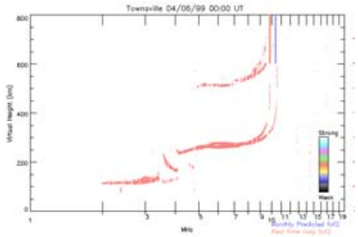

Scaling Ionograms

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IPS

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1

This PowerPoint presentation introduces ionogram scaling to people who are familiar with a mid-latitude ionograms, but who have not given much thought to the effort that is required to reduce the ionogram image to consistent and unambiguous parameters that can be used in modelling the ionosphere.

There are three sections

- some basic scaling ideas are introduced
- these ideas are expanded with a series of nighttime examples
- followed by a series of daytime ionogram examples.

Basic Scaling

- Regions of the Ionosphere
  - Normal regions: E, F2, F2 & sporadic E
  - Less familiar: E2, F0.5, F1.5, meteors
  - Notable conditions: spread F, absorption
  - Notorious effects: interference, equipment failure

2

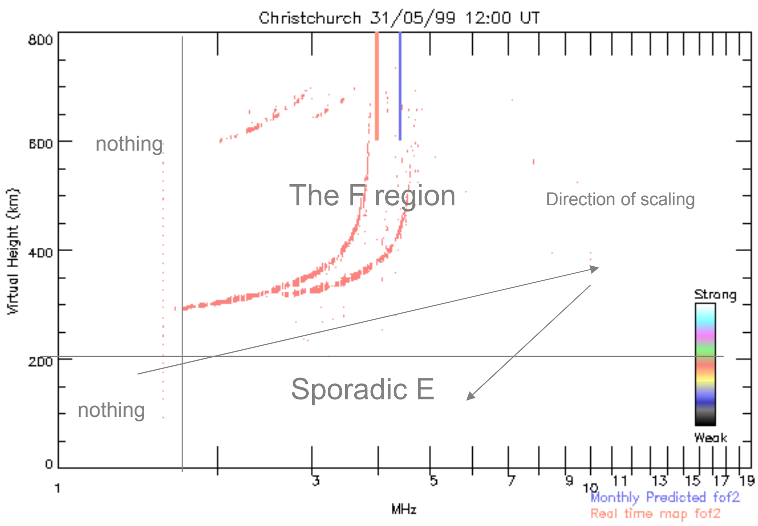
I assume people are familiar with the ionospheric layers and conditions that can complicate the scaling of parameters from an ionogram.

The normal regions will usually be familiar while the less familiar regions may be unknown, and often rarely encountered.

Impediments to scaling include features that may, in themselves, be important (such as spread F, TIDs), or just a problem due to environment (interference) of the equipment.

In scaling ionograms, all these must be taken into account so that the data best represents the ionospheric conditions. Conventions have been developed to make this task straightforward. Ideally, two scalers from different parts of the world will agree on the basic elements of scaling an ionogram. Their level of agreement may reduce as local conditions become important.

Nighttime



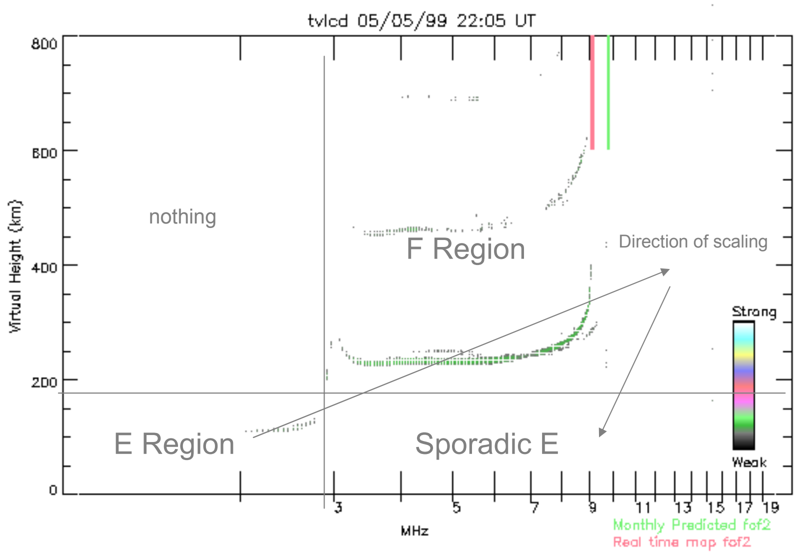
3

So; this is a nighttime ionogram.

The ionogram can almost always be divided up into regions, as is shown here. The lowest frequency for which there is a return from the ionosphere is called fmin.

Below fmin, there we can observe nothing. Above fmin, but below 200 km, the returns must be from asporadic E layer. (There are cases when this is not true, but it is rather hard to find examples, which says something about occurrences).

Daytime



4

In daytime, the vertical dividing line runs through foE, the peak electron density of the E region.

Again, the horizontal line runs through at about 200 km.

It is possible we may (rare though) get a multiple from the normal E region. Normally, though, there will be no interesting ionospheric returns from this region.

In both the nighttime and daytime case, it is possible sporadic E multiplies will appear in the upper right quadrant, but generally it is useful to regard this as the F-region domain.

This, therefore, suggests the regions where we expect to find the primary returns from the different ionospheric regions.

Basic Scaling

- 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; recognise and eliminate them when scaling
  - recognise unusual things; particle E, spurs, travelling disturbances

5

In deducing what is happening to form an ionogram, so that the important parameters can be recognised with confidence, it is usually sufficient to think in terms of specular reflections from a reflecting surface sitting above the ionosonde site. The condition of this surface may vary with time, tilts and undulations in its surface resulting in unusual, but interpretable ionograms.

Usually, scalers become familiar with the many different types of behaviour possible in the vicinity of their station and after a time develop a good ability to make use of these changes to refine their knowledge of what they scale. This knowledge develops with experience and an advanced scaler can often draw a researcher’s attention to rather subtle details.

This course will not dwell on this side of scaling, but instead focuses on developing the basic scaling skills that will allow this experience to develop over time.

Basic Scaling

- **Resources**
  - UAG-23A; the bible, 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 scaling notes
  - ionograms and your own common sense
  - ***look at, and scale, lots of ionograms***

6

As with all subjects, there is a wide range of material available to assist the scaler in learning their trade. Some of these sources are shown here.

The bottom line is:

• scale lots of ionograms, with care and thought, so that you become more and more confident in your interpretations.

• Refer back to the resources mentioned to constantly revise and cross-check your interpretations..

Nuts and Bolts of Scaling

- 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 more objective things.

7

The basic tools for preserving your interpretation of an ionogram, and to convey this information to others, are found in a range of scaling letters.

The accuracy of your interpretation of a parameter can, if necessary, be qualified by a letter indicating the extent of the errors you feel are present.

A descriptive letter is added to indicate why this reduced level of accuracy has affected your interpretation.

On occasions, special conditions are observed where a flag is added to the ionogram interpretation, as a descriptive letter.

Nobody will say this is an ideal set of rules, but they have been used widely and generally if used with care can convey a significant amount of information.

Ionospheric Features

- **Once you recognise these you are understanding much of the ionogram.**
  - ∗ Spread F: a well known night time phenomenon.
  - ∗ sporadic E
  - ∗ Travelling ionospheric disturbances (TID); medium scale features.
  - ∗ Ionospheric storms - These are global events.
  - ∗ Troughs: a sub auroral, large scale features.

8

This slide summarises some of the features you will learn to recognise over time. Only a few of these are discussed in these notes. The features of most interest here are those that will affect mid-latitude iongrams. Partly, that is because most scalers start dealing with ionograms from mid latitudes, and partly because there is least controversy about the subjective interpretation of these ionograms.

Ionospheric Regions

- There are distinctive aspects to the different regions
  - Mid latitudes
    - sporadic E, travelling ionospheric disturbances, ionospheric storms
  - Low latitudes
    - absorption, thick ionosphere and variability, nighttime HF interference
  - High latitudes
    - particle effects (Es-K, B) and troughs and ridges of ionisation, much spreading in E and F region

9

This slide summarises typical issues affecting ionograms from different parts of the world.

Course Objectives

- recognise and scale all the conventional parameters,
- use scaling letters effectively,
- recognise good and bad ionograms,
- use simple principles to scale complex ionograms.
- appreciate the sources affecting ionograms,

In addition you may

- recognise large scale ionospheric processes,
- become more confident in assessing ionospheric effects on HF systems.

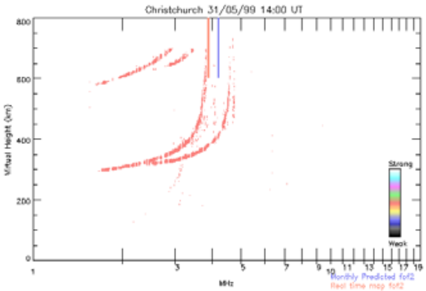
10

The scaling course objectives outlined on this slide are rather broad and, at first glance, may appear over ambitious. However, this course, in conjunction with a couple of days intensive scaling practice has been effective in training people with no familiarity with ionograms to the point where they can scale complex ionograms with some confidence.

Mistakes will still happen, misconceptions will remain, but the basic ideas of scaling and recognising features to aid scaling, can easily be developed.

Sample Ionograms : nighttime

- Boring nighttime ionogram
- Clear foF2 and fxF2
- Multiples present
- No interference effects
- A few odd details worth noting:
  - around the time base echo
  - slight spreading



foF2, fmin, h'F, all Es are easy; fxI is too.

11

All the training is carried out using ionograms like those in the slide. They have been taken off the IPS website. All that is of interest is the red ionogram trace. The course focuses on recognising the main features sufficiently well so that a pointer can be placed on the appropriate part of the ionogram.

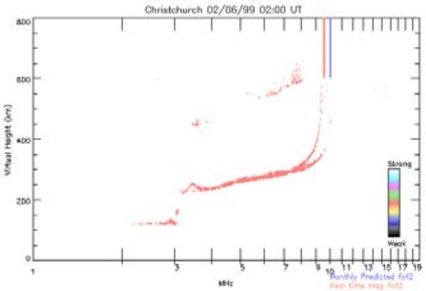
First, nighttime iongrams are considered. This is because night can be the least complicated. There is one layer present, absorption is low, but often interference can be high.

Sample Ionograms : daytime

- Typical daytime ionogram
- E/F region layers
- multiples
- extraordinary weak
- sporadic E present
- easy to scale

Scaling problems:

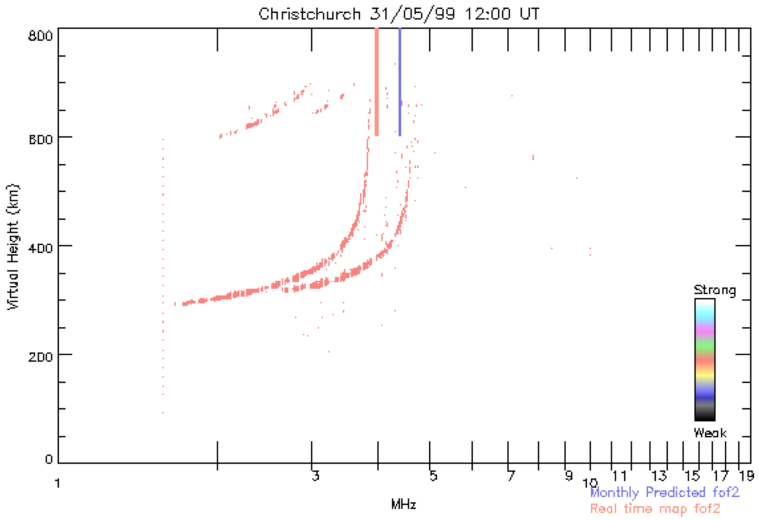
- foE - extrapolation
- Es - weak traces
- fxI - interference



12

After looking at several types of nighttime ionogram, daytime ionograms are considered. Now absorption and additional ionospheric layers become important.

Sample Ionograms : nighttime
(Chch 31/05/99 12 UT)

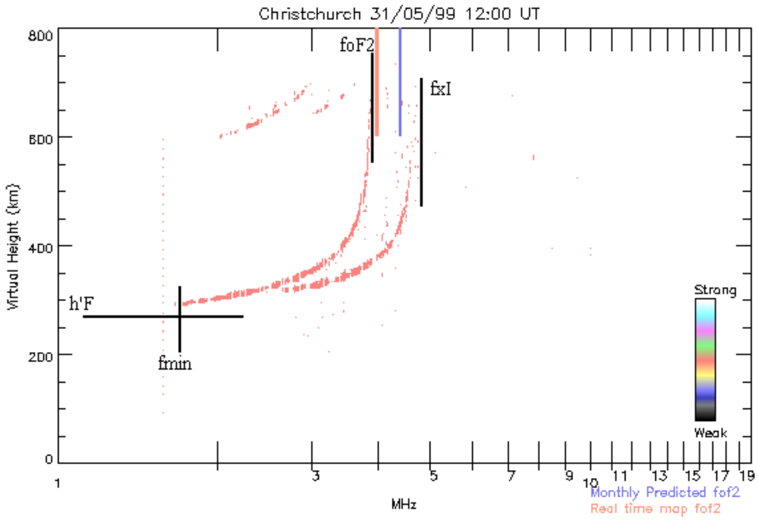


13

So; this is a nighttime ionogram. In this, and successive examples, the ionogram is shown, then it is shown with the scaled parameters marked in.

Before moving to the next frame, identify fmin, foF2, fxI, h’F on this ionogram, and all successive ionograms.

Sample Ionograms : nighttime (Chch 31/05/99 12 UT)

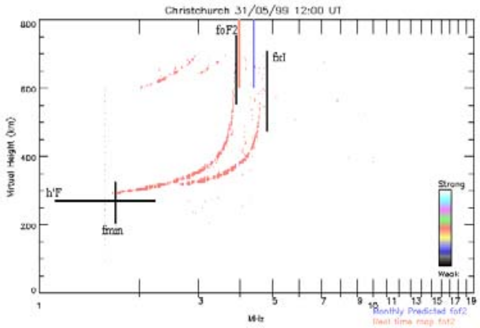


14

The base height of the F region, h'F, and the peak of the layer, foF2, define the layer reasonably well. For completeness, we should also add some information about the layer thickness. For the F region, this comes from scaling M(3000)F2, which can then be interpreted as the peak height of the F region.

Sample Ionograms : nighttime (Chch 31/05/99 12 UT)

•



What can we say?

– Clear fmin (__ES)
– no Es parameters
– Clear foF2,
– fxI ≠ foF2+split
– h'F, extrapolate down, *maybe* (__US) This is the hardest decision you will make scaling ionograms like this.

15

This now summarises the parameters that have been identified.

Look at each in turn, flick back to the original ionogram, and make sure you agree with the interpretations.

Fmin is clear, by it is a limit placed on us by interference. (In modern ionosondes this limit is often less obvious because the ionogram "just starts". You need to become familiar with your instrument so you can easily identify when the limit is forced on you.)

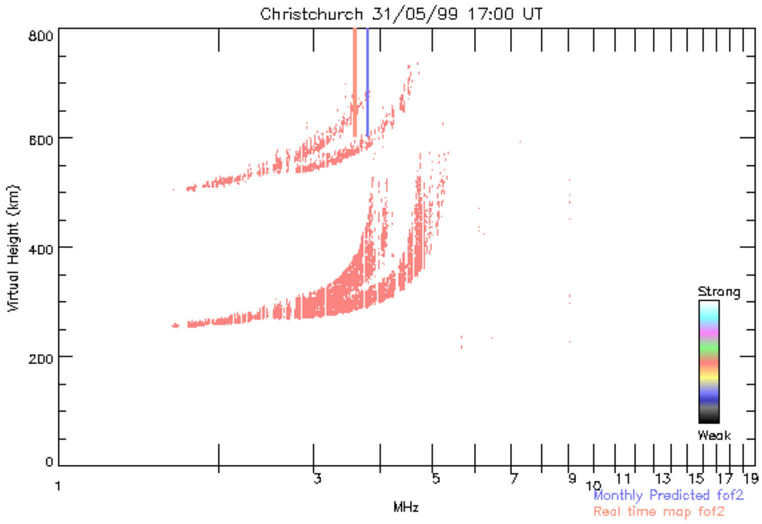
Was extrapolation needed to estimate h'F? You need to look at this carefully. There are two decisions here.

• First, you may well have had to extrapolate h'F, I would, but you may have been very confident in making this extrapolation. You are trying to estimate where the F-region trace is asymptotically flat.

• Second, you want to decide how accurately you can carry this task out. Initially, it will be hard to make this type of decision as it will seem arbitrary. However, it isn't. There are not so many options available to you, and soon you will become familiar with making estimates. You are seeking a consistent answer and your error estimate, which is subjective, indicates the extent of your consistency. By doing this, you are assuming that you and another analyst would both come up with very similar results.

With practice, you will get good at this.

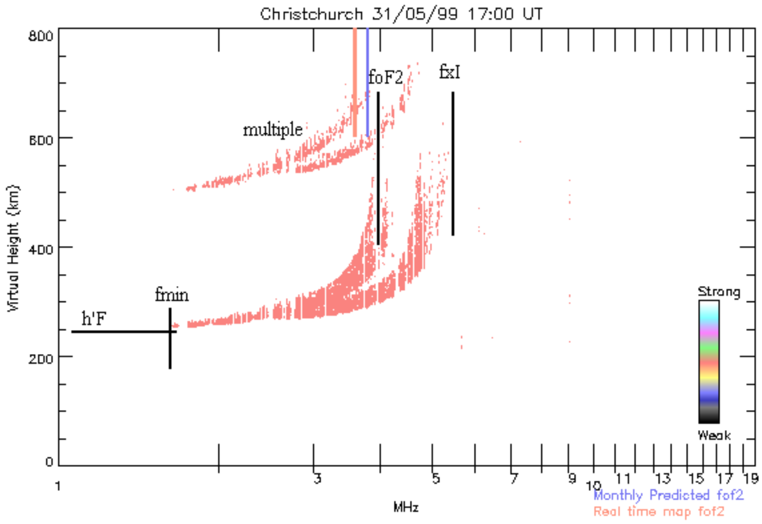
Sample Ionograms : nighttime (Chch 31/05/99 17 UT)



16

Now scaling all those parameters is slightly more difficult because the ionogram is spread. Nothing else has changed.

