.

Although this is the normal URSI convention, it can lead to identification problems. At times, two layers are present, such as in fig. 4.20 p122 UAG-23A, where only the lower layer has a blanketing frequency. This can lead to indecision. However, as shown in the caption, fbEs is still scaled for the same layer for which foEs was scaled. On other occasions, when more than one sporadic-E layer is present, fbEs can clearly be controlled by a layer with a lower foEs. There are no conventions that allow this condition to be flagged. Presumably it happens infrequently and rules defining it could be unworkable.

5.5.2 Qualifying letter usage

A full range of accuracy is allowed, exclusions being discussed with the appropriate descriptive letter.

No interpolation is allowed.

As the blanketing frequency, fbEs, is not a critical frequency, but is a minimum transmission frequency for sporadic-E, normally a thin layer, it is difficult to relate the various similar minimum frequencies for other magnetoionic components to one and other.

There is nothing in UAG-23A to give guidance on when the X mode cannot be used to deduce O mode parameters. Such deductions will be incorrect when the normal relationship

$$fx - fo \sim 0.5\ fB$$

is incorrect. This problem should only arise when foEs ™ 3 MHz. This is particularly significant for fbEs, because when sporadic-E layers are less than 1 km thick, mode coupling can occur causing the 0.5 fB relationships to fail. However, R. H. Clarke showed that for Brisbane, mode coupling was statistically unimportant. Thus, fobEs could be deduced from fxbEs with reasonable safety, the qualifier J warning of unknown errors. Clarke pointed out that there was also a significant scatter associated with this result and postulated that this resulted from spatial gradients between the O and X wave reflection points. This introduces two effects, one is the parameter s of the Es region observed and the other is the F region observed. During periods when the F region is disturbed, the latter can also be an important factor.

A further important factor is that for fbEs within about 1 MHz of foE, differential, non-deviative absorption between the ordinary and extraordinary components could introduce a variable bias favouring higher fxbEs values.

Thus while mode coupling may be rare, and absorption small, in general, errors are larger than normally experienced when deducing one component from others. Because of this, a usage such as this is regarded as provisionally acceptable until tested further.

The qualifying letter A is only used with fbEs and has the descriptive letter A. This was introduced because fbEs is measured from the layer, normally the F layer, seen through the Es layer. When the blanketing is high enough no returns are seen and therefore no fbEs value can be measured. In these cases fbEs is recorded as (foEs)AA. Piggott pointed out that a better estimate of fbEs can be made by using foEs measured from the second multiple. This seems reasonable on inspecting specific cases and can be used with AA when cases are found. It is a situation where a little extra effort looking at a sequence of ionograms may support the hypothesis.

5.5.3 Flags used with fbEs

No flags are used with fbEs.

5.5.4 Descriptive letter usage

5.5.4.1 A - blanketing and obscuration by multiples

This will often be used when multiples of the sporadic E layer are superposed over the F trace making the determination of fbEs inaccurate. _EA, _DA and _UA will all be possible, but replacement A would be unusual.

Possibly when there is confusion over whether the blanketing frequency scaled is controlled by the same layer controlling foEs, descriptive letter A could be scaled. No accuracy range would be appropriate however, as a value was chosen and only a subjective error of judgment is being recorded.

5.5.4.2 B - nondeviative absorption

Absorption may affect fbEs by varying degrees. It will probably be unusual if enough evidence exists for a limit to be placed on the extent of the effect, particularly at mid latitudes where parameters are often insensitive to gain changes, so accuracy limits will often be subjective, descriptive letter B being most appropriate. The limit DB is excluded as having no meaning, and JB is excluded as the extraordinary component will almost certainly be affected producing biased results for the deduced fobEs.

5.5.4.3 C - equipment problems

_JC will be for the very rare occasion when the O component is lost but X is seen. _JS follows for similar reasons.

5.5.4.4 D - upper limit of ionosonde

If a blanketing layer clearly extended to the top frequency of the ionosonde, it may be appropriate to scale _AD rather than _AA, as AA is not really correct now (as the event is so rare, it is hardly worth worrying).

5.5.4.5 E - lower limit of ionosonde

When foEs < fmin, and fmin falls below the lower limit of the ionosonde, fbEs is scaled as (fmin) EE.

5.5.4.6 F - spread affecting measurement

fbEs is normally measured from the F region which, if spread, may affect the final value of fbEs. No _DF or replacement F is allowed. The issue here is that a confusion of Es and possibly oblique F traces may make fbEs suspect. A more correct scaling would be H - implying a disturbed ionosphere.

5.5.4.7 G - insufficient ionisation

When no sporadic-E layer is observed during daytime, the limit value scaled for fbEs is (foE) EG. The same limit is scaled when a non-blanketing sporadic-E layer is present.

When foEs > foE but fbEs < foE, then fbEs always carries the descriptive letter G, which supersedes all other descriptive letters on fbEs. Note that UG and DG must also be possible because of this.

Replacement G can be scaled when foE is scaled with only a replacement letter - see foEs for a discussion of this case.

5.5.4.8 H - disturbances

If the layer from which fbEs is measured (normally the F layer) is tilted then fbEs can be in error by some unknown amount. If fbEs < foEs, but the layer is clearly tilted, describe fbEs by H. If fbEs > foEs, and the layer appears tilted, describe fbEs by Y (see Y for further comments).

When H is scaled this way, _UH may be reasonable, but _EH is unusual and _DH is not possible.

5.5.4.9 K - particle E

Whenever fbEs is scaled from the particle-E layer that controls foEs, fbEs is always described by K.

A more correct scaling would be H - implying a disturbed ionosphere.

Because of the definition fbEs = foE, for particle E, _JK is a possible scaling.

The scaling _AK is not allowed because, when particle E is present, fbEs = foEs = foE always, and there is no doubt about the value of fbEs.

5.5.4.10 R - retardation and defocusing

If fbEs is within, say, 0.3 MHz of a critical frequency, then deviative absorption will probably increase fbEs by some unknown amount. Descriptive letter R only is appropriate.

Small-scale travelling ionospheric waves in the lower F region can produce focusing and defocusing. These can result in part(s), or all, of the F trace disappearing between foE and foF1, during the daytime. In such cases, _R, _UR and in extreme cases, (if the sequence suggests large enough excursions) _ER are all appropriate. In these cases, if fbEs > foEs, scale fbEs = (foEs)UR, with U or E as appropriate.

In general R is preferred to Y or H, as these are not large tilts, but are only small reductions in signal strength caused by defocusing in the F region and the reflected amplitude is already reduced.

5.5.4.11 Y - gaps and large tilts

During daytime, when fbEs > foEs, R will usually be more appropriate than Y. However, at night, large tilts are possible and the defocusing effects, seen in a region of large retardation, will not be observed so descriptive letter Y can be used. In either case, assuming foEs = fbEs (at most), an accuracy limit may be placed on fbEs depending on how large (fbEs - foEs) is. No DY case exists. Remember that if fbEs > foEs then the value of fbEs is almost certainly disturbed and some descriptive letter is appropriate.

If there is good evidence for the F region and fbEs being constant, while foEs varies, then if fbEs > foEs it may be more appropriate to scale fbEs from the F region. However, this is an unusual condition and should only be scaled in this way if a sequence shows this to be the case. Remember, Y is not flag and does not signify lacuna is present.

5.6 h'Es, virtual height of the layer associated with foEs

h’Es is the minimum virtual height of the trace used to give foEs.

5.6.1 General Comments

At mid-latitudes, the height of high and cusp type sporadic-E layers may possibly contribute to tidal observations of the upper E region. When h'Es is scaled from thick particle-E layers it is technically possible to use this height to estimate the energy of the particles producing the layer.

Currently, at IPS, range spread in Es layers is flagged on h'Es by the descriptive letters Q and F ?

These are possible areas where h'Es can contribute useful information and hence are reasons for scaling h'Es - a parameter URSI has considered not worth supporting in the past.

5.6.2 Qualifying letter usage

Full accuracy usage is allowed, bar the use of D. As with all heights measured from ionograms, D is not used.

Interpolation is not allowed for sporadic E parameters.

On occasions (Magnetoionic components) h'oEs will occasionally be deduced from h'xEs. This is only done for thin layers (c, h, f, l types) where the errors are considered small enough to be qualified by U. The qualifier J is attractive, as any bias could be assessed, but this is not advocated all the same.

5.6.3 Flags used with h'Es

The range spread flag, Q, is the only flag used with h'Es.

5.6.4 Descriptive letter usage

5.6.4.1 A - blanketing

There are two occasions when descriptive letter A is used with h'Es. When a cusp or high type Es is observed but is obscured by range spreading on a lower Es layer and when the Es_a or Es_r heights are blanketed. Both are rare and peculiar cases. Because of the oblique traces involved, only descriptive letter A is allowed. Normally, when particle E is present, descriptive letter K supersedes A anyway.

5.6.4.2 B - non-deviative absorption

Absorption will not affect the heights of thin layers, such as flat, low, cusp and high layers. However, it could affect thick or amorphous layers like particle E (Es-k and r) or auroral Es. In these cases, the condition will probably be unusual and the error limits unknown. Only descriptive letter and replacement B is allowed.

5.6.4.3 C - equipment problems

If height markers were missing on ionograms, sporadic-E layers could give a good estimate of 100 km but associated heights, including h'Es, would all be in error by 10-20% and scaled UC at best.

5.6.4.4 E - lower frequency limit of ionosonde

When no sporadic-E layer is present and fmin is _EE then the replacement letter E is scaled.

5.6.4.5 F - spread present

As a local rule, F is scaled if the Es layer is spread, but not spread enough for Q to be used. Unlike Q, this is not a flag and can be superseded by other descriptive letters if required. While F is rather unusual on a height parameter, it may be useful.

5.6.4.6 G - insufficient ionisation

For a high or cusp type sporadic-E layer, if foEs is close to foE, retardation associated with the normal E layer can bias h'Es too high. It is conventional to scale (h'Es) EG in these cases, a good value for h'Es only being scaled when a horizontal trace is observed because it is generally not possible to assess accuracy limits for this case. Although it is not easily proven, it is probably rare when UG is actually a good assessment of the accuracy, even when it seems it should be. (Where "tidal" layers, or sequential Es, are concerned, as h'Es decreases, foEs can often increase, making it even harder to assess accuracy.)

When no Es layer is present, and foEs is scaled (foE) EG, it is conventional at IPS to scale h'Es as replacement letter G.

5.6.4.7 H - disturbance

If there is evidence for large tilts in the sporadic-E layer (from inspection of multiples, for instance) h'Es may also be in error by some unknown amount. At most, descriptive letter H could be used but it will be rare.

5.6.4.8 K - particle E

No replacement K is allowed.

As with h'E, if h'Es is scaled from a particle E layer, it is always described by K, and K is only superseded by Q as the descriptive letter on h'Es.

