Scaling Ionograms

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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
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
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
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
  - bumps; H, V
  - things; F, K, P, Q, X, Z
- Flags
  - which are more objective things.
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.
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
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.
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; fxl is too.
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
- fxl - interference
Sample Ionograms: nighttime
(Chch 31/05/99 12 UT)
Sample Ionograms: nighttime
(Chch 31/05/99 12 UT)
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.
Sample Ionograms : nighttime
(Chch 31/05/99 17 UT)
Sample Ionograms: nighttime
(Chch 31/05/99 17 UT)
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 (__ . F)
    - fxl - 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!
Sample Ionograms: nighttime
(Hobart 31/05/99 11 UT)
Sample Ionograms: nighttime
(Hobart 31/05/99 11 UT)
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)
  - f0F2
    - Clearly spread F is present, scale inside edge (___F)
      - but did you recognise the Z-trace?
    - fxl - scale outside edge of the spread F.
  - h’F, extrapolate down, maybe (___US)

- Note:
  - multiple is spread less
  - You can get a good f0F2 value from the Z-trace

You ought to be able to scale these better than autoscale did!
Sample Ionograms: nighttime
(Townsville 31/05/99 16 UT)
Sample Ionograms: nighttime
(Townsville 31/05/99 16 UT)

- What can we say?
  - Clear f\text{min} (\_ES)
  - no Es parameters
  - foF2
    - Clearly spread F is present, scale inside edge (\_UF)
    - fxI - scale outside edge
  - h’F, extrapolate down, \textit{maybe} (\_US)

- Note:
  - More spread
  - but multiple gives some guidance
  - multiple has \textit{odd} shape
Sample Ionograms: nighttime
(Townsville 31/05/99 17 UT)
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
Sample Ionograms: nighttime
(Christchurch 30/05/99 19 UT)
Sample Ionograms: nighttime
(Christchurch 30/05/99 19 UT)
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
- F/S = 3P
Sample Ionograms: nighttime
(Townsville 30/05/99 14 UT)
Sample Ionograms: nighttime
(Townsville 30/05/99 14 UT)
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 (___US).
  – 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)
And now for something completely different

Daytime
Sample Ionograms: daytime
(Christchurch 31/05/99 03 UT)
Sample Ionograms: daytime
(Christchurch 31/05/99 03 UT)
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 okay
• 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)
Sample Ionograms: daytime
(Townsville 31/05/99 00 UT)
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
Sample Ionograms: daytime
(Hobart 23/05/99 23 UT)
Sample Ionograms: daytime
(Hobart 23/05/99 23 UT)
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
Sample Ionograms: daytime
(Townsville 29/05/99 05 UT)
Sample Ionograms: daytime
(Townsville 29/05/99 05 UT)

- $F_{\text{min}}$? Weak trace rule
- $f_oF2$: easy, autoscale agrees
- $h'F2$: poorly formed F1, none there
- $h'F$: (___ U A) or (___ UH) or (___) ??
- $f_oEs$? How many Es traces and which
- $f_oE$?
Sample Ionograms: daytime
(Townsville 29/05/99 05 UT)
Sample Ionograms: daytime (Townsville 29/05/99 05 UT)
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
• foE: using c, h Es layers, foe = good value
Sample Ionograms: daytime
(Mundaring 02/06/99 02 UT)
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.
Sample Ionograms: daytime
(Christchurch 31/05/99 03 UT)
Sample Ionograms: daytime
(Christchurch 24/05/99 23 UT)
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
  - \( f_{min} \) - weak trace rule needed?
  - \( f_{oE} \) - extrapolation, probably \( (\_\_UA) \)
    - (and maybe scaled even higher than here)
  - \( h’Es \) - extrapolation \( (\_\_UG) \)
Sample Ionograms: daytime (Hobart 26/05/99 00 UT)
Sample Ionograms: daytime
(Hobart 26/05/99 00 UT)
Sample Ionograms: daytime
(Hobart 26/05/99 23 UT)