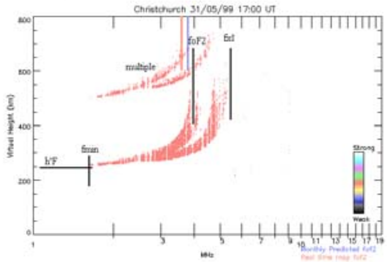
Sample Ionograms : nighttime (Chch 31/05/99 17 UT)



17

Look at the ionogram, identify all the parts of it, and then scale the parameters.

Sample Ionograms : nighttime (Chch 31/05/99 17 UT)



- What can we say?
  - Clear fmin (__ES)
  - no Es parameters
  - foF2
    - Clearly spread F is present, scale inside edge (__ UF)
    - fxI - scale outside edge of trace (could be slightly high here)
  - h'F, extrapolate down, *probably* (__. .)
- Note:
  - multiple is spread less
  - primary appears to be split.
  - Clear gaps in trace due to interference

You ought to be able to scale these better than autoscale did!

18

Fmin was no more difficult.

Although foF2 looked less obvious, the rule is to: *scale the inside edge of the spread for foF2 if there is no obvious overhead trace present.*

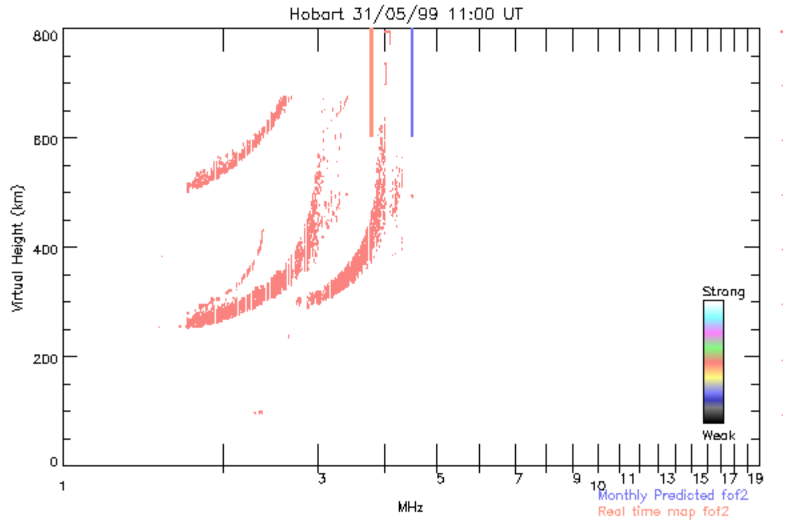
However, maybe the multiple can help in this. If it cannot, we normally add the qualifier U, although in this case it may not be needed as the spreading is not so great.

In cases like this, we always add the descriptive letter F, so we will be able to develop useful statistics of the occurrence of spread F.

fxI is now the highest return, and it differs from (foF2 + split), that we would have used for an un-spread trace.

)A novice scaler ought to be able to handle an ionogram like this better than a computer program.)

Sample Ionograms : nighttime
(Hobart 31/05/99 11 UT)



19

Look carefully at this example.

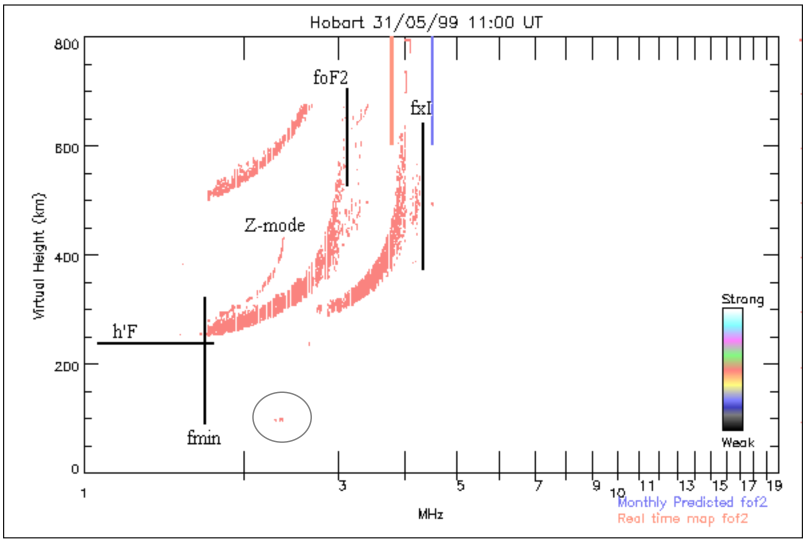
It is different from the last one in some interesting ways. Identify those differences.

When scaling ionograms, get used to first just looking at the ionogram. Think about the last ionogram in the sequence, and notice what has changed.

(In this case, there isn't a true sequence, but the principle still holds).

Don't spend too long, just relax momentarily and look. Feel confident that you will already be able to recognise what is new and different. Assume, that with experience, you will get fast at this.

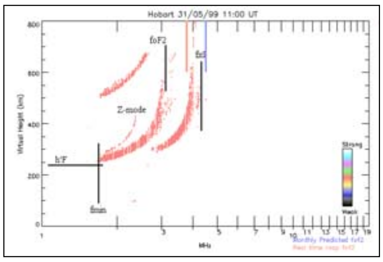
Sample Ionograms : nighttime
(Hobart 31/05/99 11 UT)



20

The tricky part here was to recognise the Z-mode echo. Even if you haven't seen one before, it stands out as unusual.

Sample Ionograms : nighttime (Hobart 31/05/99 11 UT)



- What can we say?
  - Clear fmin (__ES) (You can get to like fmin)
  - no Es parameters (Phew)
  - foF2
    - Clearly spread F is present, scale inside edge (__ . F)
      - but did you recognise the Z-trace?
    - fxI - scale outside edge of the spread F.
  - h'F, extrapolate down, *maybe* (__US)
- Note:
  - multiple is spread less
  - You can get a good foF2 value from the Z-trace

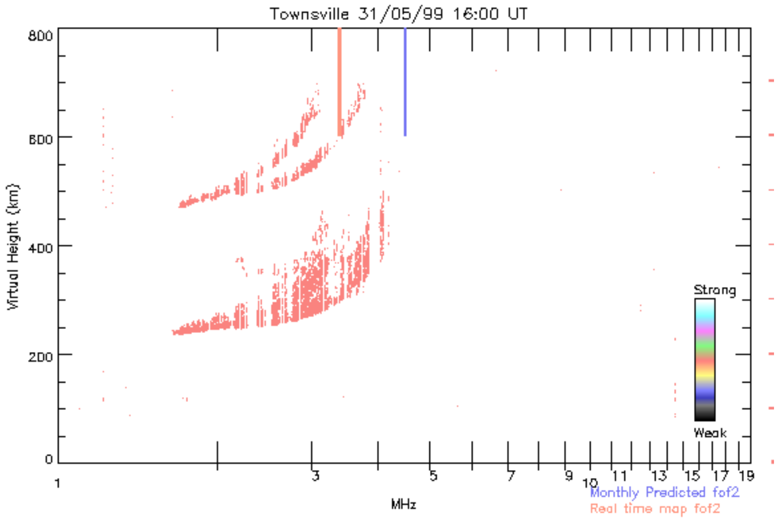
You ought to be able to scale these better than autoscale did!

21

Again, the scaling is straightforward. It just takes a little time to become familiar with the elements.

The other minor points to note are the presence of the X-mode multiple adjacent to the O-mode returns, giving the impression of a TID (or maybe it is a night TID? What do you think?) and the little fluff of spread close to the X-trace.

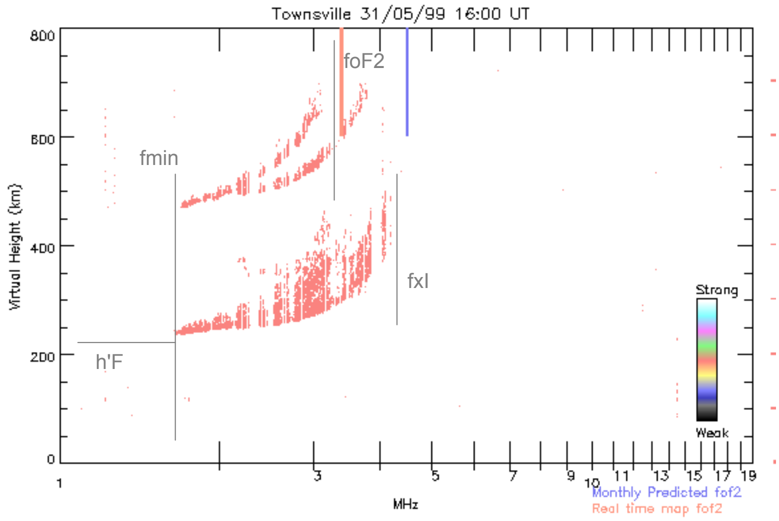
Sample Ionograms : nighttime (Townsville 31/05/99 16 UT)



22

More spread. Really, spreading and sporadic E are the main elements you need to be familiar for the vast majority of nighttime ionograms. Lots of practice will make you good at dealing with it. Sometimes, a good bit of effort will be needed to get a result, but you should always be able to handle the ionograms.

Sample Ionograms : nighttime (Townsville 31/05/99 16 UT)

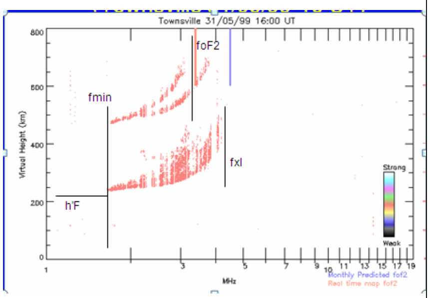


23

There is one issue that is more awkward to deal with:

is the trace complete, or is interference causing us to lose the last few channels of ionospheric returns? It is a matter of experience how this is interpreted.

Sample Ionograms : nighttime (Townsville 31/05/99 16 UT)

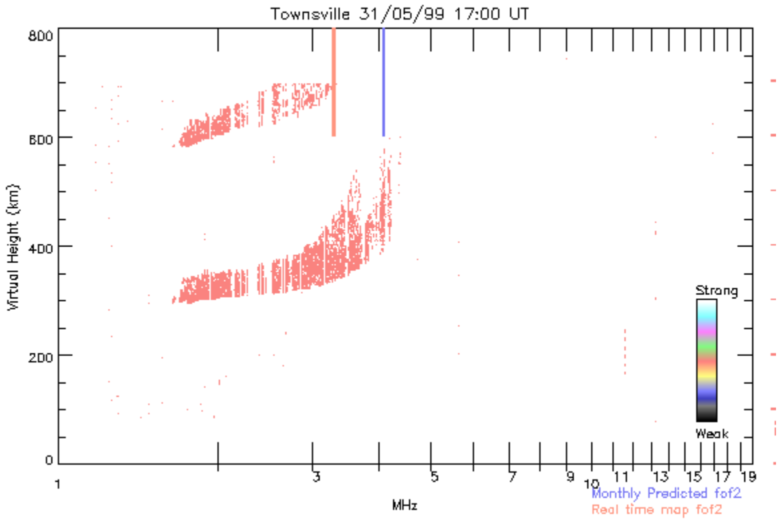


- What can we say?
  - Clear fmin (__ES)
  - no Es parameters
  - foF2
    - Clearly spread F is present, scale inside edge (__ UF)
    - fxI - scale outside edge (may be __ S)
  - h'F, extrapolate down, *maybe* (__US)
- Note:
  - More spread
  - but multiple gives some guidance
  - multiple has *odd* shape

24

And in scaling it, all the results follow in the same way.

Sample Ionograms : nighttime (Townsville 31/05/99 17 UT)

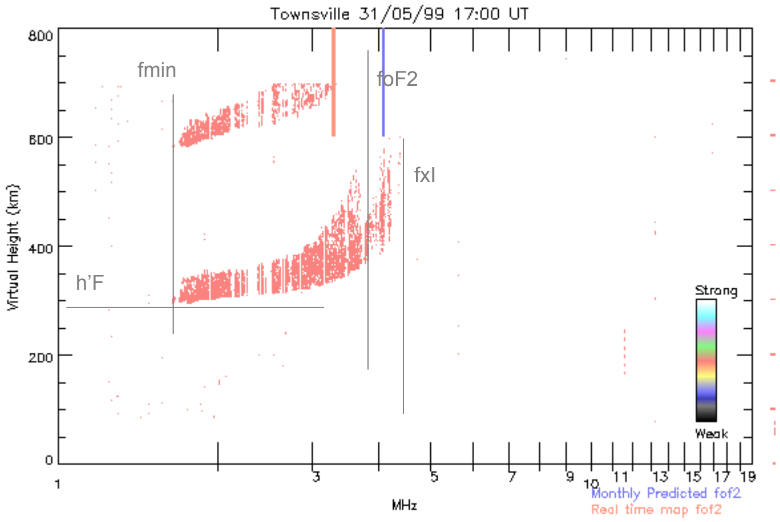


25

Now the spreading is more extensive, and scaling is harder. Extrapolation is more difficult, and the multiples give little guidance as they also are spread as well as being cut off by the display.

Is there anything new about this display?

Sample Ionograms : nighttime
(Townsville 31/05/99 17 UT)



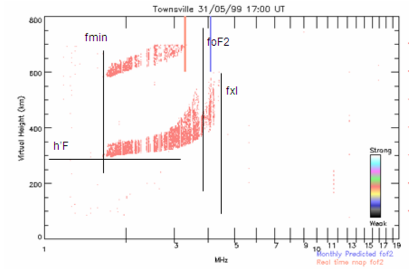
26

The issue of a weak trace near fxI is clearer on this example. Picking fxI is difficult to place with confidence, partly because some of the final returns would not be seen on a less sensitive display. It is a matter of judgment whether you seek to get information like this from an ionogram. The main thing is to be consistent in how you interpret such examples, both with your latter efforts, and those of others also scaling with you.

What is new?

Sample Ionograms : nighttime (Townsville 31/05/99 17 UT)

- What can we say?
  - Clear fmin (__ES)
  - no Es parameters
  - foF2
    - Clearly spread F is present, scale inside edge (__ UF) or worse
    - fxI - scale outside edge
  - h'F, extrapolate down, *maybe* (__ . Q) (for range spread)
- Note:
  - multiple is not much help
  - traces are now rather broad
  - interference evident

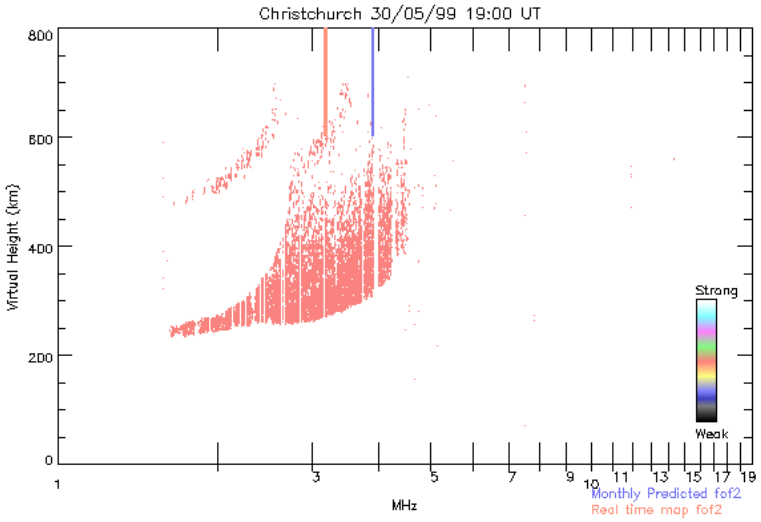


27

The scaling is pretty much as for the other spread ionograms, with one difference:

the F trace is thick near fmin. This is usually called range spread, and if it is thick enough (> 30 km) a descriptive letter Q is added to h'F to signify range spread is present.

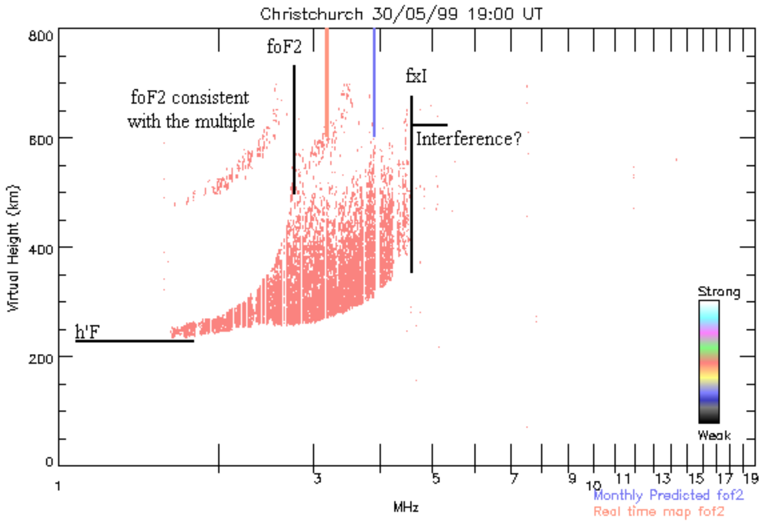
Sample Ionograms : nighttime (Christchurch 30/05/99 19 UT)



28

This is a really significant amount of spreading.

Sample Ionograms : nighttime (Christchurch 30/05/99 19 UT)

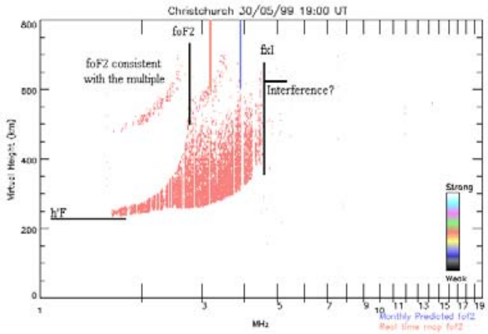


29

But it is still relatively easy to recognise the important parts of the ionogram.