5.6.4.9 R - retardation

Retardation cannot affect h'Es, so descriptive letter R is not used with h'Es.

The two occasions where it might be significant are when foEs is too close to foE, so G is the descriptive letter, and when h'Es is scaled from a thick layer that does not go horizontal, probably E, S or B will be appropriate although a case for R is possible.

5.7 foF1, critical frequency of the F1 layer

foF1 is the ordinary wave F1 critical frequency.

5.7.1 General Comments

foF1 is scaled at all Australian stations. UAG-23A, p19 suggests that at low latitudes it can sometimes be difficult to identify foF1 unambiguously, however, foF1 is scaled at Vanimo (geographic lat. = 2°S) nevertheless, and evidently poses no problems. During solar maximum, in winter, foF1, is not observed at most Australian stations unless a travelling disturbance "makes it visible".

The principal problem, associated with scaling foF1, is deciding what level of accuracy to scale when the foF1 cusp is ill-defined and scaling letter L is appropriate. In particular, UAG-23A, p85, had advocated a _DL scaling where the more physically correct scaling would have been _EL. In 1981 URSI accepted that the _DL scaling was inappropriate and that replacement L should be used. The argument for this was that although _DL was wrong, and _EL more appropriate, neither was of value because the ionogram often highlights small changes in ionisation, especially near cusps. Thus, there was almost certainly no useful information associated with the cusp when _EL is appropriate, and scaling it is therefore deceptive. Furthermore, analysis carried out to prove these points also showed that the error associated with _EL is really unknown, the E being a lower limit flag.

This is discussed in INAG 27. At IPS, the _DL scaling was replaced by L, as proposed by URSI, although _EL may be recorded if scalers wish. The latter scaling is accepted because it is often possible to feel certain about the scaling, and using a replacement value appears to be an inappropriate interpretation of the accuracy rules. It also breaks a cardinal scaling rule; **get a value if possible and leave it to the researchers to interpret it**.

It is worth remembering that the arguments against using _EL are also true for _UL, which also must be biased too high. So it is wrong to think that banning _EL would ban the bias.

The various scaling options are outlined, UAG-23A, pp. 85, 87) and are summarised in table 4.

Case	1	2	3	4	5	6
M(3000)F1	Indistinct	Indistinct	Indistinct	Defined	Defined	Defined
h'F2	No tangent	No tangent	Tangent	No Tangent	Tangent	Tangent
foF1	No cusp	Poor cusp	Poor cusp	Poor cusp	Poor cusp	Cusp
Scale						
h'F2	No entry	L	_L	L	_L	_
foF1	No entry	L	L or _EL	L or _EL	-UL	_

- where, for cases 1 to 3, M(3000)F1 = indistinct, means the M slider couldn't fit the curve.
- and for cases 4, 5 and 6 h'F2 = tangent, means the F2 trace can be fitted by a horizontal tangent.
- and for cases 2 to 5 foF1 = poor cusp, means the cusp is rounded.

(see h'F2, for further discussion.) Note: entry 3 is probably uncommon.

Before leaving this table, it is interesting to speculate on how much the usage of L depends on the use of an M(3000)F1 slider. Had a shorter distance MUF been chosen, would foF1 be defined more often? In other words, is the L usage a measure of the F1 layer height? I feel it is and, because of this, would have preferred if foF1 was defined by only requiring h'F2 to be defined. As h'F2 is the minimum in retardation between foF1 and foF2, if h'F2 isn't defined, it implies there is insufficient retardation in the F1 region, making the F1 region less significant. A rather more elaborate method has been proposed for scaling foF1, but it is not used at IPS.

In winter, during solar maximum, foF1 may only appear because of a TID, or during an ionospheric storm. Particularly a TID, it would seem more appropriate to scale H - the reason for foF1 appearing - rather than L - the appearance on the ionogram. Piggott argued strongly in favour of L, on the basis that if disturbances are really causing the trace to appear, then statistical studies will prove it. This is obviously the correct approach because while a disturbance may have made the F1 region more visible, it could be that this happens only at certain preferred times, so H is only part of the story. Furthermore, H is not a flag for disturbances on ionograms and has a more precise meaning with foF1 scaling.

foF1 can be difficult to scale in the presence of F0.5 and F1.5. One possible way to aid in identification of the correct trace is to use the ratio of (foE/foF1) for guidance. Piggott claims this is a reasonably constant value for any one location. However, obtaining it requires care - our raw data shows a large scatter. If selected good data are used for foE and foF1, each station can obtain these ratios - and should. In general, foF1 will be continuous over a day, and consistent from one day to the next and, for Australian stations, F0.5 and F1.5 are more variable or evolve faster. Plus, experience should help scalers in picking foF1 out consistently.

Note: see h'F for comments on intermediate layer sequences.

5.7.2 Qualifying letter usage

Full accuracy is allowed, as is interpolation. Both extraordinary and Z modes may be used to deduce the ordinary component.

5.7.3 Flags used with foF1

Two flags are used with foF1 - Y for lacuna in the F1 region and Z for the Z mode observed for the F1 region. If a Z mode occurs at the same time as lacuna (unusual or rare) then Y takes precedence, and the Z is scaled on h'F. (Note, h'F2 seems more appropriate as a substitute for foF1 but h'F2 is also used for lacuna.)

5.7.4 Descriptive letter usage

5.7.4.1 A - blanketing

_JA is considered unusual and _ZA will not occur if the component is blanketed. _DA is excluded.

5.7.4.2 D - upper frequency limit

foF1 will never reach this limit unless it is lowered artificially for some equipment reason, hence scale C.

5.7.4.3 E - lower frequency limit

Nor will foF1 reach the lower frequency limit of a modern ionosonde. Again C is appropriate.

5.7.4.4 F - measurements affected by spread echoes

While a full range of accuracy is allowed, spread greater than 0.2 MHz on foF1 is uncommon at Australian stations, so several scaling outcomes are unusual and worth noting when they occur.

Because daytime spread is a strong indicator of a disturbed ionosphere, it seems its presence should be flagged on foF1. However, at present, it isn't, because spread must exceed 0.2 MHz for normal URSI conventions.

5.7.4.5 G - insufficient ionisation

During severe ionospheric storms, foF2 drops below foF1 and foF1 can also be depressed by 0.5 MHz or so. At solar maximum this condition, combined with high foE, could result in foF1 dropping below foE. It would be a rare occurrence. Examples of this are worth finding.

If the normal E region were enhanced by particle E (Es-k), then A should supersede G, and limit values on foF1 and foF2 are no longer mandatory. However, if a significant depression is apparent from a near normal foE _K value, _EG may still be a better scaling for the ionogram. If you see it, save the ionogram. Irrespective of this, _EG is rejected as unlikely.

5.7.4.6 H - disturbance

The F1 cusp region frequently shows the presence of disturbances which can make the scaling of foF1 more difficult. When this occurs, the multiples, and other magnetoionic components may be used to obtain an estimate of foF1 together with an accuracy limit bracketing the possible values (e.g. E/D/U). When a single component (X or Z) is used to determine foF1, it implies greater confidence in this component than in the average scaling for all components.

Replacement H implies foF1 is in error by roughly 0.8 MHz, but it is still regarded as acceptable.

5.7.4.7 L - ill-defined cusp

Correct use of L poses a number of minor difficulties. The use of L is tied to whether the F1 region is developed enough to warrant scaling, as has been discussed in sec. 3.8.1. In a sense, L is a flag for this condition and normal accuracy limits have been suspended. Thus _EL or L implies foF1 is barely visible and _UL implies it is just visible. There is no real need for _L which, by rights, can contribute no more information.

Should a Z or X mode cusp be more easily scaled than the ordinary cusp, then it appears likely that a disturbance has affected the F1 region and, for instance, _JH would be more appropriate that _JL. Without this ruling _JL would be required for most disturbances observed. This is different from scaling H when a disturbance causes an F1 region to appear.

5.7.4.8 R - deviative absorption

It often seems that retardation effects are accentuated by equipment limitations rather than pure ionospheric effects (probably a failure in design, rather than routine operation). For instance, Piggott suggested narrow pulse widths resulted in more R results at solar maximum. This could make R a sensitive equipment parameter worth careful scaling.

For foF1, which is normally observed on ionograms because of an inflection in the n(h) profile, retardation would appear to be reasonably unlikely to affect foF1 beyond _UR.

Replacement R should be very rare and is therefore not included in the tables. Normally there will be enough information to extrapolate to foF1 from both E and F2 sides to give a value. If foF1 < fmin occurs often enough, R is unlikely to be appropriate - C should be used as it implies major equipment problems.

Both _ZR and _JR appear unusual, although if R is an equipment effect, then the X or Z modes could be stronger than the ordinary mode.

5.7.4.9 W - upper height limit

It will be unusual for foF1 to be affected by a W condition that accompanies an (foF1)EG condition, particularly near dawn. Descriptive letter W is maybe the most likely usage, with _UW and _DW are also possible. Replacement W is very rare.

5.7.4.10 V - forked trace

Particularly during G conditions, V could appear on foF1.

5.7.4.11 Y - lacuna (a flag)

As Y is a lacuna flag on foF1, it will be necessary to scale gaps or severe tilts in the F1 trace by some other letter. H is most appropriate.

5.7.4.12 Z mode in F1 region (a flag)

If lacuna is present, scale Z on h'F if h'F not used for the range spread flag Q.

5.8 h'F2, minimum virtual height of highest stable F layer

h’F2 is the minimum virtual height of the ordinary wave trace for the highest stable stratification in the F region.

5.8.1 General Comments

h'F2 is the minimum in retardation between the F1 and F2 regions - its physical value is not clear, although by scaling it, a better overall picture of the ionogram can be obtained. It is scaled at all Australian stations applying almost the same rules as for foF1.

The principal rule used for recognising h'F2 is whether the F2 trace shows a horizontal tangent. If it does, h'F2 can be scaled, if not, it cannot - consistent with comments in UAG-23A, p22. Possible h'F2 results were shown in the foF1 table. No _UL scaling is considered because there seems little advantage in indicating that a tangent is almost present, as _UL implies. Extrapolation cannot be used with L to infer a tangent because; "what is observable, is all there is to observe". In other words, extrapolating implicitly assumes that h'F2 can be defined and that the underlying ionisation is preventing it from being observed. This is not the case, a lack of a tangent shows that there is insufficient ionisation present in the F1 region to define one.

Piggott suggested h'F2 should only be scaled when foF1 is not described by L. While there is some merit in this approach, it is easier to scale h'F2 when a tangent is possible, and add L if foF1 is described by L, as a reminder that the value is probably of limited value.

Normally, the frequency at which h'F is scaled is clearly lower than where h'F2 is scaled. However, when there is additional ionisation in the E(F) region, retardation can be greater and so the minimum virtual height within the F region appears close to F2, where h'F2 would normally be scaled. This then presents a problem for the scaler. If normal scaling conventions are followed, h'F = h'F2, and the h'F series of measurements appears to contain a discontinuity. If the sequence is scaled treating parameters as roughly constant in height/frequency then h'F2 < h'F.