- E region
  - spread Es well developed
  - $fxE_s \neq f_{oE_s} + \text{split}$ (spread Es is signal strength dependent)
  - $f_{bE_s}$ 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
    - $f_{oF_2}$: (___ . $V$) although (___ . H) is just as good
  - $fxI$ will have descriptive letter X; no spread.
Sample Ionograms: daytime (Christchurch 23/05/99 00 UT)
Sample Ionograms: daytime
(Christchurch 23/05/99 00 UT)
Sample Ionograms: daytime
(Christchurch 23/05/99 23 UT)

- One day earlier
  - 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)
Sample Ionograms: daytime
(Hobart 29/05/99 00 UT)
Sample Ionograms: daytime
(Hobart 29/05/99 00 UT)
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)
Sample Ionograms: nighttime
(Hobart 30/05/99 15 UT)
Sample Ionograms: nighttime
(Hobart 30/05/99 15 UT)
Sample Ionograms: nighttime
(Hobart 30/05/99 15 UT)

- A nighttime travelling ionospheric disturbance (TID)
  - Note fxl $\neq$ foF2 + split
- Need to estimate overhead trace carefully, but not much information in one ionogram.
- h’F: this requires considerable extrapolation
  - ( __ UF ) or even ( __ EF ) if you are uncertain.
Sample Ionograms: daytime
(Hobart 02/06/99 02 UT)
Sample Ionograms: daytime (Hobart 02/06/99 02 UT)
Sample Ionograms: daytime
(Hobart 02/06/99 02 UT)

• \( \text{foF}_2 \) - maybe wrong, multiple not consistent ( __ .H )
  – or F if spreading is sufficient
• \( \text{foE} \) - can’t be scaled from this ionogram,
  – maybe knowing \( \text{foE} \) would help
• \( \text{Es} \) is showing clear range spread
  – and \( \text{fbEs} \) may need a sequence to define it
• Probably no x-mode \( \text{Es} \) present,
  – although this is contentious, scale \( \text{foEs} \) ( __ .F )
  – \( \text{h’Es} \) ( __ . Q )
• \( \text{fmin} \) - accept weak trace; whole trace is weakening
Sample Ionograms: daytime
(Hobart 31/05/99 22 UT)
Sample Ionograms: daytime
(Hobart 31/05/99 22 UT)
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
• Sporadic E, possibly, but probably not
Sample Ionograms: daytime
(Hobart 31/05/99 22 UT)
Sample Ionograms: daytime
(Hobart 23/05/99 22 UT)
Sample Ionograms: daytime
(Hobart 23/05/99 22 UT)

• Compare these two days
• Substantial development, but:
  – $f_0E$ is clearer, isn’t it? Still not easy.
  – $f_0Es$ appears in second ionogram
  – layers look more like $f_0.5$, or $E2$ in the former
  – Note multiples are disorganised; a dynamic change near dawn.
Sample Ionograms: daytime
(Townsville 28/05/99 07 UT)
Sample Ionograms: daytime
(Townsville 28/05/99 07 UT)
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
Sample Ionograms: nighttime
(Hobart 26/05/99 12 UT)
Sample Ionograms: nighttime
(Hobart 26/05/99 12 UT)
Sample Ionograms: nighttime
(Hobart 26/05/99 12 UT)

• E region
  – figure out where the multiples are
  – \( f_{bE} \) slightly higher than \( f_{\text{min}} \)
  – \( f_{oE} = f_{xE} - \) split (note: weakened trace)

• F region
  – Is \( f_{oF2} \) (___ . F)?
  – Either way, \( f_{xl} = (___ . . ) \); no X
Sample Ionograms : nighttime  
(Hobart 27/05/99 07 UT)
Sample Ionograms: nighttime
(Hobart 27/05/99 07 UT)
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
Sample Ionograms: daytime
(Christchurch 24/05/99 19 UT)
Sample Ionograms: daytime
(Christchurch 24/05/99 19 UT)
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
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.
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
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**: fxl 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
Sample Ionograms: daytime
(Hobart 28/05/99 22 UT)
Sample Ionograms: daytime
(Hobart 28/05/99 22 UT)
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.
Oblique sporadic E or ?