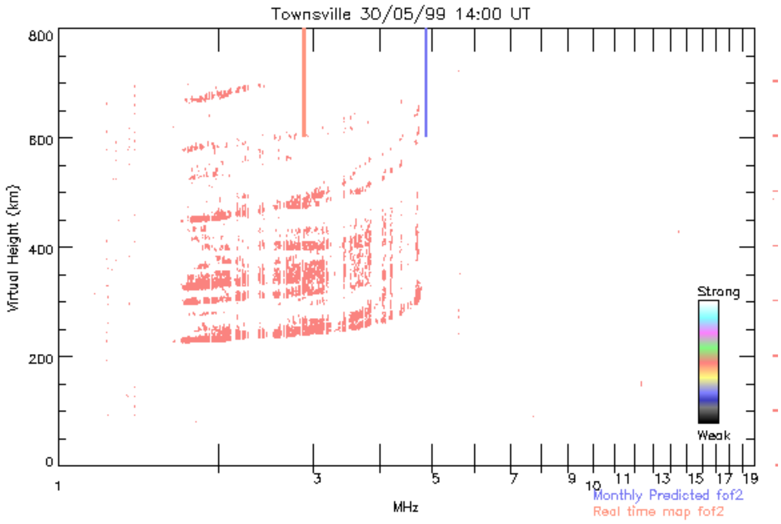
Sample Ionograms : nighttime (Christchurch 30/05/99 19 UT)

- Well developed mid latitude spread F
- What is fxI
  - possibly interference obscures part of the trace, (__ US)
  - Note X-multiple



30

Sample Ionograms : nighttime (Townsville 30/05/99 14 UT)



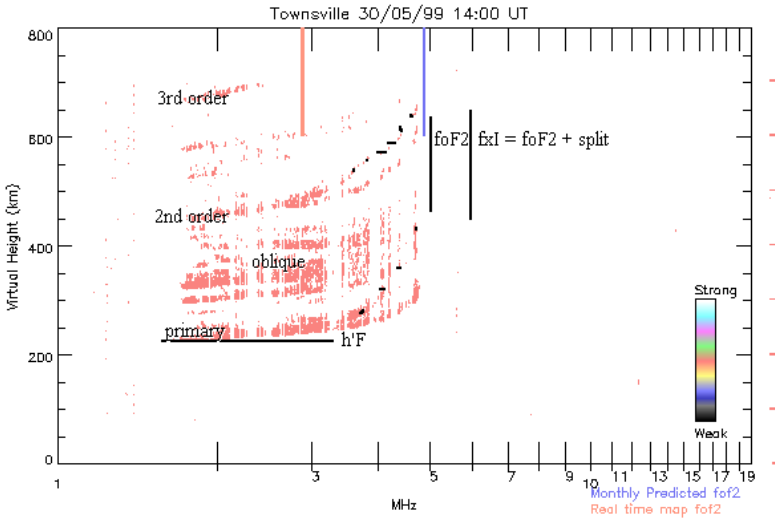
31

Does this one look different?

Look carefully at it and decide what is happening.

Can you identify any parameters? all of them?

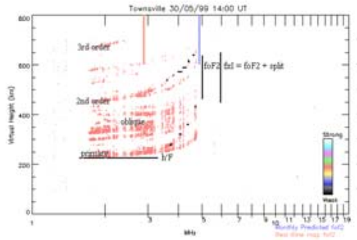
Sample Ionograms : nighttime
(Townsville 30/05/99 14 UT)



32

Although it is chaotic, it isn’t so hard after all.

Sample Ionograms : nighttime (Townsville 30/05/99 14 UT)



- What can we say?
  - Clear fmin (__ES)
  - no Es parameters
  - foF2
    - Looks awful? Look at multiple, back to primary, and foF2 is clear, and probably not spread.
    - fxI - scale outside edge. Probably (__ U S).
  - h'F, extrapolate down, *probably* (__ . Q) (for range spread)
- Note:
  - (the black dash/dots were my attempt to identify the main trace)
  - multiple, once identified, is valuable
  - many traces are now present, confusing the ionogram
  - interference very evident (it can get worse)

33

That is an example of equatorial spread F. It can be more difficult to handle than this, but as always the principles remain the same. Think about what is happening, draw on past experience, identify what is different, and decide how the ionogram has evolved.

In the case of equatorial spread F, you cannot, with any ease, project your past experience to this point and anticipate an example like this. Instead, you would need to collect many examples similar to this to convince yourself it was a common occurrence. Look at other locations, look at examples of ionograms published in INAG Bulletins etc. This is an example of something new.

It is hard to recognise a new feature you couldn't previously have expected from old friends appearing in a different light.

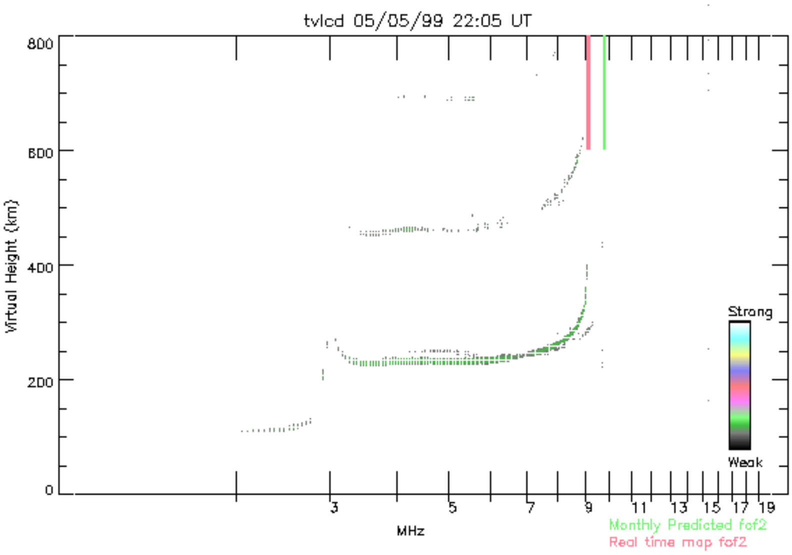
And now for something completely different

Daytime

34

To this point, there have been no examples of sporadic E. However, let's first deal with the daytime ionosphere.

Sample Ionograms : daytime (Townsville 05/05/99 22:05 UT)

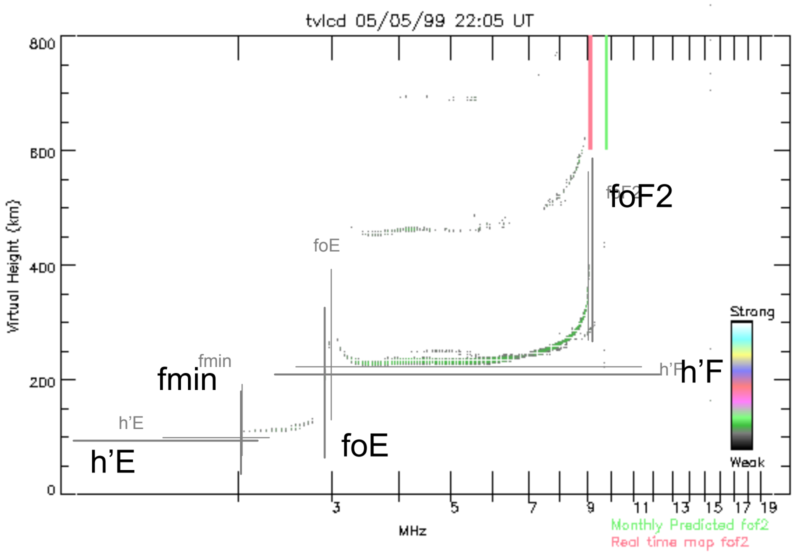


35

Daytime differs on two counts: more layers and absorption. These are a direct result of the presence of the sun. The sun’s ionising radiation produces ionisation that can be observed using an ionosonde. As the incoming radiation changes, so the production of ionisation will respond, resulting in changes in the ionosphere.

The normal E region follows this closely and is an excellent indicator of the suns presence.

Sample Ionograms : daytime
(Townsville 05/05/99 22:05 UT)



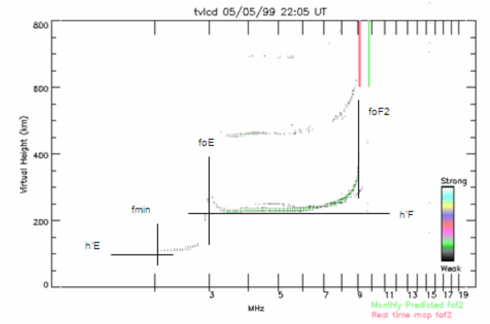
36

(Note that h'F is marked too low, and foE is too low. It is a result of how the plotting system works)

This is a straight forward ionogram to scale. All the parameters can be scaled with reasonable accuracy.

Sample Ionograms : daytime (Townsville 05/05/99 22:05 UT)

- What can we say?
  - Clear fmin (__) (with no scaling letters)
  - good foE value
  - foF2: good value
  - h'F okay



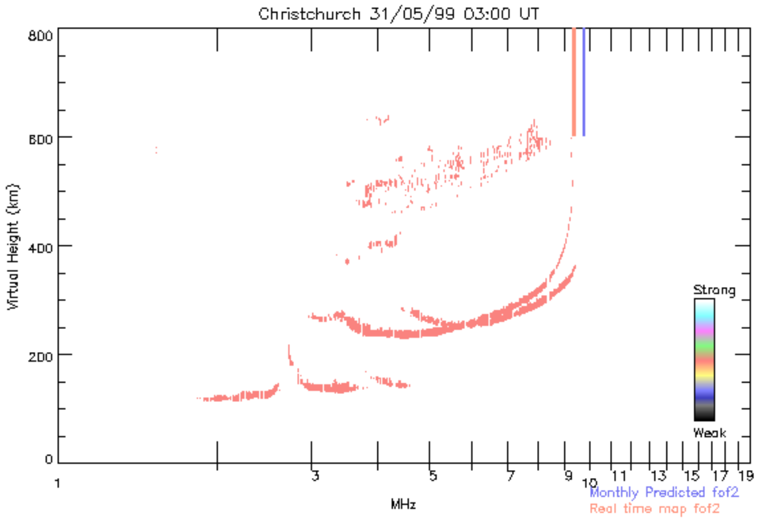
- Note:
  - This is a good daytime ionogram to scale
  - Traces "seem" thinner, less strongly defined. Partly, a different ionosonde.

37

The scaling is straightforward.

All values can be scaled with good accuracy, although the trace seems a little thinner than the previous examples. Why is that? Partly increased absorption, partly it is a different ionosonde. This is a key problem, as ionosondes change, so the apparent "visibility" of the ionograms can change. While the scaling conventions are supposed to prevent these changes being apparent, it is inevitable that some of the effects will pass through into the scaling. However, try not to do this. Try to develop scaling habits that allow you to look beyond the ionosonde type, and ionogram display, to the basic issues in scaling.

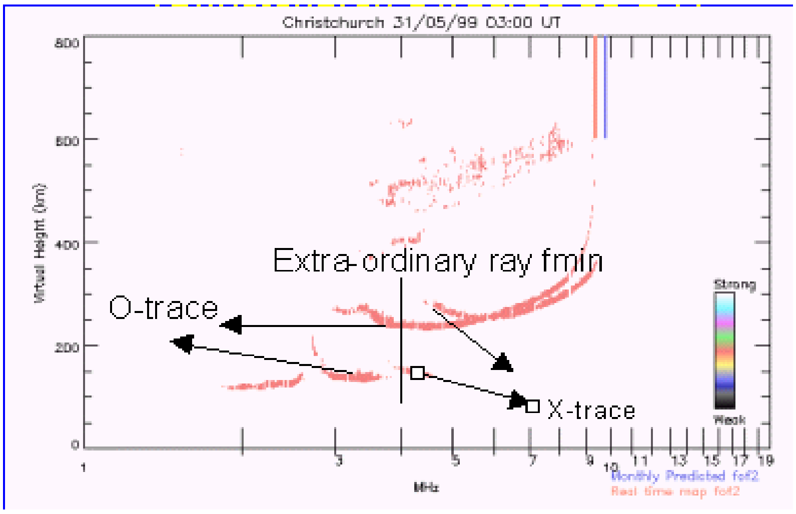
Sample Ionograms : daytime (Christchurch 31/05/99 03 UT)



38

What is different here.

Sample Ionograms : daytime (Christchurch 31/05/99 03 UT)

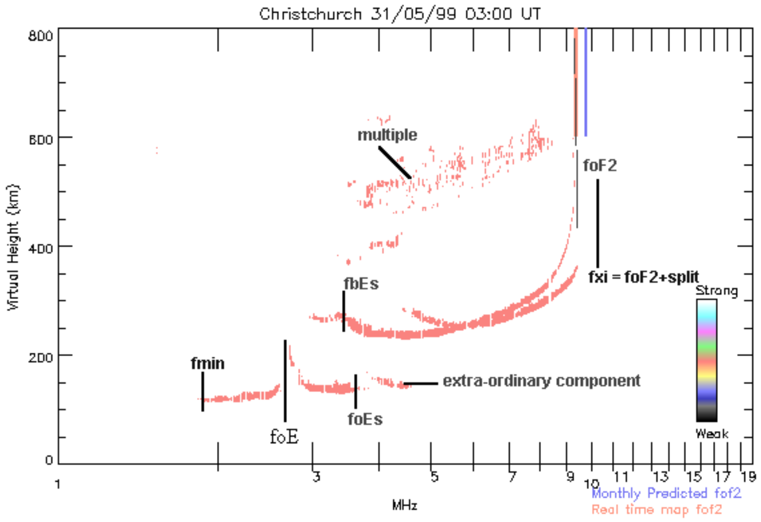


39

In this example, the sporadic-E layer is well developed and very easy to identify and scale. It isn't usually so easy.

The convention for identifying the ordinary, or o-component of sporadic E is to look at the F-region extra-ordinary (x-) component. Assuming on a given frequency that the effects of absorption on the F region returns and Es-region returns are the same (which they often are), if there is no F-region x-component present, then there will be no x-component Es reflections to observe either.

Sample Ionograms : daytime (Christchurch 31/05/99 03 UT)



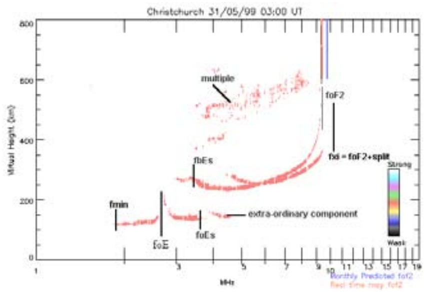
40

Sporadic E. Now that is sorted out, for this example at least, it is apparent that it is a nice example of a clear sporadic E layer.

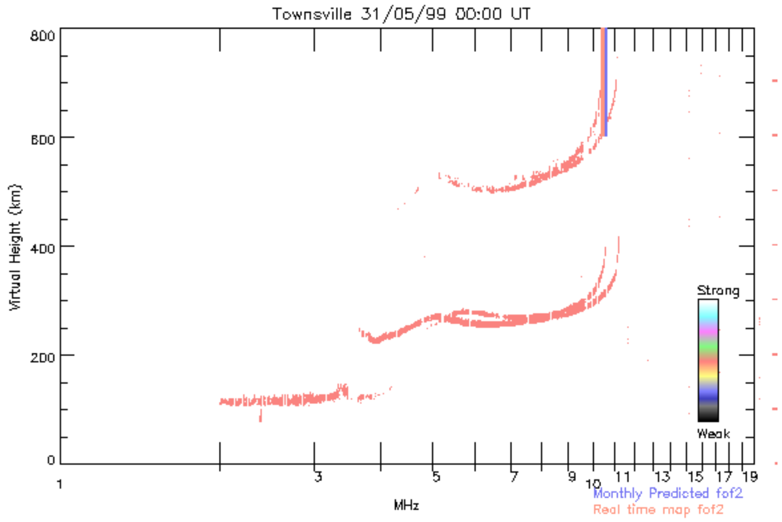
By convention, and it is a good convention, we only scale the sporadic E layer details from the ordinary ray reflections. The main reason for this is that we need to discriminate between the two layers to produce a more consistent data set for later study.

Sample Ionograms : daytime (Christchurch 31/05/99 03 UT)

- What can we say?
  - Clear fmin (__) (with no scaling letters) (bit high here)
  - Sporadic E is present
    - foEs: descending layer, multiple present, extra-ordinary present
    - fbEs: tip of F region present
  - foF2: good value
  - h'F or h'F2 (need to know where to expect foF1)
- Note:
  - This is a good daytime ionogram to scale
  - disturbed multiple
  - how many sporadic E layers are present?



Sample Ionograms : daytime (Townsville 31/05/99 00 UT)

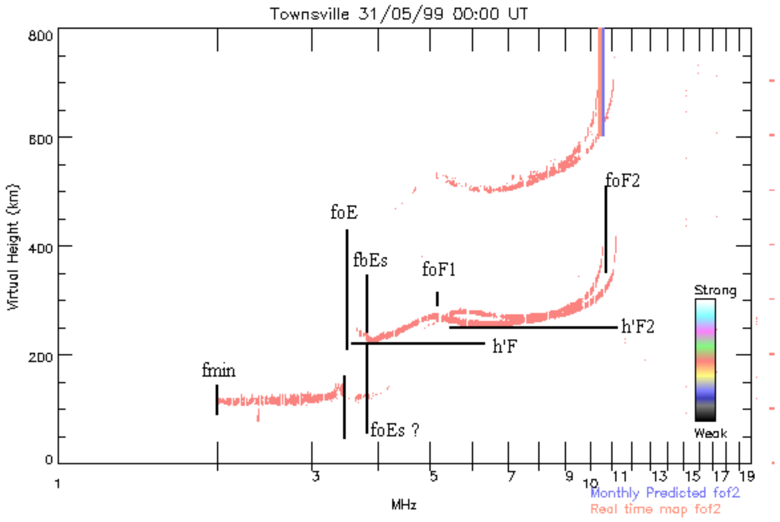


42

This is more like the typical daytime ionogram. Reasonable layers, a puff of sporadic E, and it all takes time to scale, but offers little intellectual effort once the rules are understood.