This event is evidently reasonably common for New Zealand stations and so, like New Zealand, we shall scale h'F from the F1 region and h'F2 from the F2 region, describing both with H. *This is a local convention* and the results should be reported to INAG. This approach was suggested partly to maintain consistency with New Zealand scaling conventions, since IPS now scale their ionograms, partly to alleviate concern over apparent UAG-23A contradictions and partly to ease automatic error checking of parameter s.

5.8.2 Qualifying letter usage

Full accuracy , bar qualifier D, is allowed, as is interpolation. Because h'F2 is measured from a thick layer, Z and X traces can not be used to determine h'F2.

5.8.3 Flags on h'F2

When F2 region lacuna removes the point where h'F2 would be measured, Y is flagged on h'F2. If foF2 is also affected by lacuna, then a Y will appear there also.

This is an unconventional scaling and could lead to difficulties if no foF1 or h'F2 value is defined. For now, Y is scaled on these parameters as a descriptive letter, even if the parameters would not normally be scaled according to the ionogram sequence being inspected.

5.8.4 Descriptive letter usage

5.8.4.1 F - spread affecting measurements

As virtual heights are measured from the minimum height associated with a layer, it is hard to see what measurable errors are present. There will be the occasional rare instance when oblique traces have shorter time delays, and hence could be scaled as the virtual height the virtual height parameter, but this will be rare and probably does not affect h'F2. Thus F indicates an unknown error and the qualifying letter would be a height-dependent indicator of the height range of the spread.

If range spread is scaled on h'F2 as a flag, there is less of a problem, Q being scaled when spread exceeds 30 km and F being used when spread is less than 30 km, but possibly affecting the measurement.

It appears to me that accuracy limit, E, is a subjective flag rather than a good accuracy estimate and that more use can be made of _F or _UF. Replacement F appears to be an unusual, or even rare, circumstance worthy of careful inspection. (See H for further comments.)

5.8.4.2 G - insufficient ionisation

When foF2 < foF1, h'F2 replacement G is used with h'F2. No other results are required.

5.8.4.3 H - stratification

When satellite traces are present in the minimum near h'F2, the measurement of h'F2 could be in error. However, the extent of the error may be hard to assess. Variations in the patterns of O and X components may place limits on the error, but it will be subjective. Often spread conditions near h'F take the form of satellite traces, suggesting H is a more appropriate descriptive letter than F (or Q). There appear to be no clear conventions here, probably because it is difficult to define terms of reference that will remain consistent.

At IPS, satellite traces near h'F2 are not used as a criteria for deciding whether F or H is appropriate. Instead H retains its usual meaning, and is used to describe h'F in the presence of disturbances. The effects of these disturbances may cause discrete spread traces near h'F2 and it is left to the scaler's discretion to decide whether F or H is a better description of the reduced accuracy of h'F2.

Although interpolation or replacement H are both considered unusual, they are both acceptable results.

When F1.5 is present, h'F2 is scaled with descriptive letter H - *an IPS convention.*

5.8.4.4 L - poorly defined cusp at foF1

As already mentioned in section 3.9.1 and shown in table 4, only L or _L are normally allowed. The descriptive letter L is not a reason for loss of accuracy, and extrapolation is not used to obtain a tangent. Nevertheless _UL is accepted although it appears unnecessary.

5.8.4.5 Q - range spread flag?

Currently, Q is normally a range spread flag, F being used if measurements are affected by spread echoes. If Q is used as a range spread flag on h'F2, then range spread must exceed 30 km before it is scaled.

I favour flagging range spread, rather than using F to indicate possible unknown errors in h'F2. Q is only accepted provisionally. *This will be experimented with as a local flag*. Daytime spread is usually associated with disturbed days, so it is important to be aware of and able to forecast these events.

5.8.4.6 R - retardation

As h'F2 is the minimum in retardation between foF1 and foF2 it should be the last part of the ionogram affected by retardation. For h'F2 to be affected by R, some other effect like low equipment sensitivity (C), or high absorption (B), or a large tilt (H or Y) will be more appropriate.

To allow for cases where foF2 approaches foF1 and retardation is large, _R and _UR are allowed.

5.8.4.7 W - upper height limit of ionosonde

W cases are not common, and UAG-23A emphasises that care must be taken not to scale W when G is more appropriate. While replacement W, like replacement G, is possible, it is hard to see how accuracy conditions would be appropriate. The trace will either be there, or not.

The only possible error is the gross one of not being sure it is the F2 region or not - then descriptive letter W may be appropriate. Descriptive letter W could also be used at low latitudes when an unusual stratification could be confused with foF2 and the height range of the ionosonde is too small to give unambiguous information for scaling. However, the usage is questionable.

5.9 h'F, minimum virtual height returned from the F region

h'F is the minimum virtual height of the ordinary wave F trace.

5.9.1 General Comments"

h'F is scaled from "the F region as a whole". (UAG-23A, p22). In other words, h'F is not scaled from transient phenomena that are unrepresentative of the ionosphere. The question is, how transient? A disturbance may lower h'F for a few minutes to an hour while F0.5 can produce a similar effect for several hours. Normally multiples and O and X component differences can be used to discriminate between the various possibilities. F0.5 often occurs and can eventually become disjoint from the F1 layer, dropping in height and becoming a high type sporadic E layer. UAG-23A offers a special parameter h'F0.5 for local studies of this phenomenon. However, at IPS, and probably most places, no attempt is made to discriminate between F1 and F0.5 regions, h'F being scaled from F0.5, if it is present. In the past, IPS scaled _UH on h'F if it were deduced from F0.5, this scaling being based on fig. 3.22 p83 of UAG-23A. This scaling has now been discontinued in favour of - H, U being used for accuracy only. However, because no local study is made of F0.5, we have no real information on this phenomenon which may be important for sporadic-E studies. It may be worth considering whether the condition can be better flagged. If h'F0.5 were scaled, then presumably h'F = h'F0.5 by virtue of the definition of h'F so a flag seems more appropriate than a new parameter.

As discussed with h'F2, on occasions during the day the virtual height of the F2 region, where h'F2 is normally scaled, is less than that of the F1 region (where h'F is normally scaled). This tends to be a high latitude effect and normally h'F < h'F2. Here only h'F is scaled from the F1 region, h'F from the F2 and both have descriptive letter H. *This is a local convention*.

5.9.1.1 Intermediate layer scaling

Intermediate layer sequences, at night, can produce a range of effects - the most significant being the appearance of a second stratification in the F-region. This is a disturbed condition, as inspection of a sequence of ionograms, or ionograms from local stations, shows. At IPS, h'F is scaled from the lower height, h'F2 is used to record the upper height and the intermediate frequency is recorded in foF1. M(3000)F2 is usually scaled from the upper layer. All parameters affected by the intermediate layer are described by H or descriptive letter L, with its usual accuracy meanings (see table) if the intermediate cusp is poorly defined and _EL is much preferred to replacement L. On occasions this event can distort the E region and look like particle E. The distinction between particle E (or true night E) and the intermediate layer, is that the sequence of ionograms will usually show the event starting at large virtual heights and frequencies. This is an example of a large scale TID.

There is another high latitude phenomena, much more like a layer than the midlatitude disturbance, and also associated with the term "intermediate layer". The distinction between the two types is that when the layer forms, O and X returns are consistent with overhead returns, while this is usually not true of the disturbance. When an overhead layer is formed, the descriptive letters H or L are no longer appropriate but the same scaling conventions should be adopted.

5.9.2 Qualifying letter usage

As heights are always minimum values, D cannot normally be used as a qualifier. This is particularly obvious for E region heights, and similar reasons also follow for h'F. However, a special case may arise at night, when tongues of ionisation extend down to low altitudes and can be observed at oblique angles. Here heights are obviously low and yet may be the only scaleable trace. If scaled, then it may seem reasonable to show that it is a lower limit for the heights. The _DH result will be allowed as a rare possibility.

At night h'F can be difficult to measure when it doesn't actually reach a horizontal state before the trace is cut off by interference. Extrapolation of the trace is then required and, with the aid of overlays, can be carried out effectively. It is possible to estimate h'F consistently, within the U limits on occasions. However, UAG-23A, p22 implies _ES should always be scaled. IPS also allow _US and _S, as it is consistent with the accuracy conventions we prefer.

5.9.3 Flags used with h'F

Range spread, Q, takes precedence over all other descriptive letters on h'F. If a Z mode is present in the F1 region as well as lacuna, a Z is flagged on h'F and has precedence over all letters, including Y but not Q.

5.9.4 Descriptive letter usage

5.9.4.1 A - obscured by multiples

Es layer multiples may obscure the region where h'F is measured. If it is possible to estimate h'F from the X component _JA is appropriate. It is far less likely for the Z mode to be used this way so _ZA is very rare.

5.9.4.2 B - nondeviative absorption

Interpolation may only be used during fadeouts (SID).

At high latitudes, troughs of ionisation may be associated with rapid increases in h'F. As these events may also be accompanied by absorption events and height changes and absorption are correlated, interpolation cannot be used.

5.9.4.3 E - low frequency limit of ionosonde

The lower limit of the ionosonde may affect the accuracy of h'F, but usually doesn't. Interference is the more normal limit. However, replacement E is acceptable if extrapolation errors are large.

5.9.4.4 F - measurements affected by spread

Comments made on scaling F on h'F2 apply here also. Spread may cause unknown errors in h'F, and because h'F often falls in the height range 200-300 km, Q may not necessarily be scaled. F indicates smaller errors in h'F than would be expected when Q is scaled but Replacement F is always superseded by Q. However, to remain consistent with earlier scaling conventions, F is retained. Ideally, F should only be used when errors occur because of spread. While spread of 30 km may occur, it doesn't really imply an error in h'F.

5.9.4.5 H - disturbance

H can be used as a disturbance flag instead of just to describe reasons for a loss of accuracy. It indicates such unusual events as F0.5. When evidence exists for h'F being controlled by an oblique low altitude tongue of ionisation, _DH may be used. The intermediate layer may also be described by H, although L may also be appropriate.

In addition to these conditions, H is also used in the usual way to show transient disturbances may have affected h'F.

5.9.4.6 Q - range spread flag

Whenever range spread exceeds 30 km, Q is used as a descriptive letter on h'F.

5.9.4.7 R - deviative absorption

h'F may become indistinct, with a weak trace resulting from deviative absorption, but the condition seems rare. During daytime when fmin is greater than the position where h'F is scaled, then R may be used when the event occurs on less than 25% of the days of a month otherwise B or C should be used.

Both descriptive letter R and _UR are retained for occasions when foF1 is reasonably close to foE and h'F becomes difficult to measure.

