Australian Government
Department of Defence
Science and Technology

A description of A new model of Sporadic E

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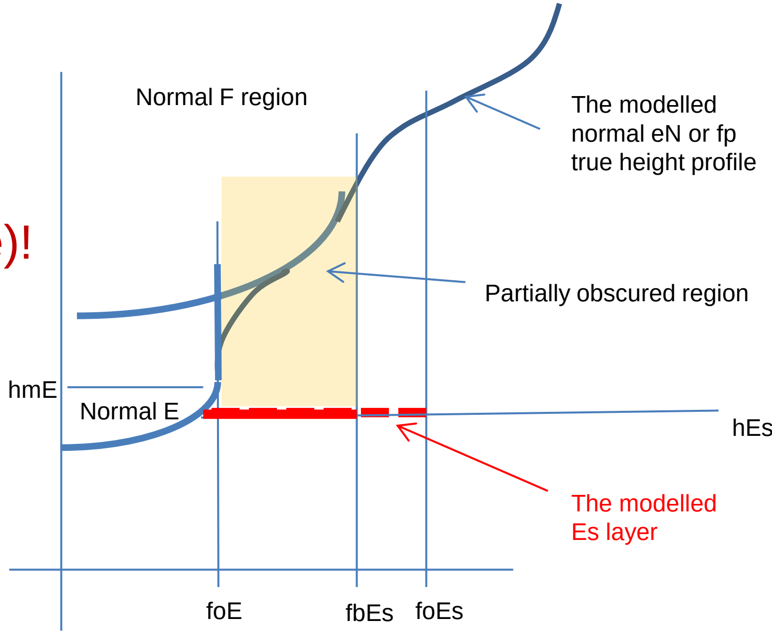
1. Brief background of Es
2. The model of height (hEs)
3. The model of amplitude/strength(foEs)
4. Summary and conclusion

(Brief) Background of Sporadic E

1. “Thin” layer of free electrons (<1km thick)
   At E region heights AND intense BUT
   observed to be Sporadic (a modelling nightmare)!
2. Observed with ionospheric sounders
   delay & freq (VIS & OIS & BSS)
3. Observed in-situ rockets & IS Radar
4. Inferred from Limb GPS sTEC (quality?)
5. Highly variable in Space and Time BUT
   Some well established patterns ie
   Height (hEs) descending and associated with diurnal/semidiurnal TIDES
   Amplitude (foEs) seasonal cycle stronger in summer (weakest in equinox)
   ref Haldoupis (2012)