This is a persistent problem with scaling; often the ionograms are sufficiently easy that it is boring work remaining accurate as many tens of 1000's, if not hundreds of 1000's of ionograms are processed.

Sample Ionograms : daytime (Townsville 31/05/99 00 UT)

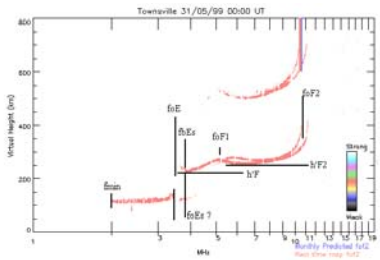


43

The problem, as foreshadowed, is the puff of sporadic E. We will scale it, because it is present, and the doubts are emphasised here.

Sample Ionograms : daytime
(Townsville 31/05/99 00 UT)

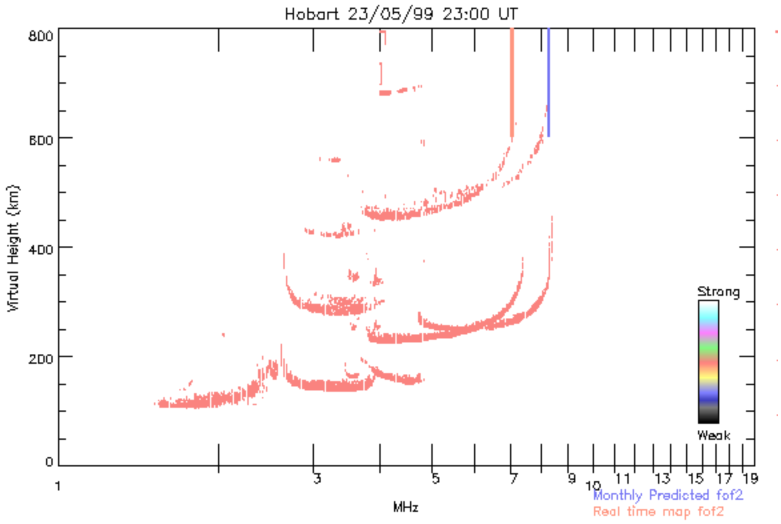
- What can we say?
  - Clear fmin (__) (with no scaling letters)
  - Sporadic E parameters are awkward
    - probably some X component present
    - a weak trace, and may depend on sequence
  - foF2: good value
  - h'F2 okay, h'F possibly disturbed
  - foE: scaled too low here.



- Note:
  - sporadic E gives problems
  - This is a typical daytime ionogram, just a little awkward

44

Sample Ionograms : daytime
(Hobart 23/05/99 23 UT)

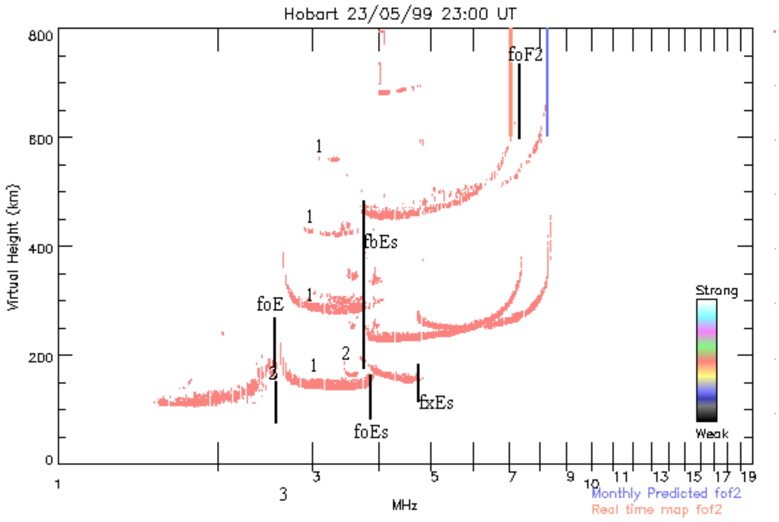


45

Sporadic E is a good reflector. Consequently, there can be several multiples of sporadic E observed on the same ionogram. These overlay and at first sight, complicate the underlying E-F region ionogram.

It is also possible to get more than one sporadic E layer per ionogram. It is questionable whether there is an additional layer present here, and the adjacent ionograms would normally be inspected to be certain this interpretation is reasonable, and consistent with what others would think if confronted by the same ionogram.

Sample Ionograms : daytime
(Hobart 23/05/99 23 UT)



46

(Sorry; not sure what the little 3's are).

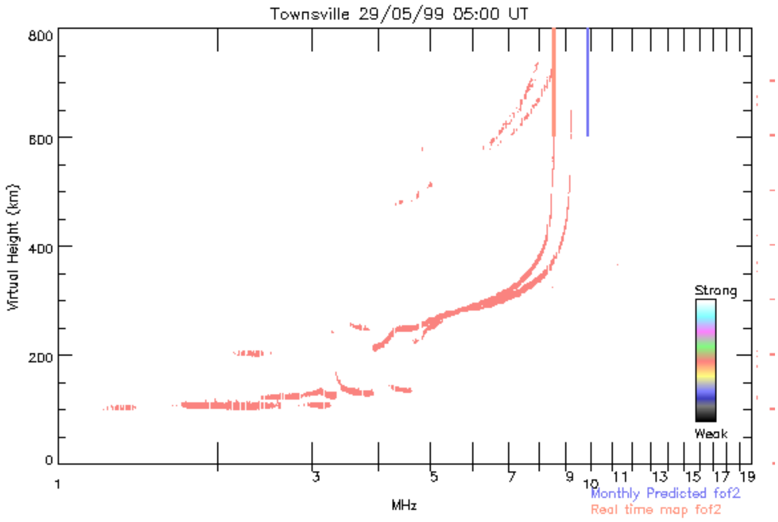
It is a useful exercise to take a few examples like this and go through and identify the multiples for different layers. Get used to figuring out where all the traces on an ionogram come from, sometimes knowing this will help re-interpret parts of the ionogram.

Sample Ionograms : daytime (Hobart 23/05/99 23 UT)

- Clear descending Es layer (but check sequence anyway)
- Another Es layers is also present
- This is a useful example of several multiples.
  - Decide which are multiples of which
  - scale the primary characteristics
- Note the possibly second Es layer
  - ordinary component is hard to detect
  - but extra ordinary is clear

47

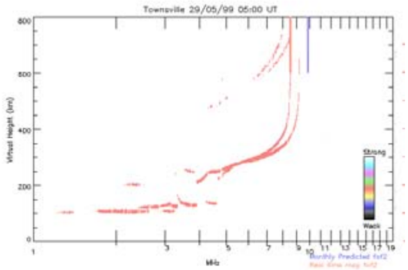
Sample Ionograms : daytime (Townsville 29/05/99 05 UT)



48

At first, this appears confusing. Then it seems unnecessary to figure out all the issues resulting in a messy looking E region.

Sample Ionograms : daytime (Townsville 29/05/99 05 UT)



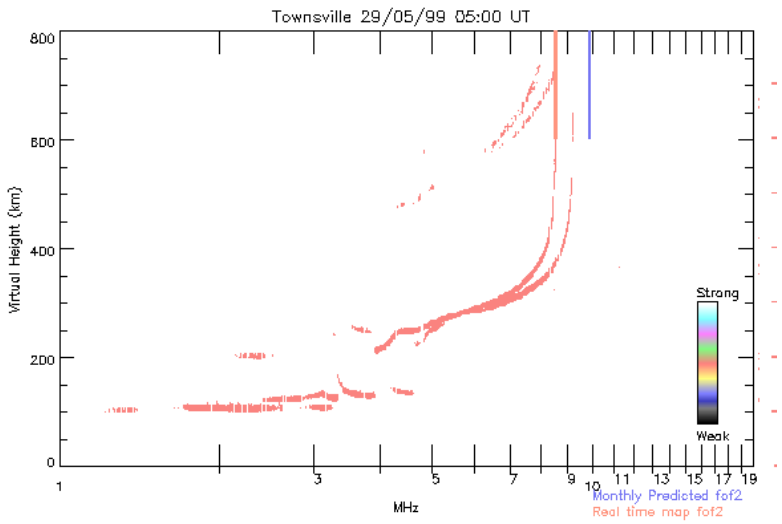
- Fmin? Weak trace rule
- foF2: easy, autoscale agrees
- h’F2: poorly formed F1, none there
- h’F: (__ U A) or (__ UH) or (__) ??
- foEs ? How many Es traces and which
- foE?

49

Let’s pose a few problems about interpreting the ionogram. The reason for doing this is to help show that by looking at all the information, eliminating parts, etc., we get a better result.

So, at first look, foF2 is obvious, and the rest is awkward.

Sample Ionograms : daytime (Townsville 29/05/99 05 UT)

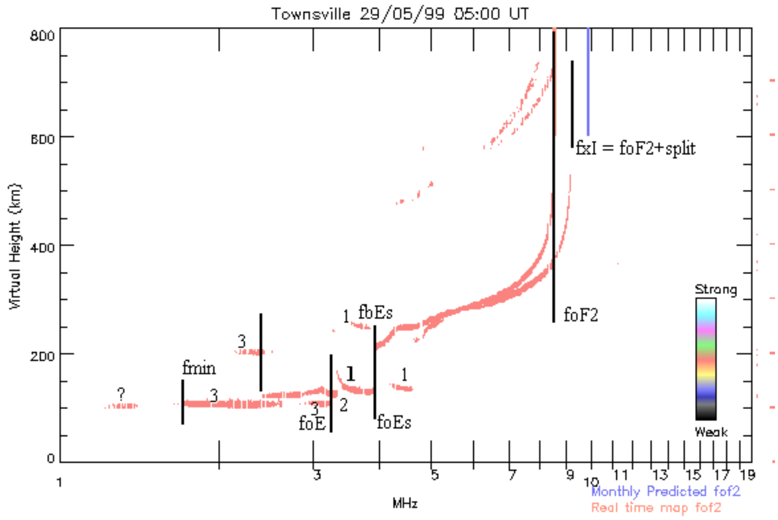


50

Now take a careful look.

Starting at fmin, work across and up the ionogram, identifying the parts, labeling them, and prepare to scale.

Sample Ionograms : daytime
(Townsville 29/05/99 05 UT)



51

Fmin has been scaled from the clear continuous trace, ignoring the weak lower return. If this return appears on adjacent ionograms, then ignoring it is less realistic. A weak trace is usually thought to be weak both in signal strength, and in lifetime. This could be a low-type Es layer. If we believe it is definitely a return from the ionosphere, then fmin should be scaled off it. In IPS, we would be sure to note this is a low-Es layer by placing L in the type table.

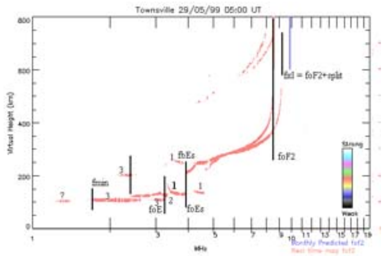
There is a second low layer present, from which fmin is scaled, and the lower part of the E region is blanketed by it. There is also a multiple of this low Es layer, which is unusual. (All this is labelled 3). Finally, there appears to be a small x-trace return from this layer. The interpretation is not definite, but it is reasonable.

The layer we are most interested in is the one offering the highest foEs value because that is the one we scale. This trace also has a small x-trace and a multiple. Finally, fbEs = foEs.

The lower F region has a bit of a kink in it and this is affecting the value we can scale for h’F.

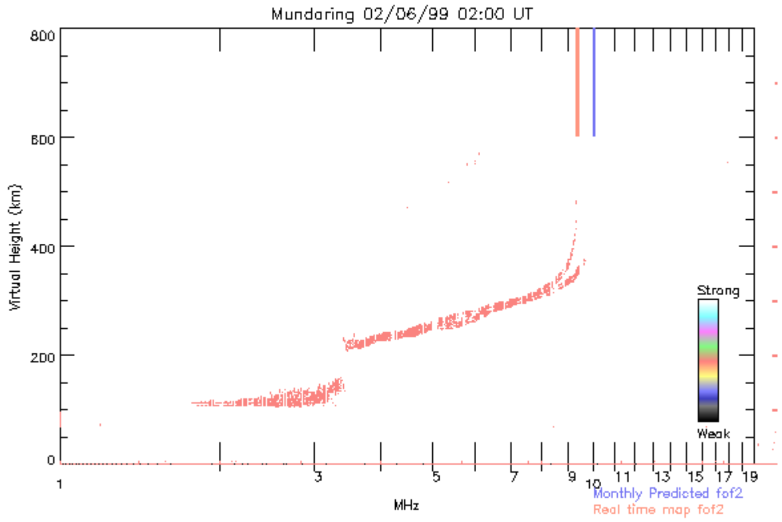
Sample Ionograms : daytime
(Townsville 29/05/99 05 UT)

- Fmin Weak trace rule - ignore the low bit
  - but some discussion over this. See a sequence.
- foF2: agreed
- h'F / h'F2:
- h'F: (__ H) only h'F scaled
- foEs: scale the highest foEs. Note low type Es
- foE: using c, h Es layers, foe = good value



52

Sample Ionograms : daytime (Mundaring 02/06/99 02 UT)



53

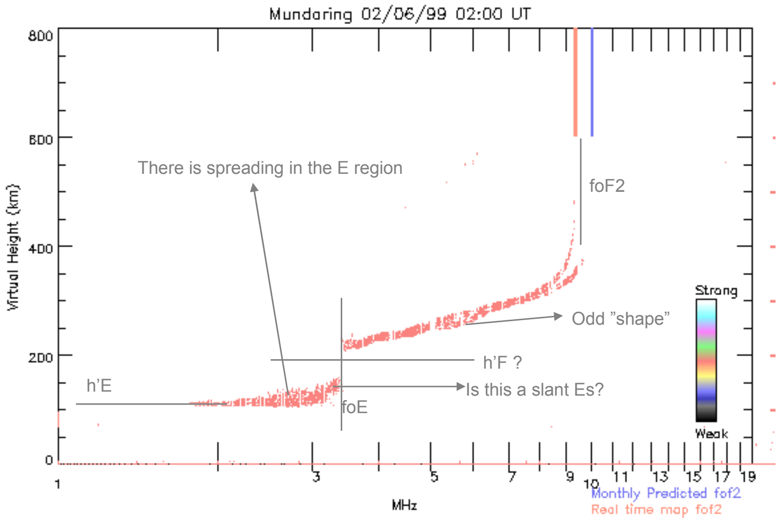
What is unfamiliar here? Take a careful look.

Are the differences due to minor, or even major, changes in familiar conditions, or is there something completely different happening?

Get used to looking carefully at ionograms, quickly asking this type of question as you scale.

But don't get bogged down either, keep moving. If the odd condition only happens infrequently, then it is not significant for scaling, although there may be scientific reasons to note the example. Get used to keeping a notebook by the scaling station and not down unusually examples that stalled you for a moment. You can always come back to these to decide whether you interpreted them correctly.

Sample Ionograms : daytime (Mundaring 02/06/99 02 UT)



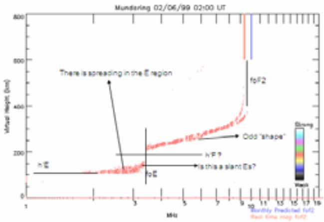
54

Spread Es is what is different here, and a possible slant Es trace also. This is a new condition and it may be worth noting its presence. IPS has special rules for noting this presence, although they do not reveal any special new knowledge.

Having dealt with that, don't forget to pay attention to the rest of the ionogram. Check out h'F; it is difficult to scale also, only here it is likely there is a small disturbance present.

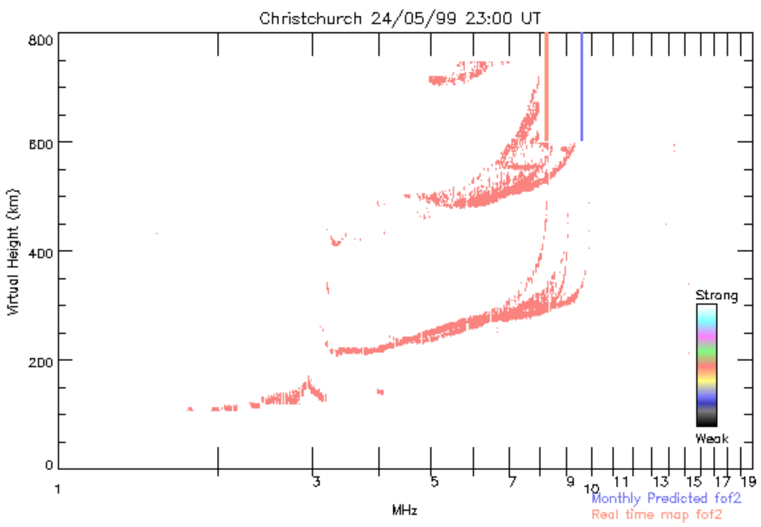
Sample Ionograms : daytime (Mundaring 02/06/99 02 UT)

- Spread Es example
- Spreading in the E region is an unusual condition we note by scaling a Q on h'Es
- There may also be a slant Es here
- Note weak F2 region criticals
- Also note the odd splitting on the Mundaring trace.
  - An example of an equipment problem you would need to recognise.



55

Sample Ionograms : daytime
(Christchurch 31/05/99 03 UT)

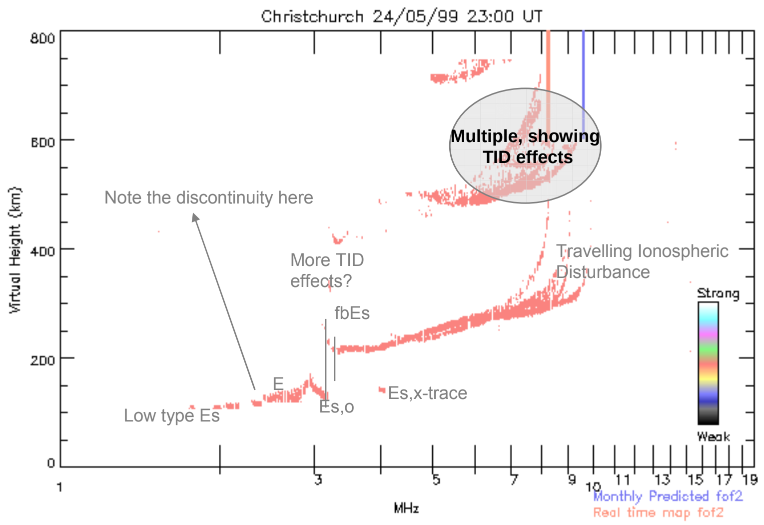


56

What's new here?