5.9.4.8 W - upper height limit of ionosonde

W will rarely, if ever, be required with h'F. Only replacement W is allowed.

5.9.4.9 Y - gaps, tilts or lacuna

Y is used to show how a variety of phenomena may be affecting the scaling of h'F. If lacuna is the cause of measurement difficulties, it will be possible to deduce this from the foF1 flag.

All results are allowed, including interpolation, although probably _UY and _IY are rare.

5.9.4.10 Z mode flag

Descriptive letter Z is an alternate Z mode flag for Z being observed for the F1 region. It will rarely be needed.

5.10 M(3000)F2, the MUF2 factor

M(3000)F2 is the 3000 km MUF factor for the F2 region.

5.10.1 General Comments

M(3000)F2 is often quoted as the second most important parameter scaled from an ionogram. Certainly, it is considered particularly important by IPS and every attempt should be made to obtain values.

Because ionograms normally have logarithmic frequency scales, the M-factor can be estimated using a special slider constructed according to instructions given in UAG-23A, p23. This approach is convenient for manual scaling, but is probably not so useful for semi-automatic systems, where the point of tangency can be estimated analytically. This would be especially desirable where blanketing approaches the normal point of tangency and the limit is not always clear.

5.10.2 Qualifying letter usage

Since IPS installed semi-automatic scaling, no limit values of M(3000)F2 have been scaled. It is not obvious why this should be, although it possibly arises because there is surprisingly little information in UAG-23A on scaling M(3000)F2 and no guidance on accuracy interpretation. *This would appear to be an oversight that INAG should rectify*. The need possibly becomes greater as alternative methods for scaling M(3000)F2 are used in different semi-automatic scaling systems.

The problems of accuracy will depend on the scaling system to some extent, but reasonable guidelines should still be possible. When manual scaling was used, it was always possible to shift the slider about to estimate the best fit for the ionogram. However, problems arise in the present IPS scaling environment, because M(3000)F2 is scaled as a point on the ionogram and later interpreted using the scaled foF2 value. When foF2 is qualified by E or D, the calculation of M(3000)F2 will also be inaccurate, but a value should be possible. If both foF2 and the location of M(3000)F2 are qualified, the problem is more difficult. However, that does not seem to be a good reason for not scaling limit values of M(3000)F2.

As an interim remedy, a look up table for the accuracy is given in the table below which gives a first estimate of accuracy for M(3000)F2 by applying limits to the expression. Inspection of the ionogram may change these entries as errors in M(3000)F2 and foF2 may compensate. Ultimately, however, the error in M(3000)F2 must be greater than the error in either foF2 or at the point of tangency to the F-region trace. As more scaling is carried out using semi-automatic systems, it may be desirable to introduce MUF(3000)F2 as a subsidiary parameter. This can be measured directly from the point of tangency and M(3000)F2 calculated later using the tabulated hourly foF2 values. Certainly IPS could do this and estimate the value of using the two approaches. Clearly, more MUF(3000)F2 values can be scaled than M(3000)F2 values because of the latter's dependence on foF2. If M(3000)F2 is calculated directly, as at present, then the final accuracy can be assigned using foF2 errors and the estimated error in the point of tangency or the estimated error in M(3000)F2. Although it is obvious when you think about it, the accuracy limits for foF2 and M(3000)F2 are reversed. This is because M(3000)F2 and foF2 are inversely proportional to one another.

Accuracy	explanation	Qualifying Letters														
Tangency	initial estimate	U	-	U	-	-	U	U	D	D	E	E	D	E	E	D
foF2	foF2 accuracy	-	U	U	E	D	E	D	U	b	U	b	E	E	D	D
M(3000)F2	final accuracy	U	U	U	D	E	D	E	D	D	E	E	replacement letter			

Table: Accuracy scaling for M(3000)F2 (Note: b means no qualifier needed)

The maximum error is always assigned. When both foF2 and the point of tangency are limit values, it will not be possible to assign a sensible value and a replacement letter is used.

Full accuracy is allowed, as is interpolation.

M(3000)F2 is normally deduced from the O component, but it can be deduced from either the X or Z component (INAG-23A, p67). Two cases are relevant here. First, the M(3000)F2 point of tangency is measured from the O component and foF2 is deduced from either X or Z. Here M(3000)F2 is qualified by Z but not J, (UAG-23A, pp. 66-67). In these cases, M(3000)F2 should be qualified by U as neither qualifier Z nor J has meaning with M(3000)F2. Second, M(3000)F2 may be deduced entirely from the X component (INAG-39 and INAG-46). Provided foF2 is not close to the gyrofrequency, fB, or foF1, corrections for underlying ionisation should not be too large. However, because the correction is not constant, the method is not normally used. Unknown errors may exist, and there is no clear guidance regarding the accuracy limits on foF2 when near foF1, or foF2 near fB while it seems M(3000)F2 deduced in this way should be flagged. Possibly the qualifier J could be added to M(3000)F2, described by the reason for not using the O component, and scaling programs allow for this. In calculating medians, such values would not be used until they are shown to be sensible.

5.10.3 Flag scaled with M(3000)F2

When the Z mode is observed in the F2 region, descriptive letter Z is scaled on M(3000)F2. This is an unconventional scaling adopted because F is flagging spread on foF2. Z has precedence over all other descriptive letters on M(3000)F2, so the scaling _ZZ could occur if the Z mode is used for calculating M(3000)F2. In addition, lacuna in the F2 region is flagged on M(3000)F2. Z and Y are considered never to occur together, but if they did Y supersedes Z.

5.10.4 Descriptive letter usage

5.10.4.1 A - blanketing

Full accuracy, excluding _EA, is allowed. If the F trace is blanketed up to or just beyond the point of tangency, a lower limit for the point of tangency will still be possible, resulting in a maximum estimate of M(3000)F2 being obtained.

5.10.4.2 B - non deviative absorption

Following the same logic as A, _DB is the only limit value allowed for M(3000)F2. As M(3000)F2 is an F region parameter. Interpolation should only be used for fadeouts.

5.10.4.3 D - upper frequency limit of ionosonde

If foF2 exceeds the upper limit of the ionosonde, then the value of M(3000)F2 calculated will be a lower limit. Thus _ED is a valid usage. _UD is rare and almost not worth having. If both foF2 and the point of tangency are above the ionosonde limit, then replacement D is scaled. All occur in unusual circumstances.

5.10.4.4 E - lower frequency limit of ionosonde

An upper limit to M(3000)F2 can be calculated, at best, and _UB may be possible when the point of tangency falls below the lower limit of the ionosonde. Once foF2 disappears below the limit, replacement E is appropriate.

5.10.4.5 F - measurement affected by spread traces

Spread F can affect M(3000)F2 measurements in two ways. First, foF2 can be affected and have reduced accuracy and second, M(3000)F2 can be hard to define.

Full accuracy is allowed, care being taken in using the correct E or D limit.

When M(3000)F2 is deduced, as shown in UAG-23A, (p78 fig 3.14) it has been conventional in IPS to scale _UF rather than just _F, as errors of at least 5% are considered present.

F is not a flag for spread-F near the M(3000)F2 point of tangency.

5.10.4.6 G - insufficient ionisation

Replacement G is allowed for a G condition. If the F2 region is just present then possibly retardation could affect the measurement and if so a descriptive letter G is allowed to show this possibility.

Note that IPS does not scale M(3000)F1 in place of M(3000)F2 in a G condition, because while M(3000)F1 may give an indication of the MUF for a storm condition, the appropriate limit to apply is not clear. Possibly descriptive letter G would be adequate. *This should be investigated*.

5.10.4.7 H - disturbances

UAG-23A states that M(3000)F2 is measured from the "regular layer as a whole", (UAG-23A, p83). This appears to be contradicted when stratifications occur as a result of disturbances, as foF2 is measured from the upper frequency - an area where a training guide is desirable. IPS interprets this to mean, scale from the main trace ignoring the cusp and describe by H.

Disturbances may affect both foF2 and the point of tangency, and the combined error limits may be hard to assess. UAG-23A suggests _UH be used where traces are clearly disturbed. Some level of accuracy limit may be assessed from comparing O and X traces. Thus, descriptive letter H is also used where a disturbance is present but not having a significant effect on accuracy. For now, E and D are unrealistic and are eliminated.

While replacement H seems less necessary for foF2 than other levels of accuracy, the same is not true for M(3000)F2 where multiple traces associated with large disturbances may produce inconsistent results. Interpolation is allowed, but is used with caution and considered rare when successful.

5.10.4.8 L - insufficient cusp

When the F2 region is sufficiently disturbed for no M(3000)F2 to be obtained, or to be possible with errors, descriptive letter L is used. In such cases the M-slider may only be tangent to the F1 layer. While disturbances may cause this, L describes the condition better. This condition means that a 3000 km circuit could be propagated by the F1 layer rather than the F2 layer.

5.10.4.9 Q - measurement affected by range spread

At low latitudes, range spread can leave foF2 undefined, and hence M(3000)F2 is undefined also. Replacement Q is appropriate. UAG-23A, p77, fig 3.13 gives an example of replacement Q for foF2. This appears to be a special use of Q and if any critical frequency appears, the accuracy would be described by F, not Q.

5.10.4.10 R - deviative absorption

Retardation will affect foF2, especially at solar maximum, and may, in extreme circumstances, affect the point of tangency for M(3000)F2. As foF2 will be, at worst, qualified by D, M(3000)F2 will at worst be qualified by E. Qualifying letter D will not be used with M(3000)F2.

Interpolation is allowed to obtain improved accuracy.

5.10.4.11 V - forked trace

As V can affect foF2, it could also affect M(3000)F2. However, these are probably small disturbances, so only descriptive letter V and _UV are allowed, the latter being used if errors are apparent. (It would be interesting to study these events one day to see if there really are errors involved.)

5.10.4.12 W - upper height limit of ionosonde

At low latitudes, descriptive letter W may be used where extrapolation gives a consistent value of foF2, but the F2 trace has not become vertical. Probably descriptive letter W would not be used at other latitudes.

As only _ DW is possible for foF2, _EW will be the only limit possible for M(3000)F2.

5.10.4.13 Y - lacuna, a flag

F2 region lacuna is scaled as a flag on M(3000)F2. When Y is used with foF2 to indicate a severe tilt, H will be used on M(3000)F2.

5.10.4.14 Z mode flag for F2 region

The presence of a Z mode in the F2 region is noted on M(3000)F2 as a priority scaling letter. *This is a local convention* and has already been discussed.

5.11 foF2, the critical frequency of the F2 region

foF2 is the ordinary wave critical frequency from the highest stratification in the F region, called the F2 critical frequency.

5.11.1 General Comments

This is the most important parameter scaled from an ionogram and also the most carefully studied. Because of this, problems that are not covered fully in UAG-23A are rare indeed. Scaling foF2 only poses two major problems not encountered with other parameters.