Can you explain all the traces you can see?

Sample Ionograms : daytime (Christchurch 31/05/99 03 UT)



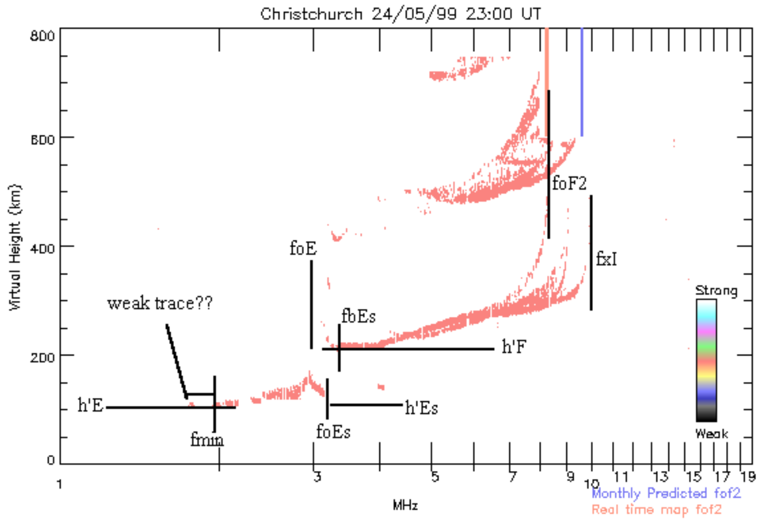
57

There is a low type Es layer here. It is apparent because of the change in altitude and discontinuity in the E region trace. Since fmin is controlled by the low layer, IPS would always scale L in the Es Type column, after the layer that contributed foEs.

The is clearly a major wave affecting the F region peak. There are multiple first-order traces, and the second order trace is highly disturbed. Often, during disturbances the second order will be more irregular than the first order,. Why do you think that is the case?

Finally, the h'F region shows signs of also being disturbed. The small reflections of retarded traces is a sign to recognise.

Sample Ionograms : daytime
(Christchurch 24/05/99 23 UT)



58

Do you disagree with some of these scaled values?

What about the low type Es layer?

There were several choices here.

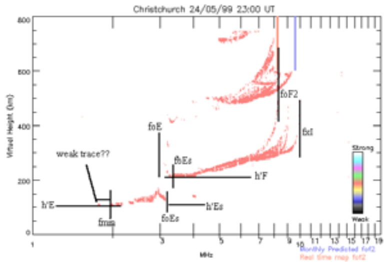
The low type layer has not been scaled correctly. This will lead to a small, but irrelevant, error in h'E. Bad scaling doesn't necessarily lead to significant errors.

It is unclear that fbEs is scaled correctly. There is a decision here whether the turn up in the F region is really overhead, or linked to the TID activity clearly present in the ionosphere. Again, it isn't a major issue, but possibly the discontinuity noted before marks fbEs. You would need a sequence of ionograms to settle this one, and then you would be lucky to resolve it unambiguously.

Clearly, the most important task is to sort out the overhead trace in the upper F region. Although the second order multiple is disturbed, it can still give guidance (Why?). Using that, the most likely location for foF2 is identified.

Sample Ionograms : daytime (Christchurch 24/05/99 23 UT)

- Travelling Ionospheric Disturbances(TIDs)
  - give some zest to scaling.
  - They affect both the E and F region,
  - but are most prominent in F2 region.
  - When present, scale H on characteristics *affected* by it.

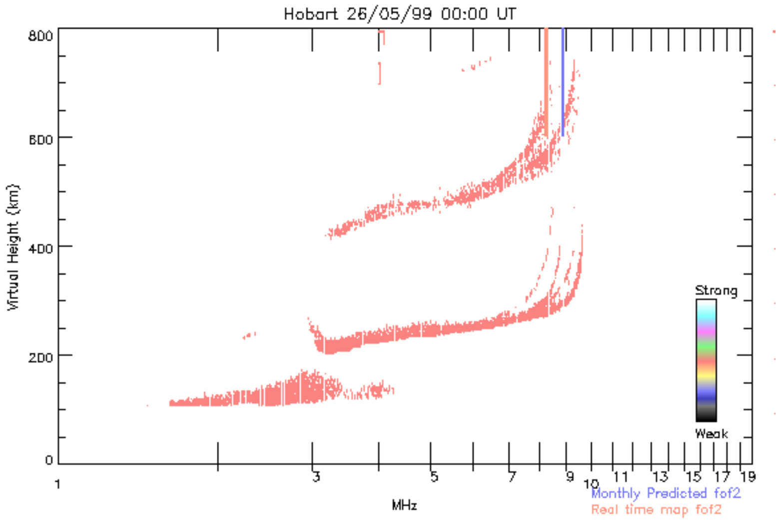


- However, this ionogram has several other tricky bits
  - fmin - weak trace rule needed?
  - foE - extrapolation, probably (__ UA)
    - (and maybe scaled even higher than here)
  - h'Es - extrapolation (__ UG)
  - foF2 - clearly affected by a TID (__ H)

59

The main point here, foF2 is described by H. However, there is probably no reason to add a U, the value for foF2 seems clear, even though the disturbance is evident. This will not always be the case, of course.

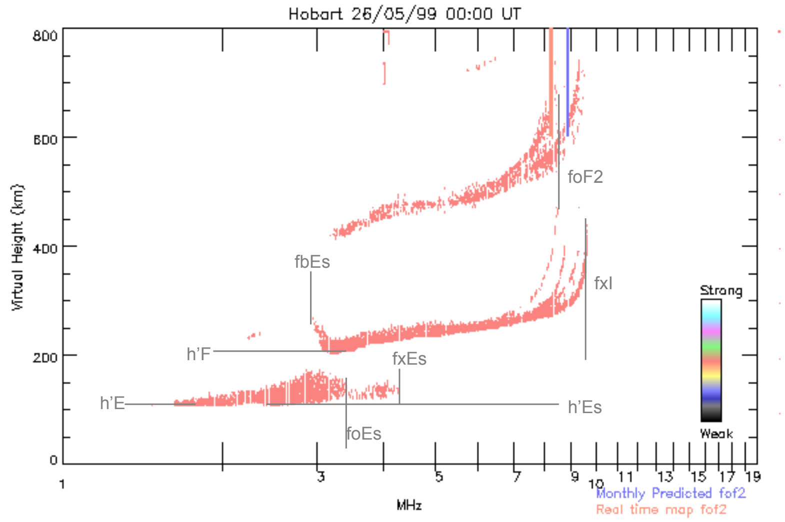
Sample Ionograms : daytime
(Hobart 26/05/99 00 UT)



60

This is a combination of two phenomena.

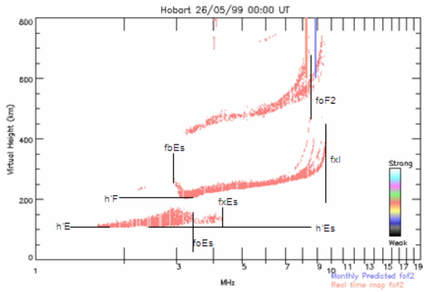
Sample Ionograms : daytime (Hobart 26/05/99 00 UT)



61

There is spreading in the E region and a TID in the F region. Some have suggested that this is the same wave phenomena affecting all of the ionosphere but appearing differently in the two regions. While interesting, the scaler does not really need to worry about this complexity.

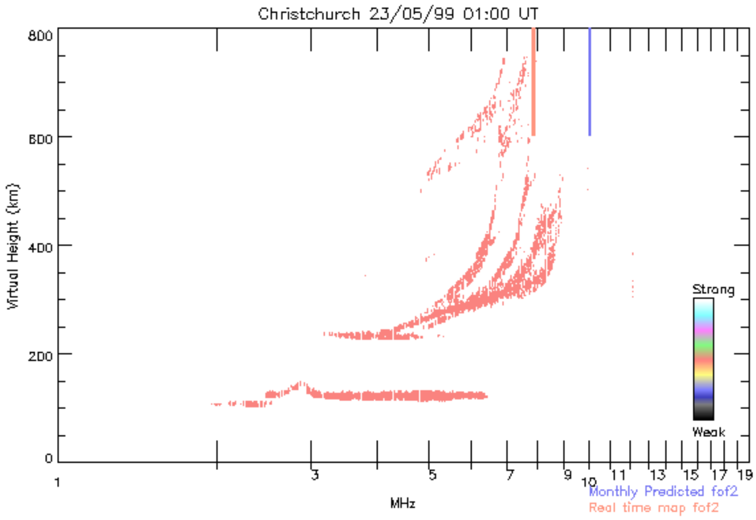
Sample Ionograms : daytime (Hobart 26/05/99 23 UT)



- E region
  - spread Es well developed
  - fxEs ≠ foEs + split (spread Es is signal strength dependent)
  - fbEs is possibly too low here.
- F2 region
  - A travelling ionospheric disturbance, the so-called **V**
    - the meaning of V is contested
    - the inner edge is inconsistent with the multiple
    - foF2: (__ . V) although (__ . H) is just as good
  - fx**I** will have descriptive letter X; no spread.

62

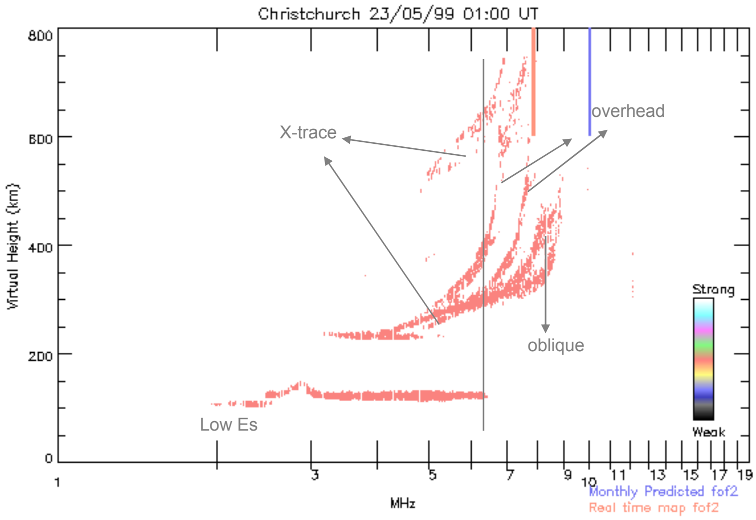
Sample Ionograms : daytime
(Christchurch 23/05/99 00 UT)



63

By now you have met with all the features in this ionogram. However, it may require a little thought to figure out what is going on.

Sample Ionograms : daytime (Christchurch 23/05/99 00 UT)



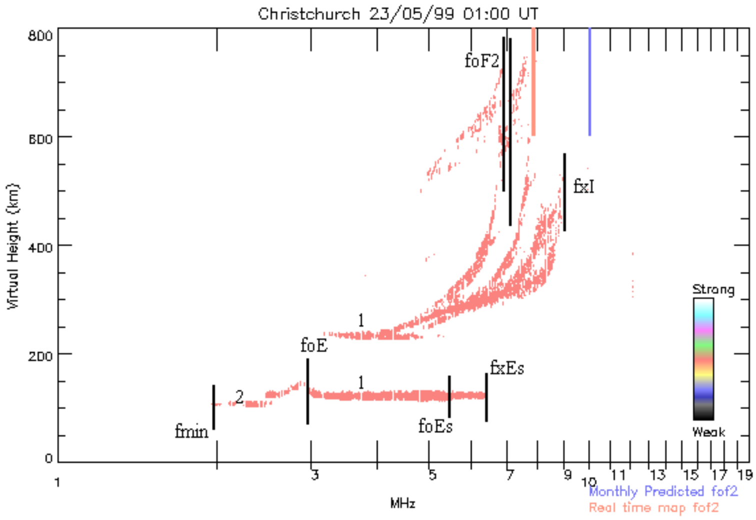
64

Note that there are two Es layers, a low layer from which fmin is scaled and a high layer. The difficult bit is to decide where foEs is.

Look at the F region and decide where the o-trace and x-traces are. The disturbance doesn't ease the complication, so look at the F region multiple. It is most likely that the X trace is present below the top frequency observed for the sporadic E layer.

A sequence of ionograms would be very helpful to confirm we have interpreted the oblique traces correctly.

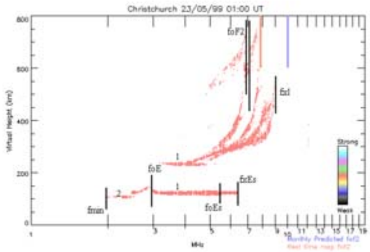
Sample Ionograms : daytime
(Christchurch 23/05/99 00 UT)



65

Using the information we can see, we can now scale the ionogram.

Sample Ionograms : daytime (Christchurch 23/05/99 23 UT)



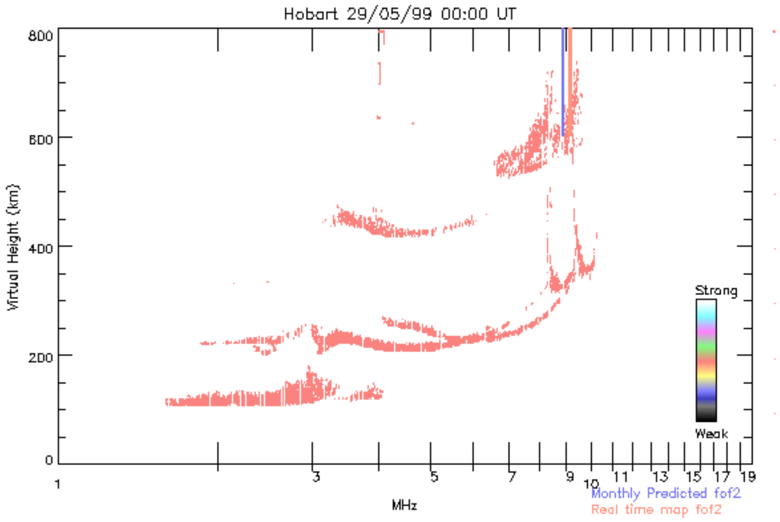
- One day earlier (than 24/05 00UT)
  - it isn't unusual to find similar cases clustering
- There are several tricky scaling issues
  - foEs = fxEs - split (note slight change in trace)
  - fmin - weak trace issues
  - foE - extrapolation (__ UA) probably
  - Note low type Es, record type, but don't scale it
  - h'F - probably (__ EA) or maybe (__ UA)
  - fxI - outside trace = (-- F)
  - foF2 (__ UH)

66

Should we use a U with foF2?

It depends how confident you are with the overhead trace identification. Using the second order multiple, it looks likely the interpretation is correct, so this should be a good value. There would ALWAYS be a descriptive letter H with foF2 for ionograms like this.

Sample Ionograms : daytime (Hobart 29/05/99 00 UT)

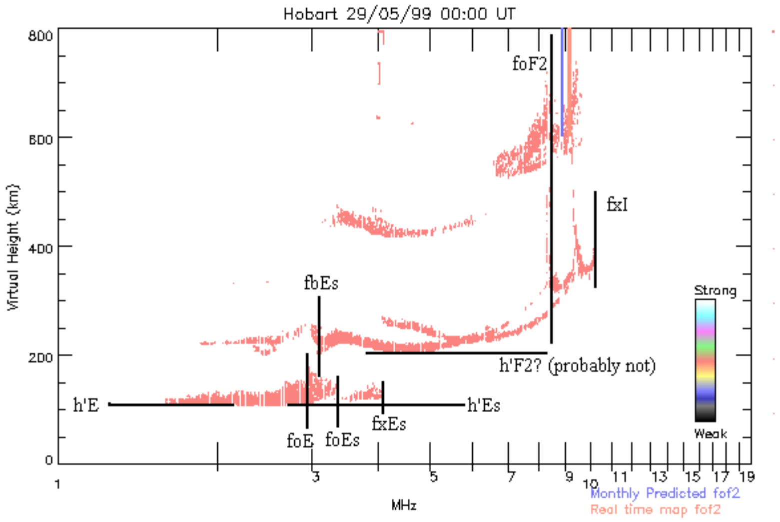


67

Another really good TID.

And also a good bit of other detail in the ionogram.

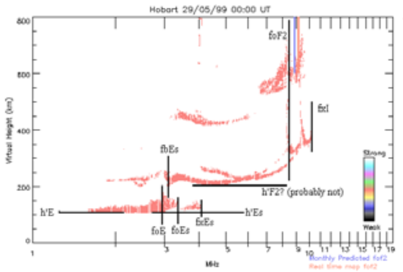
Sample Ionograms : daytime (Hobart 29/05/99 00 UT)



68

Sample Ionograms : daytime (Hobart 29/05/99 00 UT)

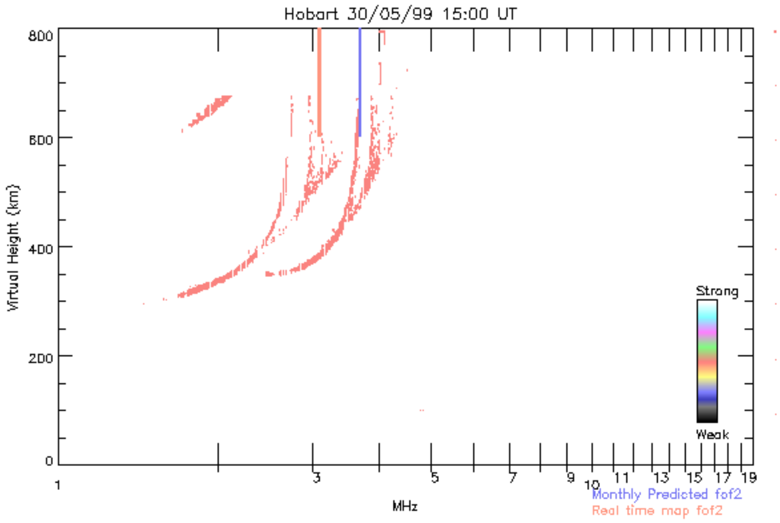
- Large TID & Spread Es - a disturbed ionogram
- E region
  - spread Es, but h'Es difficult to measure
  - foE: (00 . A) but sequence may give a value
- F1 present? Need a sequence
  - h'F (-- H)



- F2: major TID implies big gradients
  - normally scale the inside edge
  - the multiple offers some extra information (__ . H)

69

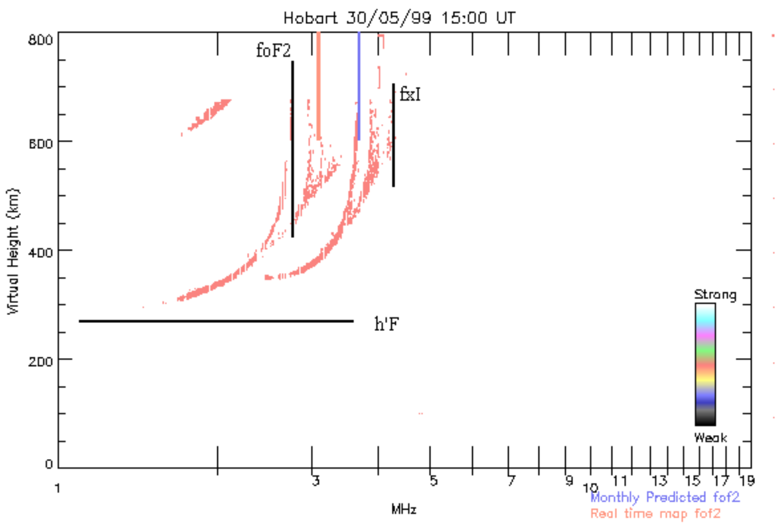
Sample Ionograms : nighttime
(Hobart 30/05/99 15 UT)



70

Now for some more nighttime ionograms showing more difficult behaviour.

Sample Ionograms : nighttime
(Hobart 30/05/99 15 UT)



71

The problems:

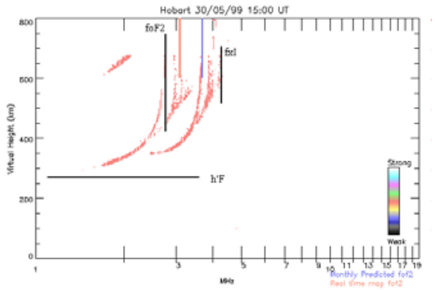
•is the overhead F layer trace correct? Continuity of traces makes it likely.

• Is the extrapolation of h'F correct? It may be a little high. This is a case where a range of extrapolated values will all look equally likely.

•What is the feature that fxI is scaled from? - a spur, or ridge of ionisation near the station.

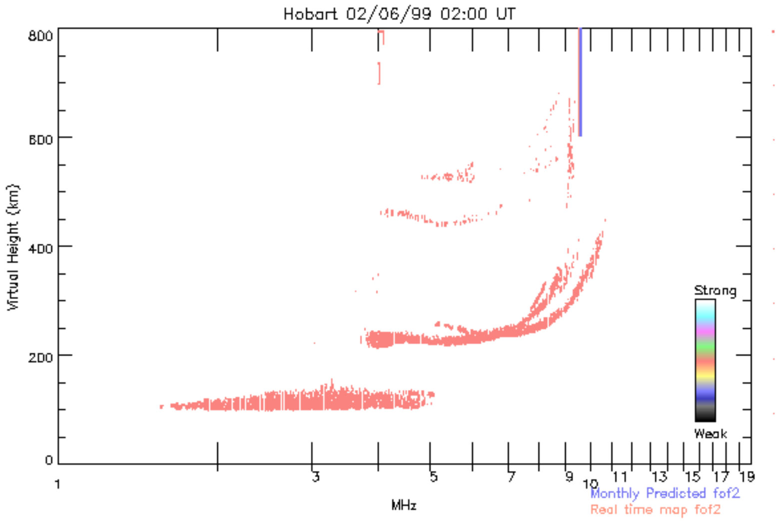
Sample Ionograms : nighttime
(Hobart 30/05/99 15 UT)

- A nighttime travelling ionospheric disturbance (TID)
  - Note fxI ≠ foF2 + split
- Need to estimate overhead trace carefully, but not much information in one ionogram.
- h’F : this requires considerable extrapolation
  - (__ US) or even (__ ES) if you are uncertain.



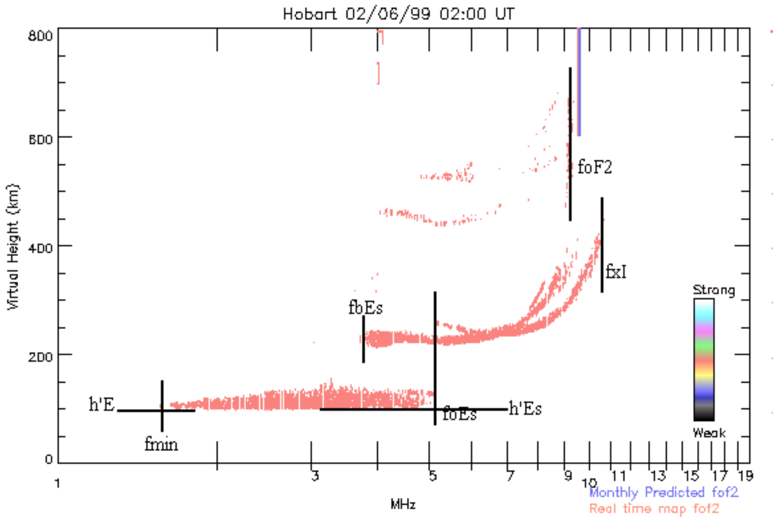
72

Sample Ionograms : daytime
(Hobart 02/06/99 02 UT)



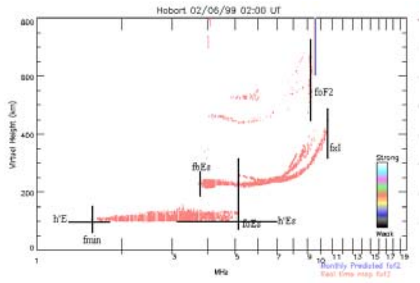
73

Sample Ionograms : daytime (Hobart 02/06/99 02 UT)



74

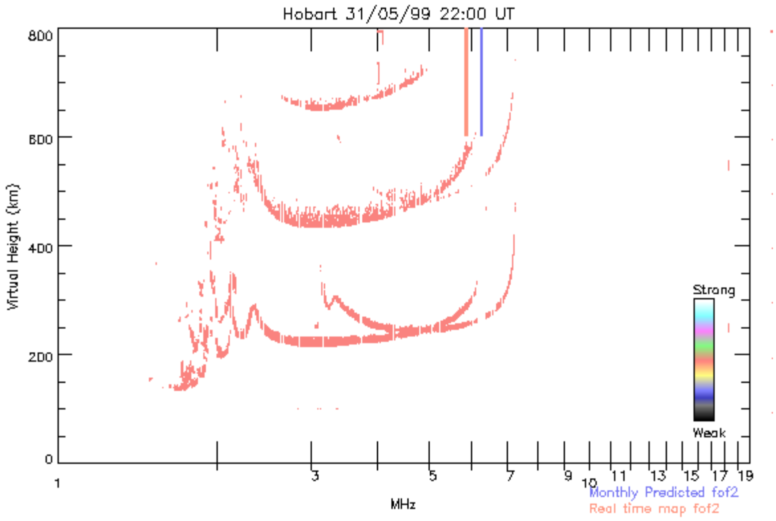
Sample Ionograms : daytime (Hobart 02/06/99 02 UT)



- foF2 - maybe wrong, multiple not consistent (__ .H)
  - or F if spreading is sufficient
- foE - can't be scaled from this ionogram,
  - maybe knowing foE would help
- Es is showing clear range spread
  - and fbEs may need a sequence to define it
- Probably no x-mode Es present,
  - although this is contentious, scale foEs (__ .F)
  - h'Es (__ . Q)
- fmin - accept weak trace; whole trace is weakening

75

Sample Ionograms : daytime (Hobart 31/05/99 22 UT)



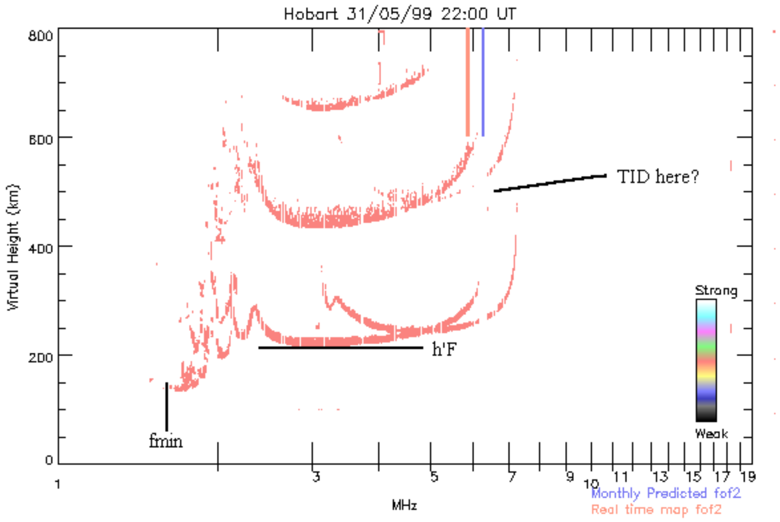
76

What is happening here? The E region is a mess –

or is it?

Have a good look and think about what is happening.

Sample Ionograms : daytime (Hobart 31/05/99 22 UT)

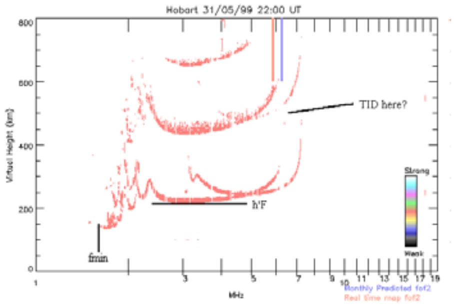


77

This is hard to resolve, so is it worth the effort?

It is if you want to feel confident scaling ionograms. However, without extra information, such a sequence of ionograms to confirm what is evolving in time, it is often too difficult to resolve a complex ionogram like this one into logical parts. Near dawn, many oblique and overhead traces can form and coalesce forming the E region.

Sample Ionograms : daytime (Hobart 31/05/99 22 UT)



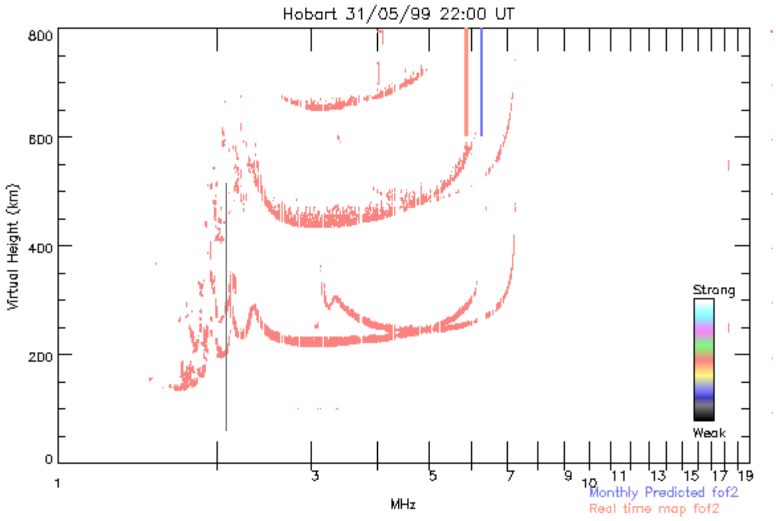
- Dawn: a time of awkward ionograms
- foF2 - small TID present; use H or not? Probably no.
- fmin - weak trace rule
- foE - you **NEED** a prediction for foE here
  - or a sequence
  - or experience from other similar days
  - foe = … H (in the absence of better information)
- Sporadic E, possibly, but probably not

78

In the absence of other information, it would be reasonable to scale no value here.

We aren’t saying there is a mystery, just that it is too complex for the available information to lead to an unambiguous definition.

Sample Ionograms : daytime
(Hobart 31/05/99 22 UT)

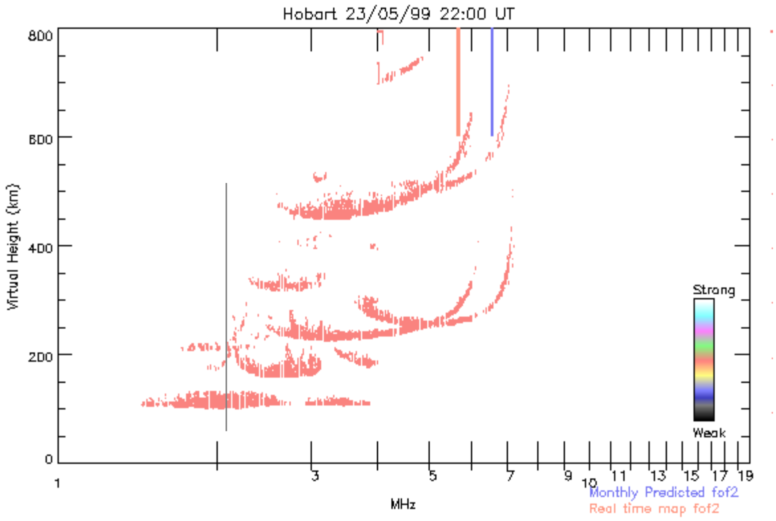


79

How will a sequence help?

A line has been drawn in on this ionogram corresponding to foE on the next ionogram.

Sample Ionograms : daytime (Hobart 23/05/99 22 UT)



80

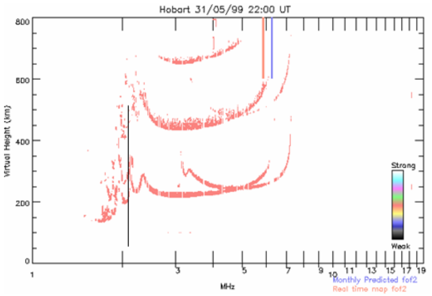
This is a few days earlier.

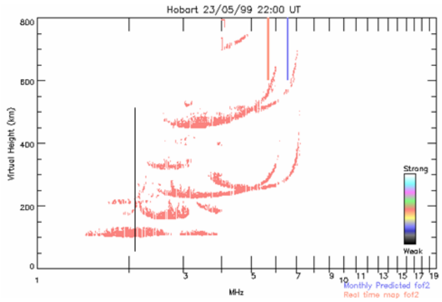
Here, even though there is sporadic E, it is likely we can see foE. In fact, there were a good many other examples of awkward and ambiguous ionograms from other days. This is often the case, and it is necessary to look through many examples to come up with one that will help clarify the target ionogram to be scaled.

Even here, there is some latitude for a slightly different interpretation, but this is a useful answer to the problem.

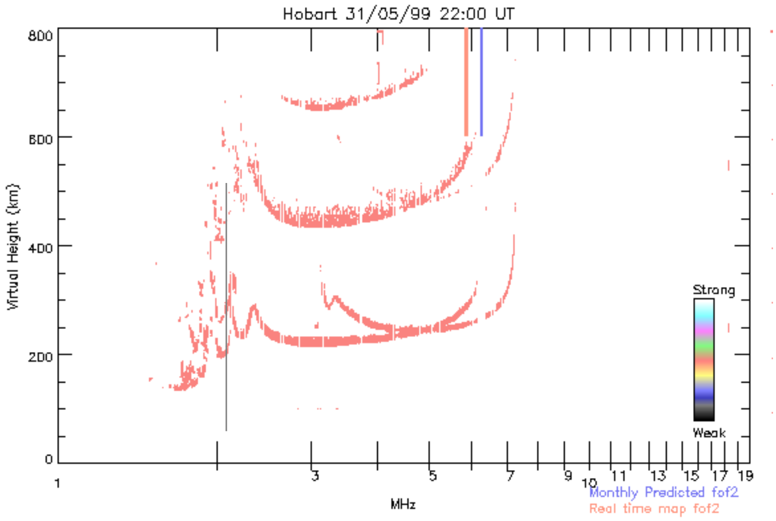
Sample Ionograms : daytime (Hobart 23/05/99 22 UT)

- Compare these two days
- Substantial development, but:
  - foE is clearer, isn't it? Still not easy.
  - foEs appears in second ionogram
  - layers look more like f0.5, or E2 in the former
  - Note multiples are disorganised; a dynamic change near dawn.





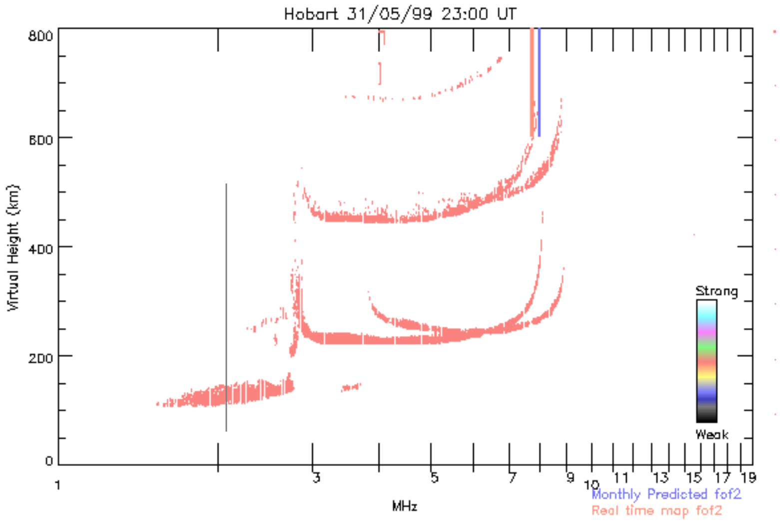
Sample Ionograms : daytime (Hobart 31/05/99 22 UT)



82

An alternative is to follow a sequence of ionograms. However, this is near dawn and the ionosphere is changing rapidly. That is why another day was sought instead.