First, because of the significance of foF2, there is sometimes a temptation to be too accurate in scaling it. That is, where interpretation proves too difficult, scalers sometimes prefer to put a replacement letter thereby reducing the number of values available for study. If scaled values are correctly qualified and described, researchers should not be mislead by values where subjective interpretation is questionable. This can arise particularly in the presence of spread, or where ridges of ionisation are located near the ionosonde station. Here, particularly with reduced height ranges, identifying the overhead trace can prove difficult, placing considerable onus on scalers trying to obtain useful values.

Second, the effects of retardation coupled, at high solar activity periods, with a reduced system response can make foF2 difficult to measure. This is a deviative absorption effect; although non-deviative absorption decreases as 1/f2, deviative absorption is affected by electron density gradients as well. This can become especially difficult at low latitudes, where the 800 km height range can be a significant disadvantage. Again, the scalers responsibility to later researchers is large and it becomes most important for consistent reasoning to be used in interpreting the ionogram, to establish what information losses exist. Often values will have to be scaled as accurate, but described by a condition influencing interpretation.

In both cases, provided consistency is preserved, then later studies should reveal any systematic variations which can then be brought to the scalers attention.

5.11.2 Qualifying letter usage

All levels of accuracy are used, including interpolation. Both X and Z components may be used to give foF2 when there is insufficient information available to obtain a value directly.

5.11.3 Flags used with foF2

When spread exceeds or is equal to 0.3 MHz near foF2, descriptive letter F is used with foF2. Historically, this is the most important flag used with any parameter.

5.11.4 Descriptive letter usage

5.11.4.1 A - blanketing

Blanketing should be either effective or not in obscuring foF2. Errors in foF2 at this point will be directly associated with errors in fbEs _AA usage.

Doubt may arise when only the vertical portion of the foF2 cusp is visible. This may then be confused with vertical noise traces that can sometimes occur on ionograms. Sequences of ionograms, together with comparisons of the Es multiples, should help resolve these cases. Normally, if ftEs of the Es multiples exceeds the apparent foF2 value, then this is evidence for the trace to be a noise effect. Alternatively it may be a multiple of foF2. Or, if only one trace is seen, it may be O or X ray. Ultimately, a subjective judgment will be required, so foF2 would probably be a good value described by A.

Where Es traces are consistent, but evidence exists for the F region being tilted - as often happens at high latitudes - the question arises as to how important the qualifiers U, E or D should become.

Possibly the X component may be identified, but the likelihood would be rare and appears to depend on spatially variable sporadic E layer.

5.11.4.2 B - non-deviation absorption

Like blanketing, absorption will result in foF2 either being present or not. If a trace were weakened enough by absorption, then interpretation may become difficult, and it will probably be equally difficult to assign a level of accuracy to this. Descriptive letter B, in these cases, will show that interpretation has been affected.

Interpolation can only be used during fadeouts.

5.11.4.3 D - upper frequency limit of ionosonde

If foF2 exceeds the upper limit of the ionosonde, then _DD is always scaled rather than replacement D.

Both _ZD and _UD will be rare situations worth noting.

5.11.4.4 E - lower frequency limit of ionosonde

Normally, interference limits the low frequency end of the ionosonde. IPS scale _EE, instead of replacement E, in this case.

For Australian stations, _JE would never be used because of the proximity of the lowest frequency sounded to the gyrofrequency.

5.11.4.5 F - spread flag

Whenever spread on the F2 trace is equal to or exceeds 0.3 MHz, a descriptive letter F is attached to foF2.

Interpolation is allowed provided foF2 would not be replaced by F.

5.11.4.6 G - insufficient ionisation

When foF2 < foF1, foF2 is scaled (foF1)EG. No other letter combinations are possible.

5.11.4.7 H - stratification or disturbance

When foF2 shows stratified or forked traces, foF2 is measured from the top frequency for both H and V disturbances, according to UAG-23A. This is a convention and, in some circumstances, may not reflect the average conditions in the ionosphere - hence the descriptive letter H or V. When O and X traces differ by more than the bounds required for U (5%) then foF2 is qualified by U (another UAG-23A convention). For consistency, this should apply to both H and V.

Obviously disturbances moving north-south are more likely to result in a U scaling, following this rule, than those moving roughly east-west as north-south disturbances are more likely to show different effects on the two magnetoionic components. Such accuracy usage is inconsistent. It would be more appropriate to use accuracy qualifications dependent on the extent of the upper and low frequency separations associated with H or V. However, as disturbances are always producing errors (greater than 5%) in foF2, it is hardly worth worrying about.

Conditions where _EH and _DH occur are very severe, and are probably typical of the more exciting ionograms one occasionally scales where it is hard to decide which is the principal (overhead) return. Often, because of lack of information, the accuracy limits E or D must be applied, as circumstances dictate. Similar conditions are probably not possible for _EV and _DV, as the smaller V disturbances usually have less effect on foF2.

Replacement H is particularly severe and is used with caution. Although a tangle of traces can be hard to interpret, a limit value is still preferred to replacement H, which is an extreme circumstance. Every effort should be made to obtain a value if possible. There will be no occasion when replacement V is possible. UAG-23A suggests that severe tilts, such as illustrated by fig 3.34 p96, are the only case where Y is appropriate. In other words, severe means the F2 region is tilted enough for it to be obscured by the underlying ionisation.

Use of the X or Z modes to deduce foF2 in the presence of a disturbance can be hazardous as there is no doubt that O, X and Z components arise in different environments when the ionosphere is disturbed.

However, when careful, a better estimate of foF2 may be possible - for instance, when the O component is forked, but the X trace shows no disturbance for several minutes, it will be reasonable to assume the X trace gives a better estimate of the undisturbed foF2.

Interpolation is allowed for both H and V provided the disturbance does not last for more than an hour or so. Because of the disturbed nature of the ionograms, it may be hard to interpolate satisfactorily, but if interpolation means replacement H is not needed, then it is preferable to use it. As replacement V is not considered possible, for accuracy reasons, interpolation will not be needed with V.

5.11.4.8 Q - measurement affected by range spread

When range spread prevents a critical frequency from being determined replacement Q is appropriate. If any estimate of foF2 can be made, then Q is no longer appropriate. Generally this will be used at low geomagnetic latitudes where equatorial range spread is common, but it can occur at high latitudes also.

5.11.4.9 R - deviative absorption effects

R is used to describe the condition where the trace weakens and eventually disappears. This is particularly common for the 4B ionosonde when foF2 exceeds 12 MHz; low equipment sensitivity and increasing deviative absorption results in the trace disappearing.

In such conditions, extrapolation, aided by overlays, can be used to deduce consistent foF2 values, and descriptive letter R is used although it could be argued that C is more appropriate. As the extrapolation becomes more ambiguous U, or D may be required. E is excluded.

Often, when _DR is required, the ionosonde is too insensitive and _DC may be more appropriate. It is a debatable point and should be remembered when checking data. Replacement R implies poor ionosonde operation.

UAG-23A suggests interpolation should be used whenever possible with retardation. However, experience shows retardation is usually effective for long periods of the day and for the same period of the day on successive days. If interpolation is used, it will need to be carried out with care.

Normally retardation will affect both magnetoionic components equally, but the X component may be stronger than the O at a particular station, dependent on aerial orientation. While the aerial might be altered to optimise on the O component, this will often be hard to do. The condition is accepted, thus _JR may become common, and is certainly preferred to _JC. This argument does not follow for the Z mode and _ZR would be unusual.

5.11.4.10 V - forked trace

This has been discussed in association with descriptive letter H.

5.11.4.11 W - upper height limit of ionosonde

W may be required for two different conditions.

During disturbed periods retardation in the F region can be very high and (especially on the 4B ionograms, with an 800 km height range) foF2 can disappear completely (see p92 fig 3.30 in UAG-23A). In these conditions, care must be taken to discriminate between G and W conditions, as they affect the medians calculations differently.

At low latitudes, during daytime, the F2 region can be present, but the F2 trace does not become vertical within the height range of the ionogram. This condition is common and while a value for foF2 can usually be estimated, it can potentially be in error because there is no clear evidence on where the trace goes vertical. Such cases are described by W.

Only D and U can be used to qualify foF2, and for W to be recognized some F2 trace must be present.

A W condition will normally affect the O trace least, so _JW and _ZW will never be usable. No interpolation is allowed.

5.11.4.12 Y - severe tilts affecting measurements

Y, on foF2, will normally be restricted to conditions where severe tilts affect foF2 and then only scaling _EY, is possible (see p95, UAG-23A). The condition, as described on p95, and by figure 3.34 on p96, is quite specific. Once less severe Y conditions appear, then H, V or R become appropriate.

Lacuna may also affect foF2, but it is unlikely. If foF2 is affected by lacuna, the condition is flagged on h'F2. Probably only replacement Y is appropriate here.

5.11.4.13 Z-mode observed for F2 region

As discussed, descriptive letter Z is not now scaled on foF2, instead it is a flag on M(3000)F2.

5.12 fxI, highest frequency reflected from the F region

fxI is the highest frequency on which reflections from the F region are recorded independent of whether they are reflected from overhead or obliquely.

5.12.1 General Comments

At IPS we always scale a value if possible for fxI.

The following long discussion is of little value to a novice scaler and can be left until reasonable facility scaling all characteristics has been achieved.

fxI can be both the easiest parameter to scale and the hardest to define. As defined, UAG-23A p21 and pp. 99-103, fxI is the highest frequency on which reflections from the F region are recorded, independent of whether they are reflected overhead or at oblique incidence.

Normally the highest observed frequency will be an X mode return. If it is necessary to deduce the X mode from the O mode, the tabulated fxI value is qualified (by O), the reason for failing to observe or scale the X component being shown by the appropriate descriptive letter (if no spread is present, X supersedes this).

Originally, fxI was conceived to provide a convenient measure of the effects of F region spread and ridges on oblique propagation MUFs. While this purpose has been retained, it is now felt that fxI also offers significant scientific advantages.

For useful applications, using fxI in interpreting the MUF of a circuit, it is necessary to first deduce foI (by subtracting 0.5 fB from fxI). Consequently, it is logical that fxI should be scaled in such a way that it remains consistent with foI. However, while foI is the parameter required, fxI is actually much easier to scale.

5.12.1.1 When fxI is not equal to (foI + 0.5 fB)...?

For most purposes no conflict should arise and the conversion of fxI to foI should be straight-forward. Unfortunately cases arise where fxI is not equal to (foI + split) on an ionogram. There are several reasons for this.