Sample Ionograms : daytime (Hobart 31/05/99 23 UT)

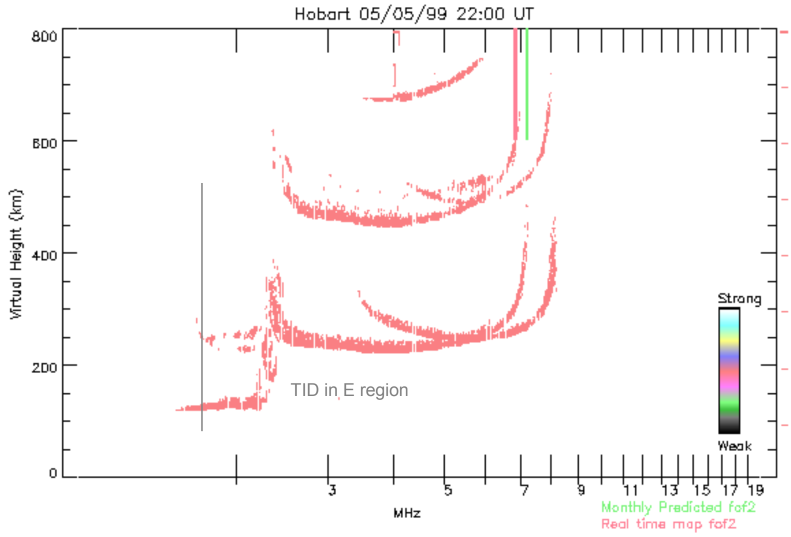


83

Here is the same day an hour later.

First, foE is clearly much higher, as the line shows. However, it also suggests that while the behaviour was unusual, it was not a permanent feature. It may be necessary to let complex examples like this slip by until you become more confident in your scaling.

Sample Ionograms : daytime (Hobart 05/05/99 22 UT)



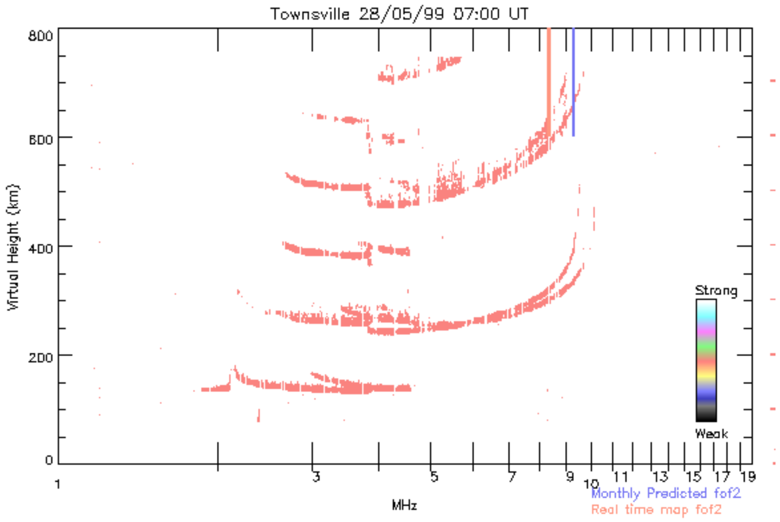
84

Much earlier in the month, structure was apparent in the E region, but less pronounced. Why?

Well, the logarithmic display affects this for a start.

Another point is that there appears to be a small TID present in the E region this time, so maybe the stratification is due to an entirely different process. Again, a sequence might resolve the issue.

Sample Ionograms : daytime (Townsville 28/05/99 07 UT)

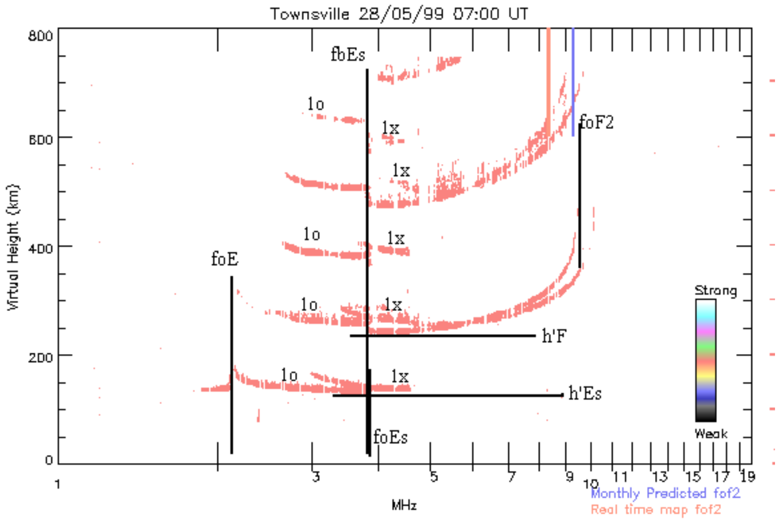


85

A classic ionogram showing a normal F region and a well developed sporadic E layer.

Both o & x-traces are present.

Sample Ionograms : daytime
(Townsville 28/05/99 07 UT)

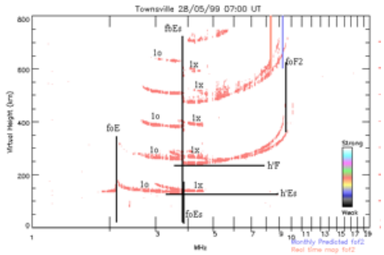


86

This labels all the bits observed.

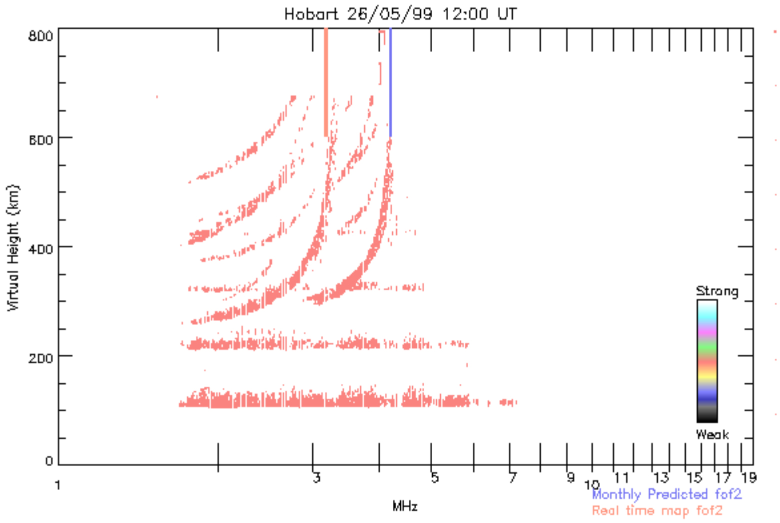
Sample Ionograms : daytime (Townsville 28/05/99 07 UT)

- Blanketing sporadic E can require much scaling skill
- Identify primary trace,
  - then O-mode and x-mode
  - then multiples of each
- Having disentangled all the extra information,
- scale foE
- Is it h’F? Use other days to know if foF1 is possible



87

Sample Ionograms : nighttime (Hobart 26/05/99 12 UT)

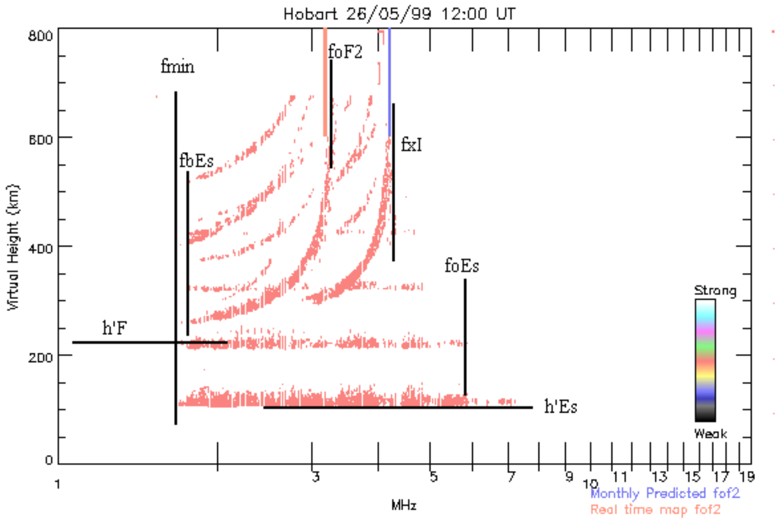


88

A similar example, lots of Es races overlaid on a normal, slightly spread F region.

Sort out all the traces.

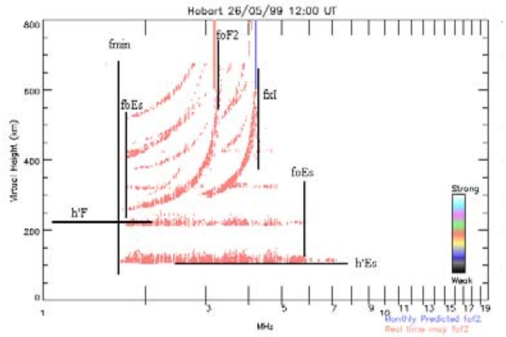
Sample Ionograms : nighttime
(Hobart 26/05/99 12 UT)



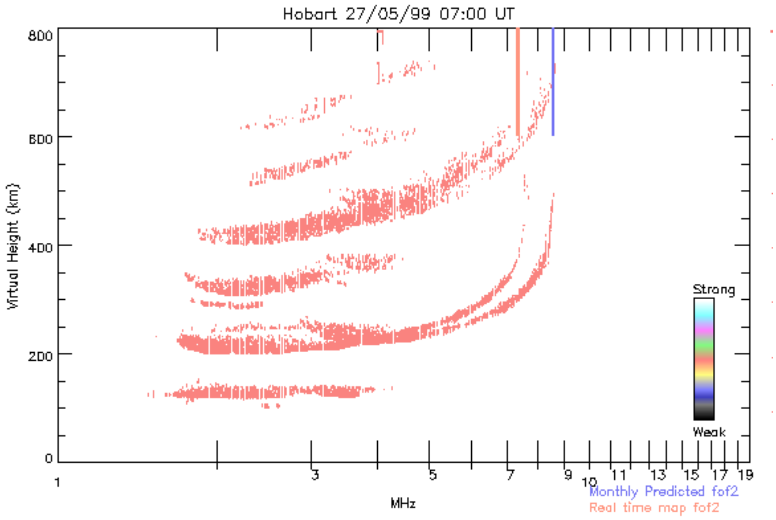
89

Sample Ionograms : nighttime
(Hobart 26/05/99 12 UT)

- E region
  - figure out where the multiples are
  - fbEs slightly higher than fmin
  - foEs = fxEs - split (note: weakened trace)
- F region
  - Is foF2 (__ . F)?
  - Either way,
    fxI = (__ . .); no X



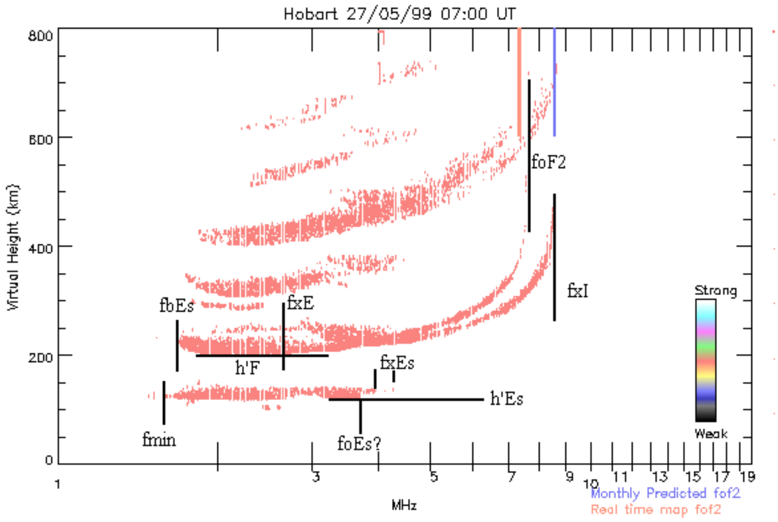
Sample Ionograms : nighttime (Hobart 27/05/99 07 UT)



91

A further example with Es overlaying a normal F region. Many multiples result. Untangle them and scale the parts of the ionogram that are important.

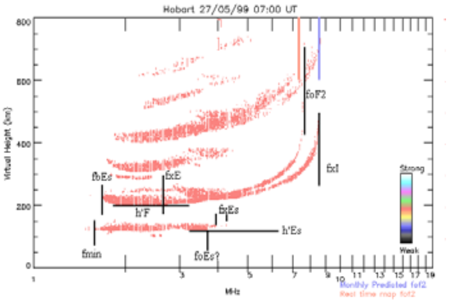
Sample Ionograms : nighttime (Hobart 27/05/99 07 UT)



92

The important point here is to recognise that x-trace F region extends below the top of the Es layer. So both traces are present in the Es layer.

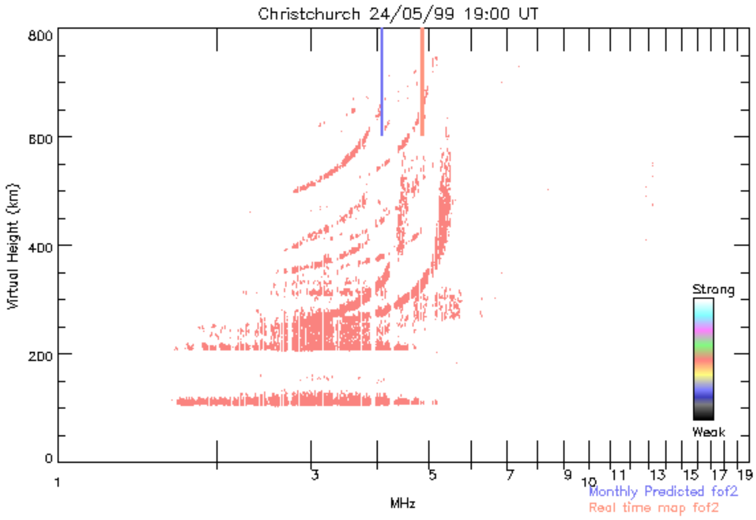
Sample Ionograms : nighttime (Hobart 27/05/99 07 UT)



- F region
  - straightforward
- E region
  - foEs: decide where fxEs is, and subtract split, or scale where the break in trace appears
  - fbEs is easier,
  - foE: (__ EB), since F trace shows retardation
  - h'E: (00 . S) replacement letter S
- fmin
  - follow the weak trace through here as no discontinuity

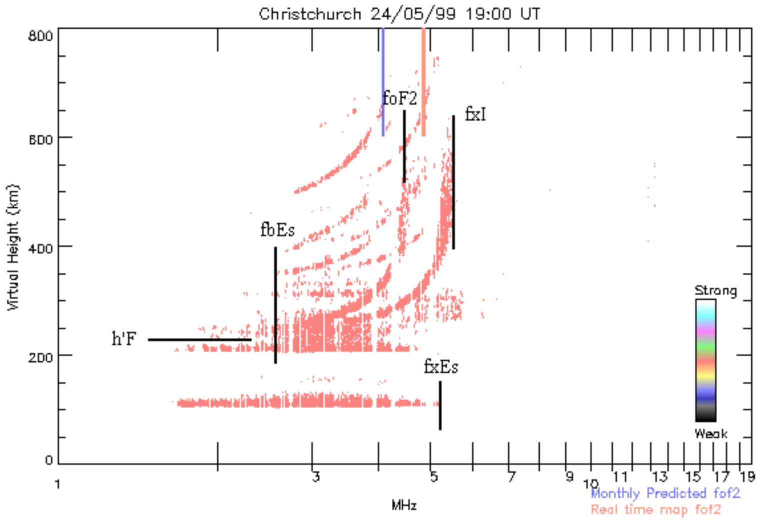
93

Sample Ionograms : daytime
(Christchurch 24/05/99 19 UT)



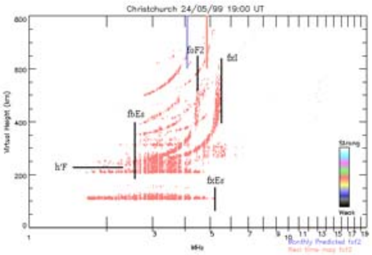
94

Sample Ionograms : daytime
(Christchurch 24/05/99 19 UT)



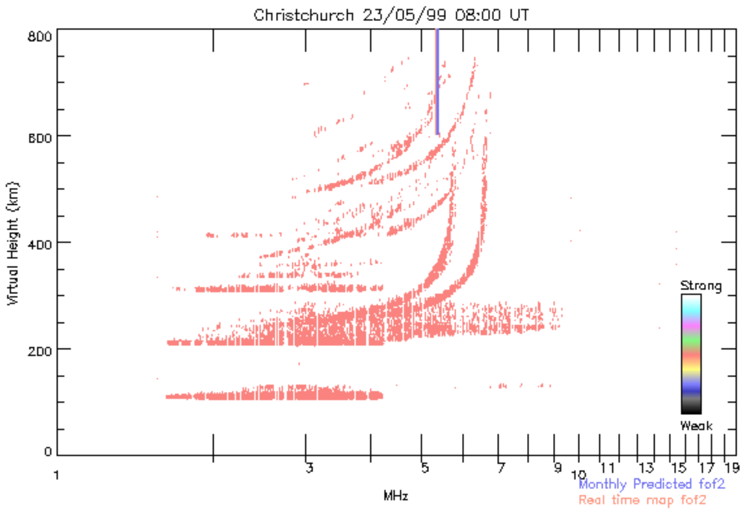
95

Sample Ionograms : daytime
(Christchurch 24/05/99 19 UT)



- F region
  - foF2 (__ . F)
  - h'F: possibly (__ . .),
    maybe (__ UA)
    It is reasonably clear where it tends to.
- E region
  - Identify, and ignore oblique traces
  - foE required? Know the time.
  - foEs = fxEs - split (__ JA) Let program do it

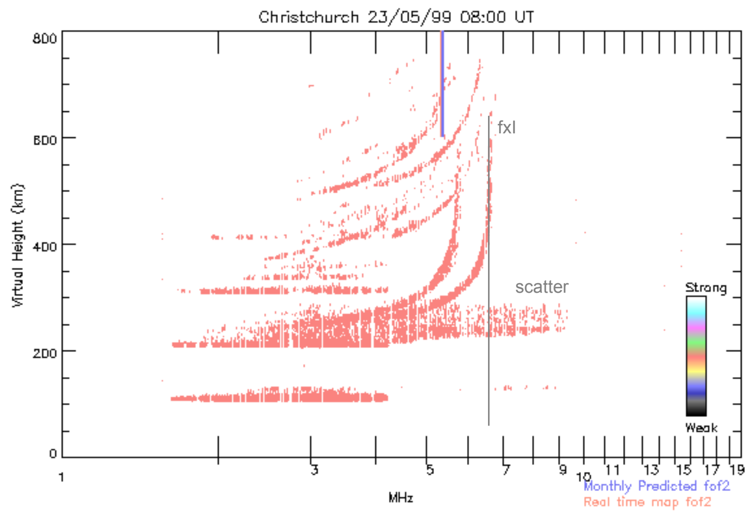
Sample Ionograms : daytime (Christchurch 23/05/99 08 UT)



97

What is fxI?