- differential absorption between O and X modes can reduce the extent of fxI with respect to foI. This can occur either when absorption is high or when fxI is near the gyrofrequency. Extrapolation of the traces may improve agreement.
- different reflection coefficients between O and X modes may occur. The O mode is reflected at right angles to the earth's magnetic field and hence at right-angles to any field-aligned irregularities, whereas the X mode, being reflected roughly parallel to the earth's magnetic field, is likely to see a smaller target area for such irregularities. Spread-F evidently appears more on the O mode than the X mode and fxI, when measured from the X mode, will give too low an estimate of foI.
- spatial gradients located near the observing station can produce different O and X mode returns. This is because the O mode is deviated poleward of the station, and the X mode equatorwards, in the magnetic meridian through the station. The reflection regions can be different for the two modes thus producing inconsistencies between foI and foI deduced from fxI. A severe example of this occurs when a spur or ridge of ionisation approaches the station travelling along the magnetic meridian but oriented at right

angles to it. A less severe case is a travelling ionospheric disturbance, which can affect the modes differently, but usually on a smaller scale.

In all of these cases, the scaler must obtain a value of fxI which will later allow a consistent foI to be deduced. These cases will now be considered.

5.12.1.1.1 Absorption

When absorption is observed to affect the X mode, fxI is obtained by scaling foI, and the magnetoionic split is added, giving fxI, which is then qualified by O and described by B. In other words excessive absorption forced this scaling to be used. If no spreading of the traces is seen, then the descriptive letter X would replace B in the tabulations because X has the highest priority of any scaling letter for use with fxI when no spread traces are observed, (as IPS use X for spread F flagging, B, although appropriate for accuracy purposes, is not tabulated because X supersedes it).

There will undoubtedly be occasions when high absorption occurs during particularly disturbed conditions and spreading of the F traces could occur. Even so, if no spreading is seen, the letter X is mandatory. It is normally bad practice to anticipate information, but it may be desirable in these cases to describe foF2 by B even though the measurement of foF2 is unaffected. The information, indirectly, may contribute to later interpretations.

5.12.1.1.2 Spatial differences

Reflection coefficient changes and spatial differences will often be difficult to resolve and for scaling purposes there will often be little reason to do so. However, it requires a clearly defined concept of fxI to obtain consistent results when such conditions exist.

Descriptive letters F or R could be used in preference to B although neither are ideal. As differences commonly occur when spread is present, descriptive letter F implies that some property of the spread is producing the observed effect. Alternatively, R might be used to show that deviative absorption is responsible for the observed differences. Both these usage are preferred to descriptive letter B which is reserved for non-deviative absorption effects.

5.12.1.2 ....scale the larger

5.12.1.2.1 Keeping fxI consistent with foI

If fxI is used to estimate foI, it might be argued fxI should always be deduced from foI when there are inconsistencies between the O and X traces on an ionogram. If this convention were adopted there would be little point in ever scaling fxI, as there would be few complex cases left where foI would not automatically be scaled. However, as already stated, there are many situations where foI can be difficult to scale.

The basic problem in adhering closely to this approach is to define what is meant by "keeping fxI consistent with foI". The values of fxI and foI can never be completely consistent - they come from different parts of the ionosphere and differences between them can reflect real ionospheric differences.

5.12.1.2.2 Just scale fxI

Alternatively, the original definition of fxI, as stated at the beginning of this discussion, may be tried - fxI is the highest frequency on which reflections from the F region are recorded (i.e. scale the X component usually). Although simpler to scale, this then allows our F region information to be biased by the lower ionosphere (absorption effects) and magnetoionic effects (O, X ray reflection parameter s). Such bias will compromise the consistency of foI deduced from fxI. It is easy to see many of inconsistencies when compared with the O component (and hence foI).

5.12.1.2.3 Compare foI and (foI + 0.5 fB)

If the definition of fxI is applied in a more general sense, then the various inconsistencies should disappear. Rather than treat fxI as an estimate of the top reflection frequency on a particular ionogram, it should be treated as an estimate of the maximum of the full range of possible top frequencies observed near the ionospheric station. In other words, assuming differences between the observed foI and fxI are a result of gradients in the ionosphere, and that small movements of the ionosonde would have resulted in changes in these relationships, fxI is the best estimate of the maximum frequency of reflection near the ionosonde if;

fxI recorded = maximum of (observed foI + 0.5 fB) and (observed fxI)

The result is consistent when converted to foI, although it may not now be the foI seen on the ionogram. Special cases may still be found that are contradictory but these do not have the same significance as earlier problems mentioned. In addition, the full power of fxI is gained for estimating the maximum foI and hence maximum likely reflection frequency in the locality of the ionosonde, but not necessarily immediately below it. This seems to be the essential thrust of Piggott's comments INAG-23, p8.

5.12.1.3 fxI in the presence of TIDs

Some general problems affect the scaling of fxI in the presence of TIDs. As first proposed, fxI was intended for use with large scale phenomena, and TIDs, being transient and generally small scale, were not considered. Although fxI will not be affected much by TIDs, compared to other ionospheric features, because inconsistencies can be introduced into the scaling philosophy, they are worth considering here.

For disturbances moving roughly east-west, both foF2 and fxI will be affected in similar fashion. If a stratification, or fork, appeared on the O component, one would also appear on the X component, foF2 and fxI being measured from the top frequency of the stratification in both cases. No problem exists.

However, for a similar disturbance moving north-south, only one component will show a stratification, or fork. If the fork were on the X component, then foF2 would be scaled from its normal position and fxI from the top frequency of the fork. Now, fxI and foI are inconsistent. The second option, with a fork on the O component, seems to cause even more problems. Now foF2 is scaled from the top frequency of the fork and fxI is calculated as (foF2 + 0.5 fB) and qualified by O.

While the changes in (fxI - foF2) might give some indication of the direction of propagation of TIDs affecting disturbances, the information is poorly preserved between scalers because of the combined scaling errors associated with foF2 and fxI.

5.12.1.4 Spurs and fxI

Spurs, or ridges of ionisation, can approach a station and then move away without actually moving overhead. In this case the effect is usually only seen on one component (O or X). In the extreme case, only part of the spur is observed and it is not clearly connected to either component, i.e. it could be either component. Such extreme cases are always treated as if they were the X component, thereby introducing a potential error of 0.5 fB in the scaled values. This is the accepted convention and the flag for spurs, P, shows a possible error is present. As P is scaled on fxI irrespective of whether the spur is connected to the O or the X component. It would appear that this is an instance where the qualifier M could have been used to refine the available information and special conditions could have been introduced to allow for this when calculating median fxI values. Although the difference is likely to be small and not worth further attention.

5.12.1.5 fxI and interference

Scaling fxI in the presence of interference bands could, at times, test the patience of a saint. There is often even more pressure on a scaler to obtain a value for fxI than foF2. This emphasis is generally to ensure values of fxI are scaled when spread-F is present. When no particularly interesting features exist, there is no problem. However, at night, in middle and low latitudes, interference can often obscure large parts of an ionogram.

This difficulty appears to be compounded by the example in UAG-23A, p102. It illustrates a common problem and complicates scaling difficulties. Part of the reason is that it assumes absolute accuracy - in other words, the bounds are objectively set by the ionogram and not by the scaler's powers of interpretation. Scalers, using the preferred IPS method of interpreting accuracy, as described earlier, find fig. 3.41 contradictory in many ways. It is quite clear to many scalers that by using normal scaling skills, useful foF2 values can be obtained and fxI deduced from these.

See the appended copy of figure in section 2 for further comments.

5.12.1.6 Evaluation of fxI when approaching fB, the gyro frequency

The X mode is weak or absent within 0.5 MHz of fB and is absent below fB, UAG-23A, p13. So fB appears to be a physical limit for fxI. However, foI continues to exist.

INAG has overcome this by the simple expedient of deducing an imaginary fxI consistent with the observed foI. Thus fxI = (foI + 0.5 fB)OB, the descriptive letter B indicating that absorption associated with the gyrofrequency has affected the measurement. This is consistent with the rules proposed for scaling fxI, but inconsistent with the physics of the ionogram.

5.12.2 Qualifying letter usage

Normally, when scaling, the reason for an inaccurate measurement (U, E or D) can be shown using a descriptive letter. This almost becomes the exception with fxI because of the flags used.

While full accuracy is supported for fxI, X will normally supersede other descriptive letters which will only be used in rare circumstances. In the following sections the descriptive letters are discussed and weighted with this in mind. If flag X were not used with fxI, then the fxI lookup tables would require significant changes.

While E, D and U are all acceptable, as medians of fxI are intended to show enhanced ionisation (with respect to foF2) it may rarely be desirable to use E. Whenever any of the F region is present D is used. An argument for _EA, when fbEs exceeds fxI, could be mounted, but for the problems associated with estimating what you cannot see.

Interpolation is not allowed with fxI. Although mid latitudes F and Es regions will usually be uncorrelated, this may not be true at high latitudes. Other examples can be devised, but with equipment failure and interference interpolation would seem reasonable. At IPS, interpolation is allowed for fxI, but with considerable reservation.

The O component will often be used to deduce fxI, as is evident from the discussion on fxI. However, the Z component will probably only be used when fxI and foF2 are missing for non-ionospheric reasons. The Z mode which is present when there is some spreading in the F region, does not show scatter, is not observed from oblique spurs and spread structures, but instead, in these conditions, is a good indicator of overhead conditions. Thus fxI will always be greater than or equal to (fxI + fB). Qualifier Z, in these conditions, clearly shows an unknown error and may introduce enough bias to distort fxI medians.

5.12.3 Flags used with fxI

Two flags are used with fxI, X for no scatter on F traces and P when a spur controls fxI. P has precedence over all other scaling letters on fxI and X is the next most important. As spurs are generally associated with spread, there will rarely be conflict between X and P.

While X is always scaled when no spread (or scatter) is seen on the F trace, if no F trace appears then X will be superseded by a replacement letter. However, where reasonable grounds exist for believing spread is not present, describe fxI by X. Thus, where retardation is large, or interference high, but no spread is seen and interpolation is possible, then a reasonable estimate can be made of whether X is appropriate.

From time to time INAG, and IPS, have toyed with the idea of scaling all spread types on fxI making the fxI descriptive letter a spread type table. Currently, IPS prefers to use a selection of spread flags, as described earlier, but there is some merit to this idea. It would, however require IPS to use spread type L.

Alternatively, using current spread flags, IPS could add an additional spread flag to fxI for the case when foI is greater than fxF2. If this were done, the IPS frequency spread classes 1,2 and 3 would all be scaled between foF2 and fxI. A suggested flag would be to use descriptive letter F on fxI in these cases. There is an unknown error as there is no way of knowing if fxI is greater than (foI + 0.5B) when foI > fxF2.

The presence of resolved or unresolved spread could also be flagged by introducing an alternate flag to F on foF2, say M or T, which would be used in the same way as F when discrete traces are present. IPS should experiment with these options and report to INAG although it is not clear that such experiments would have significant returns.

5.12.4 Descriptive letter usage

5.12.4.1 A - blanketing

Comments made on foF2 are relevant here also. Blanketing is either effective or not. When a value is scaled with descriptive letter A, it implies spread is present so interpolation is disallowed. (Although 1 minute soundings may now make it possible to use interpolation, this is a special case.) Similarly, A will not be the cause of accuracy loss, although it may complicate things.

However, descriptive letter A is allowed to show possible subjective errors in interpretation of unknown magnitude. For instance, auroral Es is present and spreading occurs within both E and F regions. On normal ionograms it may be hard to decide which was which. Descriptive letter A is more appropriate than F.

5.12.4.2 B - non-deviative absorption

When fxI approaches the gyrofrequency, fB, or during a fadeout, the extent of loss of accuracy can be assessed by _UB and _DB. However, no _EB scaling is allowed. Interpolation should be allowed during SIDs.

5.12.4.3 D - upper frequency limit

Occasional _DD and, very rarely _UD, will be possible for fxI. This condition will occur as a result of equatorial spread and possibly _DQ is more appropriate. IPS uses _DD in preference to replacement D.

5.12.4.4 E - lower frequency limit

At IPS, it is unlikely that the X component will be seen to drop below the ionosonde lower limit as fB, the gyrofrequency, is greater than 1.0 MHz for all Australian stations, at virtually all heights.

However, in this case foI may be scaled _EE, and fxI scaled with the same value.

If any foI is seen _OB becomes appropriate.

5.12.4.5 F - measurements affected by spread

IPS would only use F on fxI if it affected the scaling accuracy of fxI. However, this is a bit unnatural for fxI, the upper limit of spread being more likely to be affected by the ionosonde gain (C?) or interference (S). Of these, S is usually the prime cause. I am unclear how you can interpret a lack of accuracy in fxI, a spread - F parameter, in terms of the spread. It seems to contradict the definition.

However, I prefer _OF or _OR instead of _OB when fxI is much greater than fB, although _OB is begrudgingly accepted. *As a local rule, IPS will scale _OF where previously _OB was used.* We should test its occurrence and report to INAG.

If foF2 < foF1, and foF1 shows spreading, then it could be useful to describe fxI with F if the spread exceeds 0.2 MHz. (See also comments in earlier section on using F with fxI as a flag.)

5.12.4.6 G - insufficient ionisation

As the F1 region is part of the F region as a whole, when foF2 < foF1, fxI is scaled (fxF1) with appropriate descriptive letters as required. IPS does not scale fxI = (fxF1)EG in this case.

However, if foF1 < foE, then fxI = (fxE)EG would be appropriate because fxI is no longer measured from the F region. While this applies to the normal E region, it is not used for particle E. Particle E can be associated with tilted F layers and various other conditions making the limit value dubious. Furthermore, particle E is a sporadic E layer. For now, no _EG usage is allowed as it seems too rare to contemplate as a real scaling. There is more information in the _EG scaling than replacement letter, A.

5.12.4.7 H - disturbances

Unless a disturbance is associated with spreading, H will normally be superseded by X.

In general, TIDs will not affect the accuracy of fxI in the same way that the accuracy of foF2 is affected. With foF2, the overhead echo is sought and a TID implies "oblique return". Hence the use of V, or H, warns that the F2 region is distorted and that foF2 may well not be measured from overhead. While rules exist for selecting the most likely position for foF2 in these circumstances, it is not hard to find exceptions, either theoretically, or in practice.

Like spreading, it is hard to give a sensible meaning to the loss of accuracy in fxI because of a disturbance. Only a descriptive letter H is allowed, together with _OH.

For local convenience, when fxI is deduced from an X mode stratification, H is scaled on foF2, even if foF2 is not currently affected. When checking scaling consistency the difference between foF2 and fxI is tested. If no H appears on foF2 then it can appear that the two results are inconsistent.

5.12.4.8 P - spur controls fxI; a flag

P has precedence over all other scaling letters.

5.12.4.9 Q - range spread

When fxI is determined from a range spread trace, the descriptive letter Q is used with fxI. No precedence is quoted for Q in UAG-23A, but if it is to be useful it should always be used, having precedence over all letters other than P. UAG-23A describe P as an oblique return that, when overhead, is better scaled as F or Q.

No accuracy levels are used with Q as it will normally be expected that fxI will be ill-defined if measured from range spread. This is usually only useful for low latitude equatorial range spread.

5.12.4.10 R - deviative absorption

Normally R would not affect fxI, as in conditions where R is relevant, X would supersede it.

As mentioned earlier, when fxI < (foI + 0.5 fB) and fxI >> fB, the difference between foI and fxI is hard to explain in terms of absorption, although the added effect of deviative absorption (R) may be sufficient. If spread is present I certainly favour _OF. Thus, R is not used on fxI.

5.12.4.11 W - upper height limit of ionosonde

While W may be relevant with fxI, usually it will be superseded by X.

Replacement W could probably occur, although unusual.

5.12.4.12 X - no spreading - a flag

When the F trace shows no spreading, descriptive letter X is used with fxI. It is only superseded by P.

5.12.4.13 Y - lacuna

If fxI cannot be scaled because of F2 region lacuna, then replacement Y is appropriate. However, if any trace is present, Y will not affect the accuracy of the measurement. Large tilts will not affect the accuracy of fxI for reasons similar to those given for H.

6. SCALING LETTER LOOKUP TABLES

The IPS scaling stations contain lookup tables, based on the previous section, to check that scaling letters used with ionograms are reasonable. The letter combinations possible for each parameter have been given ranks, 0 to 6. The weights are described in the next section and then the weights for each of the major parameters follow in successive sections.

6.1 Internal Consistency Test for Scaling

Using the rules set out in UAG-23A and as explained in this document, various computer tests are made to check for internal consistency of the scaled data. These tests fall broadly into two sections. First, the various allowed combinations of descriptive and qualifying letter pairs can be tested and non-standard, or unusual pairs, are noted. Second, the various scaled parameters can be compared for internal consistency. This section is concerned with the first option; establishing combinations of letters that may be used with each of the parameters scaled. These tests have been used in the IPS Head Office automatic data monitoring program for some years now.

Each parameter scaled is discussed in a separate subsection; the normal conventions associated with scaling and any special problems and local rules are *highlighted*. The normal accuracy conventions associated with each parameter are also explained. As mentioned in an earlier section, accurate values (i.e., no descriptive letter, only a descriptive letter, qualifying and descriptive letters and replacement letter) are assumed possible and general or specific limits are discussed in the appropriate place. A summary of flags used with each parameter is included along with an explanation of the hierarchy adopted where multiple flags are allowed.

6.1.1 Grading used for qualifying/descriptive letter pairs

Six levels are used. Some levels result in the scaler being challenged about the scaling letter combinations if they are used.

6.1.1.1 Reject, Weight = 0

Pairs of letters that seem impossible are given a zero grade. Should such a pair of letters be scaled, the scaler would be asked to re-scale the parameter. However, if the scaler insists, the rejected pair is accepted. These results would be checked again in Sydney and would either be changed - in which case the scaler would be notified why - or accepted - in which case the look up tables may be revised. In either case, the example would be noted as a possible example for INAG or for use in local training.

A novice scaler should understand why the lookup table has rejected a scaling. this report should give some guidance, otherwise, contact Sydney Head Office with the example.

6.1.1.2 Rare, Weight = 1

Pairs of letters that seem most unlikely, but are conceivable, are considered rare and are given a weight of 1. These pairs are processed similar to a reject only now there is less onus on scalers to reconsider their scaling.

6.1.1.3 Unusual, Weight = 2

These pairs are considered to occur infrequently at IPS mainland stations and are weighted 2. The system will automatically accept the scaling, but the scaler will be reminded that the scaling is unusual. Further inspection of the ionogram may result in a changed scaling, but such cases would normally be accepted.

6.1.1.4 Local Convention, Weight = 3

Scaling letter combinations that are advocated by IPS, but appear to contradict normal URSI conventions, are weighted 3. It is intended that these results will be studied carefully at IPS and will be brought to INAG's attention for wider international discussion. Scalers are reminded that a particular usage is a *local convention*, so they can assess the ionogram involved to see if it is worth using as an example of a local convention. There aren't too many of these.

6.1.1.5 Accept provisionally, Weight = 4

These results seem strange or unnecessary. Again, scalers will be able to think carefully about such results and may wish to keep a copy of the ionogram sequence in question for future discussion.

6.1.1.6 Normal URSI standard usage, Weight = 5

The bulk of scaling usage fall in this category.

6.1.1.7 Flag, Weight = 6

Where a descriptive letter is being used as a flag, all letter pairs associated with the descriptive letter are given weight = 6. This will remind scalers that a flag is being used. This category includes both URSI flags and local flags.

6.1.1.8 Discussion

Alternative weightings might be used to tailor the scaling system to a particular location, in which case the letter pairs associated with different weights could vary. The weight/pair usage in this report probably represent mid-latitudes. However, significant changes would be possible if the tables were tailored for high or low latitudes. Changes are much more likely if different scaling philosophies are adopted.

Weights might also be used to train scalers by forcing them to look closely at ionograms. As yet, this has not been considered carefully.

The rest of this report is concerned with scaling conventions for the various parameters. Discussion is generally restricted to unexpected combinations of letters.

6.2 fmin letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5		3	3															3	3							6
A																											
Z																											
O																											
J																											
E				5		5													5								6
D																											
U																			5								6
I																											
r			5	5															5								

Flags:

1. fmin scaled from the Z-mode

6.3 foE letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5		5			5							5	5						6	6
A																											
Z		5		5			5		5										5	5						6	6
O																											
J		1	1	5			5		5			5							2	5						6	6
E		5	5	5		5	1		2			5							5	5						6	6
D		5		5			1		2			5							5	5						6	6
U		5	5	5		2	5		5			5							5	5						6	6
I		5	5	5					2										5	5						6	6
r		5	5	5			1		2										5	5						6	6

Flags:

1. Y Lacuna
2. Z z-mode observed in the E region
3. Y supercedes Z

6.4 h'E letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5		5			5						6		5							6
A																											
Z																											
O																											
J																											
E		5	5	5		5	2					5						6		5							6
D																											
U		5	5	5		5	2		2			5						6		5							6
I		5	5	5														6		5							6
r		5	5	5		5												6		5							6

Flags:

1. Q Range spread exceeds 30 km in the E region
2. Z Z-mode in the E region and no spread observed
3. Q supersedes Z

6.5 foEs letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5		5	5					5			5								5							6
A																											
Z												5															6
O																											
J		5		5		1						5								5							6
E			5	5		5		5				5								5							6
D				5	5							5								5							6
U									2			5								5							6
I																											
r				5	5			5												5							6

Flags:

1. Z Z-mode observed from the sporadic E layer

6.6 fbEs letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5	5	5			5							5	5						5	
A		5																									
Z												5															
O																											
J				1								5								1							
E		5	5	5		5	5	5	2			5							3	5						5	
D		5		5				5				5								5							
U		5	2	5			5	5	5			5							3	5						5	
I																											
r		2	5	5																5						5	