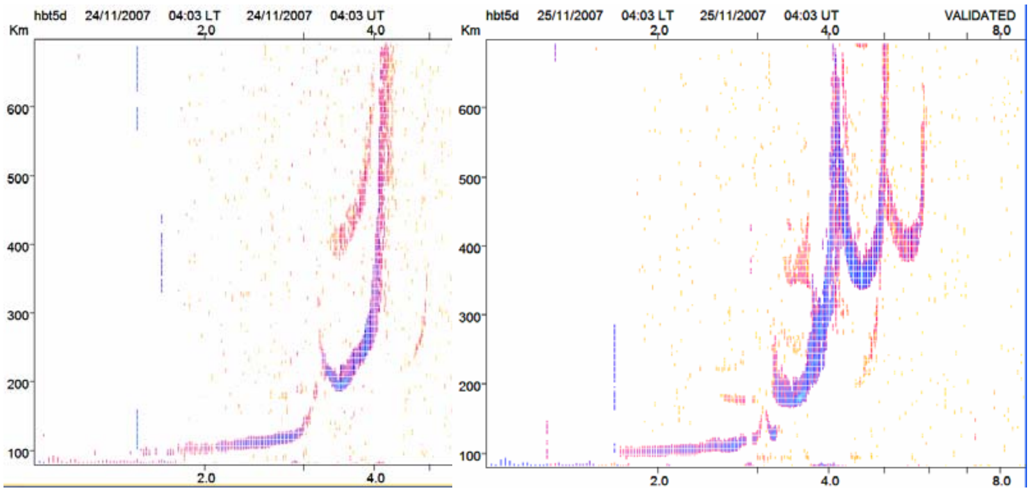
Sample Ionograms : daytime
(Christchurch 23/05/99 08 UT)



98

Clearly there is ground scatter present and it should be ignored in scaling fxI and the Es parameters. Why? Because it is due to a gradient and is therefore not an overhead return.

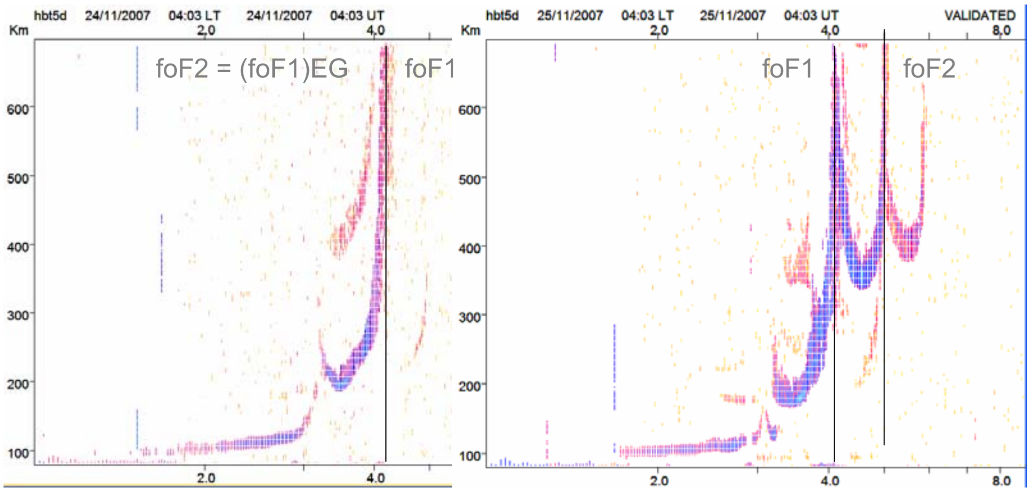
G condition



99

On 24 November 2007 the F-region ionisation is rather low. By comparing with the next day (25 November) it is apparent that on the 24th the F region ionisation is more like the F1 region the next day. This is correct. What happens is that the storm processes are dynamic and the resulting mixing causes the recombination rate in the upper F region to be sufficiently large that the peak ionisation drops below that of the F1 region.

G condition



100

The correct scaling for foF2 is shown in both cases: when foF2 is not visible (the G condition) and when it is visible.

The easiest way to decide if this is happening is to compare adjacent days. However, at some sites this will fail (Hobart, for instance, where the depressed storm conditions can persist for several days). A safer method is to know where foF1 is expected so that when no ionisation is seen above this level you will be fairly certain this is a storm condition.

G condition = storm condition

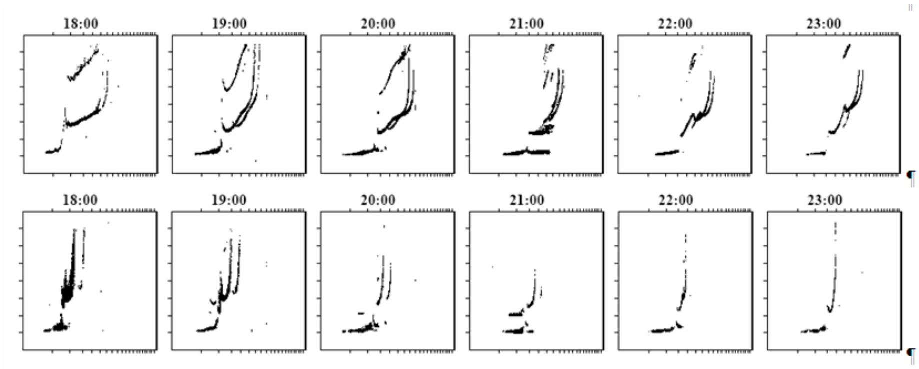
- A *G condition* occurs during a storm
  - When the F2 ionisation falls below the F1
  - foF2 < foF1
- The amount of ionisation in the F2 region is less than in the F1 region.
- This occurs due to extreme storm dynamics.
- A G-condition is a clear signal about a large storm.
- The correct scaling for foF2 is:
  - foF2 = (foF1) EG

When detected, the correct scaling for foF2 is (foF1)EG.

This means that no foF1 region was observervered, so the best estimate of foF2 is < foF1 (E = less than) because the underlying layer ionisation (F1 region in this case) is too great.

G condition:
Christchurch November 2001 Storm

23 November 2001

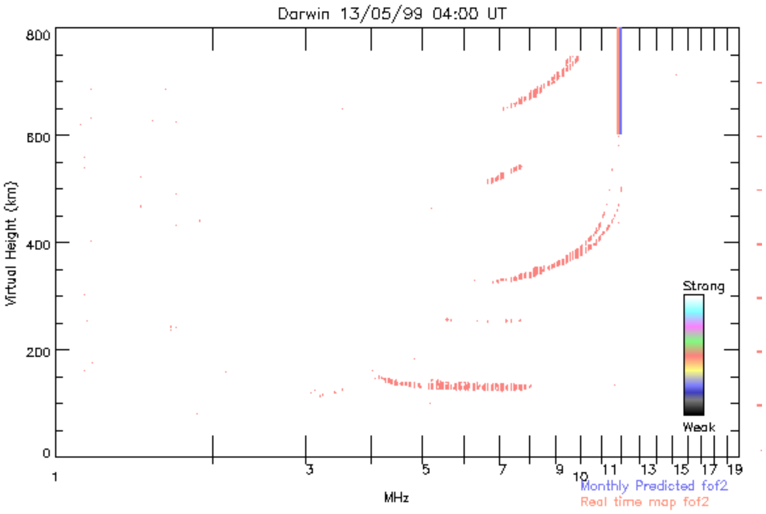


24 November 2001

102

Here a sequence in time is shown for two successive days. The F1 region is poorly defined, but there is still a clear difference between the two days. On the 21st the storm has depressed F2 ionisation significantly.

Sample Ionograms : daytime
(Darwin 13/05/99 04 UT)

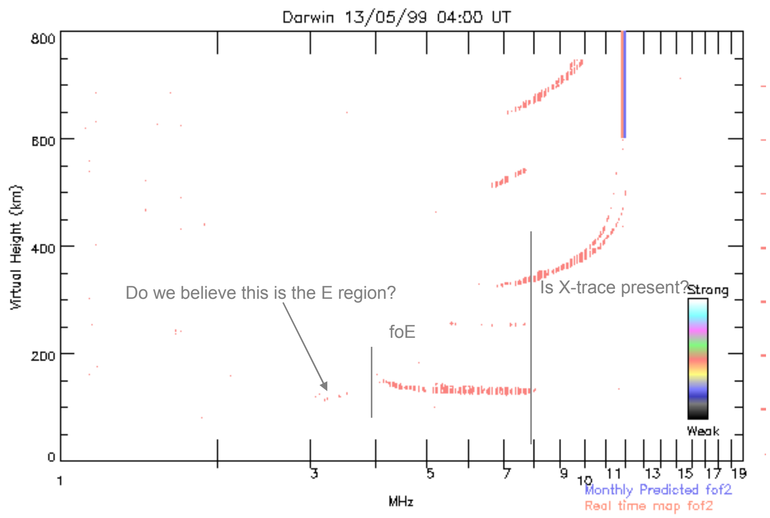


103

This is a weak return. It could be a fadeout, but more likely the ionosonde is not operating as well as it might.

How do we scale it?

Sample Ionograms : daytime
(Darwin 13/05/99 04 UT)



104

The way we scale this depends on what weight we give to these rather weak traces seen here. If we feel these are part of the ionogram, then fmin is down in the E region. In fact, that is how we would have to interpret this, in which case all similar spots would need to be interpreted the same way. The task is then very difficult, and rather slow.

This is a good case for reviewing the site equipment and maybe seeking ways to improve the gain of the system. Ideally, get right first time, when the site is established. For instance, for a low latitude site, since there is little you can do to increase the gain of the ionosonde, you will probably need to look at the antenna system for some extra gain.

Accuracy

- Feel confident about your interpretation
- Use accuracy rules to communicate your confidence
- Estimate of accuracy:
  - no scaling letters; within 5% (__ ..)
  - descriptive letter; possible errors (__ .#)
  - qualifying letter U; 4 to 10% accurate (__ U#)
  - qualifying letters E&D; within 20% (__ E/D #)
  - replacement letter; over 20% uncertainty (0 . #)
- As many values as possible should be scaled.

105

So far, we have mainly concentrated on scaling and accuracy has been mentioned more as an aside. That was deliberate. The main source of errors in interpreting ionograms are due to subjective errors of judgement about what to scale. If we can be consistent in our subjective judgements, then the scaling accuracy will be higher.

There is still a regime of accuracy for qualifying the observations we obtain. These are summarised above. The idea is to scale as many ionograms as possible as consistently as possible.

Estimating parameters

- Frequency
  - use x-mode to infer o-mode, (__ J #)
  - use o-mode to infer x-mode, (__ O #)
  - use z-mode to infer another mode (__ Z #)
  - All these imply an unknown, possible error
- Heights
  - h’z < h’o < h’x
  - with experience, you can estimate h’o

106

On occasions, we estimate parameters using other magnetoionic components (O, X and Z traces). When this is done, we may introduce an unknown error, which is why this situation is flagged with a special code. In fact, it will usually seem we have scaled an accurate value, yet we still apply the qualification.

There is an exception; when the other magnetoionic components are used to better define the ordinary component (or fxI) then no qualifier is needed.

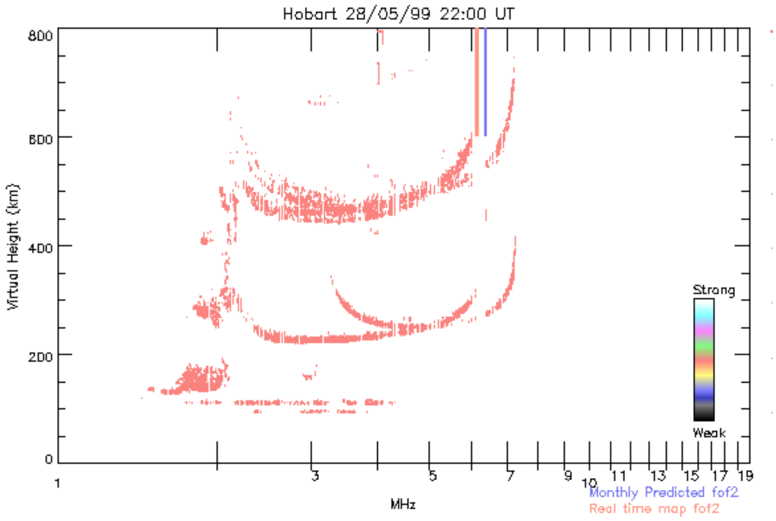
Flags

- F : spread F, spread exceeds 0.2 MHz
- k type Es : particle E present
- l type Es : fmin is scaled from low type Es layer
- L : mixed range and frequency spread (unusual)
- P : fxI measured from oblique, or unusual spur
- Q : range spread, spread exceeds 30 km
- X : no spread present in F region
- Z : Z-mode present in layer
- Disturbances : R, V, H, Y usually used on parameters

107

Finally, IPS introduced a number of flags. These are implicit in the conventional rules, but poorly spelled out so that ambiguous interpretations are possible, undermining the value of the flags.

Sample Ionograms : daytime (Hobart 28/05/99 22 UT)

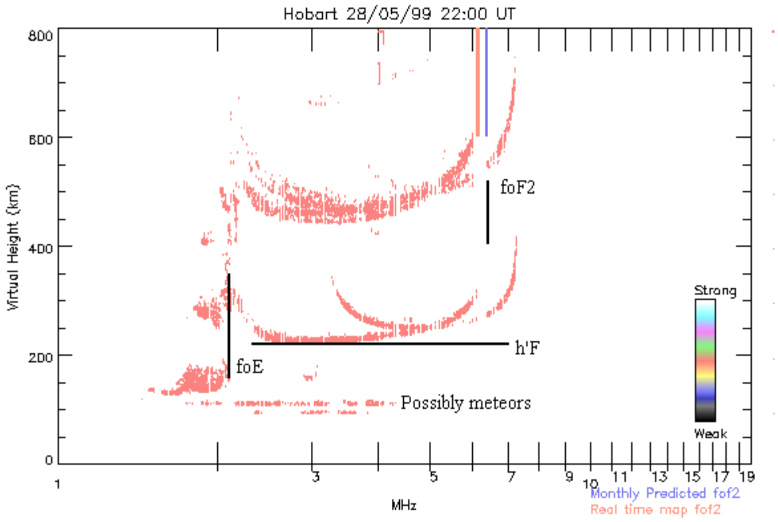


108

What is different here.

These are some exotic returns to end with.

Sample Ionograms : daytime (Hobart 28/05/99 22 UT)

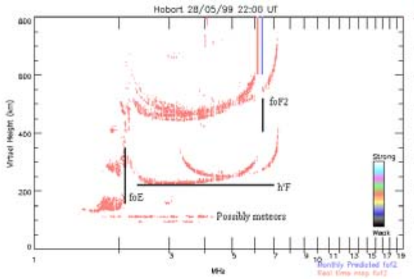


109

Meteors can be seen on most ionosondes. However, it depends on the time it takes to make an ionogram and the system sensitivity.

As a general rule, meteors often are not connected to the main traces, they almost always appear in the E region, sometimes higher up than normal Es, the traces are generally broken (due to fading), they rarely appear on adjacent ionograms (even when sampling is made every minute), they are most often seen in the early morning hours near E layer sunrise and on rare occasions during major meteor showers.

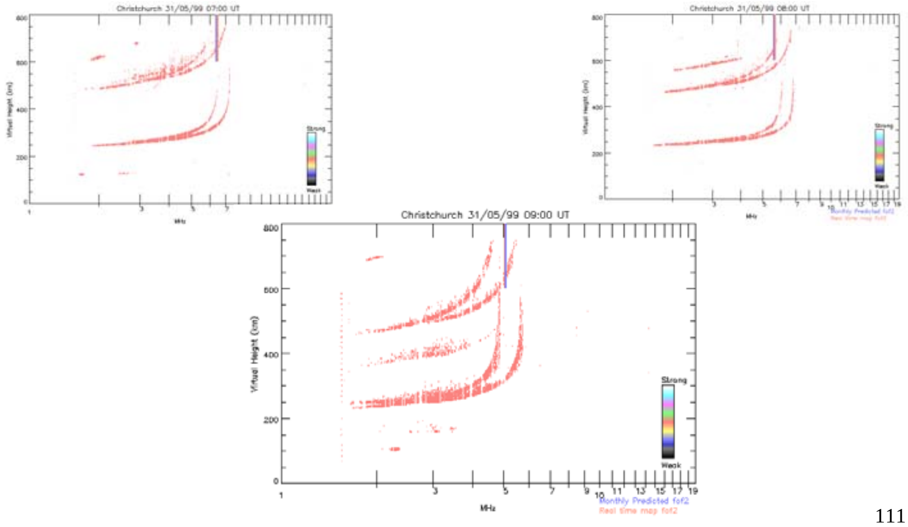
Sample Ionograms : daytime (Hobart 28/05/99 22 UT)



- F region
  - very easy
- E region
  - foE: looks spread, but fxE isn’t? (__ . H)
  - foEs: possible meteor traces. Right characteristics. Check the sequence.

110

Oblique sporadic E or ?



111

Well, we think it’s another ionosonde, don’t we.