Flags:

1. No flags used on fbEs

6.7 h’Es letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	2	5			3	2	1			5						6		5							
A																											
Z																											
O																											
J																											
E				5			3	5				5						6	5								
D																											
U				5			3	2				5						6	5								
I																											
r			5	5		5	3	5										6	5								

Flags:

1. Q range spread exceeds 30 km.

6.8 foF1 letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5		5										5	5			2	2		6	6
A																											
Z				5			5		5				1						5	5						6	6
O																											
J		2	5	5			5		5				1						5	5						6	6
E		5	5	5			5		5				4						5	5						6	6
D							5		5										5	5				2		6	6
U		5	5	5			5		5				5						5	5				5		6	6
I		5	5	5					5										2	5							
r		5	5	5			5		5				5						2	5				1		6	6

Flags:

1. Y lacuna in the F1 region
2. Z Z-mode in the F1 region
3. Y supersedes Z

6.9 h'F2 letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5		5				5					3	2	5				5			
A																											
Z																											
O																											
J																											
E		5	5	5			2		5									3		5							
D																											
U		5	5	5			2		5				4					3	2	5							
I		5	5	5					5									3		5							
r		5	5	5				5	5				5					3		5				5			

Flags:

1. No flags on h'F2
2. but one trial letter if daytime spread is observed.

6.10 h'F letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5		5									6	2	5						5	6
A																											
Z																											
O																											
J																											
E		5	5	5		5	5		5									6		5						5	6
D									1																		
U		5	5	5		5	5		5									6	2	5						5	6
I		5	5	5					2											5						5	6
r		5	5	5		5			2									6		5				1		5	6

Flags:

1. Q range spread exceeds 30 km
2. Z Z-mode observed in the F1 region and lacuna also observed in F1 region
3. Q supersedes Z

6.11 M(3000)F2 letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	5	5	5			5	5	5				4						5	5			5	5		6	6
A																											
Z																											
O																											
J																											
E				5	2		5		2										5	5				5		6	6
D		5	5	5		2	5		2											5						6	6
U		5	5	5	2	2	5		5				4						5	5			5	5		6	6
I		5	5	5					1										5	5						6	6
r		5	5	5	2	5	5	5	5				4					5	5	5				5		6	6

Flags:

1. Z Z-mode observed in the F2 region
2. Y lacuna observed in the F2 region
3. Y supersedes Z

6.12 foF2 letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	2	2	5			6		5										5	5			5	5			
A																											
Z				5	1		6		5										2	5							
O																											
J		2		5			6		5										5	5							
E				5			6	5	5											5						5	
D			2	5			6		5										5	5				5			
U		2	2	5			6		5										5	5			5	5			
I		5	5	5			6		5										2	5						5	
r		5	5	5			6		5									5	2	5				5		5	

Flags:

1. F frequency spread exceeds 0.2 MHz.

6.13 fmin letter combinations

	b	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
b	5	2	5	5			5		2								6	5		5				5	6		
A																											
Z				5																5					6		
O			5	5			3		2								6			5				5	6		
J																											
E				2		5														2					6		
D			5	5	5												6			5				5	6		
U			5	5	1												6			5				5	6		
I				4													6			4					6		
r		5	5	5													6			5				5	6	5	

Flags:

1. X no frequency spread is observed on the F trace
2. P fxI is scaled from a spur
3. P supersedes X

7. TESTS CARRIED OUT ON DATA

As well as checking all letter combinations, the scaling station has a number of other parameter checks built in. These check the values scaled and intercompare parameters. The complete list, as I know it, of tests, including tests using the R/S and F/S parameters are given below.

7.1 THE HANDLING OF SCALING BY IPS DATA PROGRAMS

This section describes how the ionogram paramet4ers are converted to correct units. The process is for the film scaling station and much of it is not used in scaling digital ionograms. However, it is retained here for completeness. This section still needs to be cleaned up.

7.1.1 TO COMPUTE HEIGHTS -

[a] if height value < or =0; no action.

[b] calculate deskewed height coordinate, B; (0 < B < YY) *now redundant for graphical scaling but retained for film scaling*

[c] interpolate value in 0-800 kms range 800.*B/YY. (YY = frame width)

[d] round off to the nearest 5 km IFIX(HT*.2+.5)*5. *This step is not now done, heights being kept accurate to 1 km.*

7.1.2 TO COMPUTE FREQUENCY -

[a] if frequency value < or =0; no action.

[b] calculate deskewed frequency coordinate, A; (0 < A < XX) *Not used with digital ionograms.*

[c] interpolate value to a frequency channel number into range 0-255 and convert frequency channel to frequency value (Mhz). FR = 2.**(4.5*A/XX) (XX = frame height)

[d] if computing foE or M(3000)F2, round the value to nearest 50 khz; *no rounding done.* IFIX(FR*20.+.5)*5 otherwise, round the value to the nearest 100 khz; IFIX(FR*10.+.5)

Note:

1) if computing foF2, save A in AFOF2.

2) A, B, XX, YY are in bitpad units.

7.1.3 TO COMPUTE M(3000)F2 -

[a] if tangent point is not scaled; no action.

[b] calculate deskewed values of A and B

[c] compute heights, VAR of the tangent point. VAR = 800.*B/YY

[d] interpolate along the M(3000) transmission curve for frequency ANS.

[e] convert ANS to frequency coordinates. ALOGIO (ANS/100.)*XX/1.3546

[f] if foF2 is qualified by J or Z, convert foF2 to frequency coordinate, AFOF2; otherwise use AFOF2 saved when fof2 scaled.

[g] convert frequency coordinate on ionogram to frequency coordinate on M(3000)) transmission curve frequency sale. ANS-AFOF2+A

[h] convert to frequency and round off to the nearest 50 khz.

7.2 TREATMENT OF PARAMETERS

A series of parameter checks are carreid out. Specific tests are list in this section.

7.2.1 fmin

[a] if fmin = 0; all parameters are described by the scaled replacement letter.

[b] if min is not = 0; default Es values filled in Efmin#, Efmin#, #. (# is replaced by the descriptive letter on fmin if not B).

7.2.2 foE

[a] if foE = 0; no action.

[b] if foE qualified by J, split is subtracted from scaled value.

[c] if Es scaled; no action - otherwise default Es values filled in by EfoEG, EfoEG, G.

7.2.3 h'E - no action.

7.2.4 Es type

[a] if Es type is K; default Es values filled in as EfoEK, EfoEK, K.

[b] if foEs = 0; no action, except if Es type is L or S and foE is not equal to zero, default Es values filled in as EfoEg, EfoEG, G, otherwise if foE = 0 default Es values filled in as EfminS, EfminS, S.

7.2.5 foEs

[a] if qualified by J; split is subtracted from the value scaled.

[b] if foEs is greater than or equal to fmin; no action, otherwise, replace foEs with fmin, then replace fbEs by foEs.

7.2.6 fbEs

[a] if fbEs is not qualified by A; no action, otherwise, describe the remainder of the parameters (h'F-FS) by A, and fbEs is made equal to foEs if fbEs is greater than foEs.

[b] if fbEs is not equal to 0 and fmin equals 0; no action.

[c] if fbEs equals 0; replace fbEs by either EfoEG and update foEs if fbES is now greater than foEs, or, EfminB and update foEs if fbEs is now greater than foES and replace B by the descriptive letter on fmin if not equal to B.

7.2.7 h'Es - no action.

7.2.8 foF1

[a] if foF1 is qualified by J, then subtract the split from the value scaled.

7.2.9 h'F - no action.

7.2.10 foF2

[a] if foF2 is described by G; replace foF2 by foF1 value and qualify with E.

[b] if foF2 is qualified by J; subtract the split from the value scaled.

[c] if foF2 is qualified by Z; add the split to the value scaled.

7.2.11 fxI

[a] if fxI is qualified by O; add the split to the value scaled.

[b] if fxI is qualified by O and described by X; add the split to the value scaled.

7.2.12 h'F2 - no action.

7.2.13 M(3000)F2

[a] if foF2 is qualified by U and M(3000)F2 is not equal to 0; M(3000)F2 is also qualified by U, and described by the descriptive letter on foF2.

7.2.14 RS

[a] range spread can be either entered directly from the height scale, or the value of the maximum height of the F-layer can be entered; in the latter case, h'F is subtracted from the value entered.

[b] if the descriptive letter, K or P, has been entered as a qualifying letter it is shifted to the descriptive letter position.

7.2.15 FS

[a] frequency spread is entered anywhere in the frequency range using the height scale; 1, 2 and 3 values are produced from the height ranges 50-149, 150-249, 250-349 respectively.

[b] if the descriptive letter, K or P, has been entered as a qualifying letter it is shifted to the descriptive letter position.

7.3 TESTS

Finally, a number of tests are carreid out on all parameters.

[1] all qualifying and descriptive letters are checked for validity.

[2] all parameters are checked for use of valid letter combinations.

[3] all parameters are checked for use of valid replacement letters.

[4] all parameters that should have a value or a replacement letter scaled are checked for zero values.

[5] foF2-fxI split checked; split +1 or -1 is accepted.

[6] fxI should not be described by X if foF2 is described by F.

[7] foEs should not be qualified by E if an Es type is present, except when Es type is L or S.

[8] h'f2 should be scaled, or a replacement letter used, if foF1 is scaled, or a replacement letter is used.

[9] h'F2 should be between 200 and 500 kms.

[10] foEs should be equal to or greater than fbEs.

[11] h'Es should be between 80 and 200 kms, except if h'Es equals zero.

[12] h'E should be between 80 and 150 kms, except if h'E equals zero.

[13] h'F should be between 180 and 400 kms, except if h'F equals zero.

[14] M(3000)F2 should be between 200 and 400, except if M(3000)F2 equals zero.

[15] foE should be between 100 and 500, except if foE equals zero, or is described by K.

[16] h'E should be scaled, or a replacement letter used, when foE is scaled, or a replacement letter is used.

[17] foE should be scaled, or a replacement letter used, when h'E is scaled, or a replacement letter is used.

[18] Es type should be present if h'Es is not equal to zero.

[19] foF1 should be between 30 and 70, except if foF1 equals zero.

[20] foF1 should be scaled or a replacement letter used if h'F2 is scaled or a replacement letter is used.

******************** end of tests for high latitude data ********************

[1] foF2 should be described by F if FS equals 2 or 3.

[2] h"F2 should be described by Q if RS is greater than 25.

[3] RS should be greater than zero if h'F is described by Q.

[4] FS should be greater than zero if foF2 is described by F.

[5] RS should be described by K or P if RS is greater than zero.

[6] FS should be described by K or P if FS is greater than zero.

[7] foE should be scaled or a replacement letter used after 0700 and before 1700 hours.

[8] foE should not be scaled except when night E present; or have a replacement letter, except letter C, between 2000 and 0400 hours.