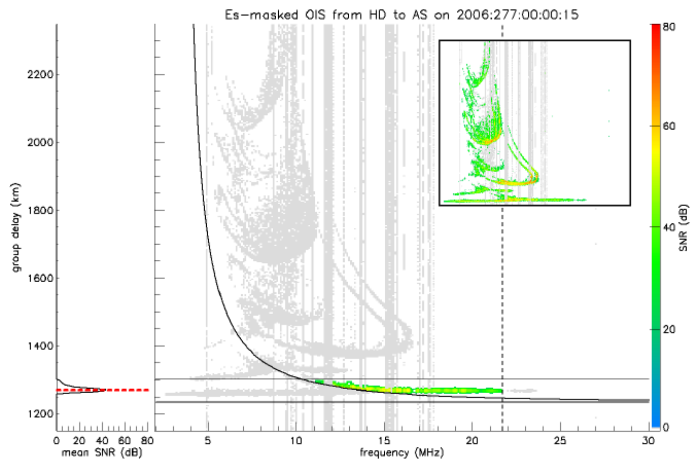


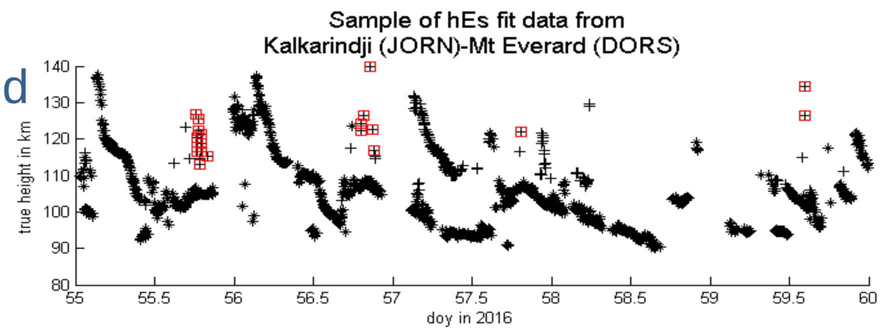
(Brief) Background of Sporadic E

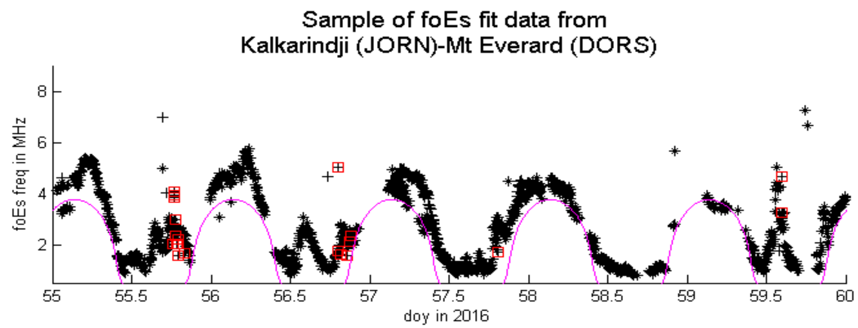
A lot has changed in the last 10-20 years

1 Understanding of Es physics has improved

2 Sounders have got a lot better







3 Automatic Sounder Processing has got a lot better

4 Large Networks of good quality sounders (37 + routine sites) have become available

{Es from Limb GPS has value but isn't precise enough (in hEs &foEs) for our purposes}

So what can we do with all this real time sounder data?

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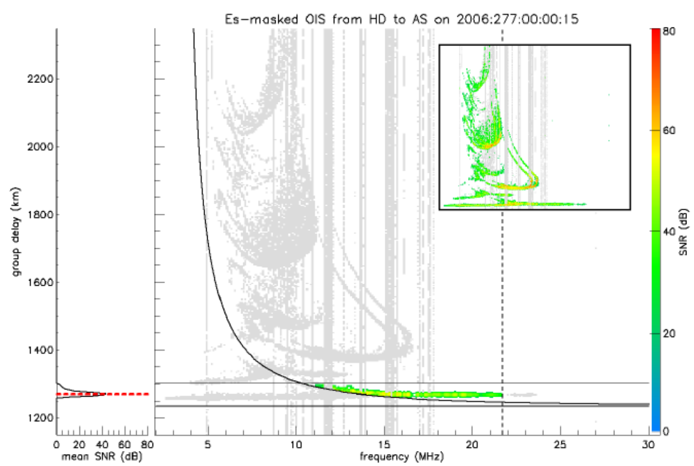

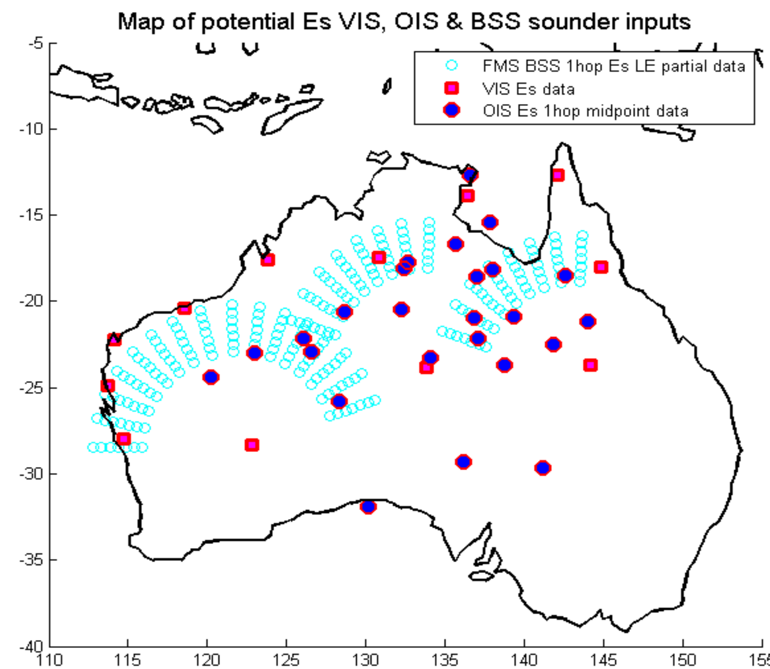

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So what can we do with all this real time sounder data?

Modelling hEs (height and delay)(1)

So what can we do with all this real time hEs data?

First we observe that hEs isn't very sporadic rather

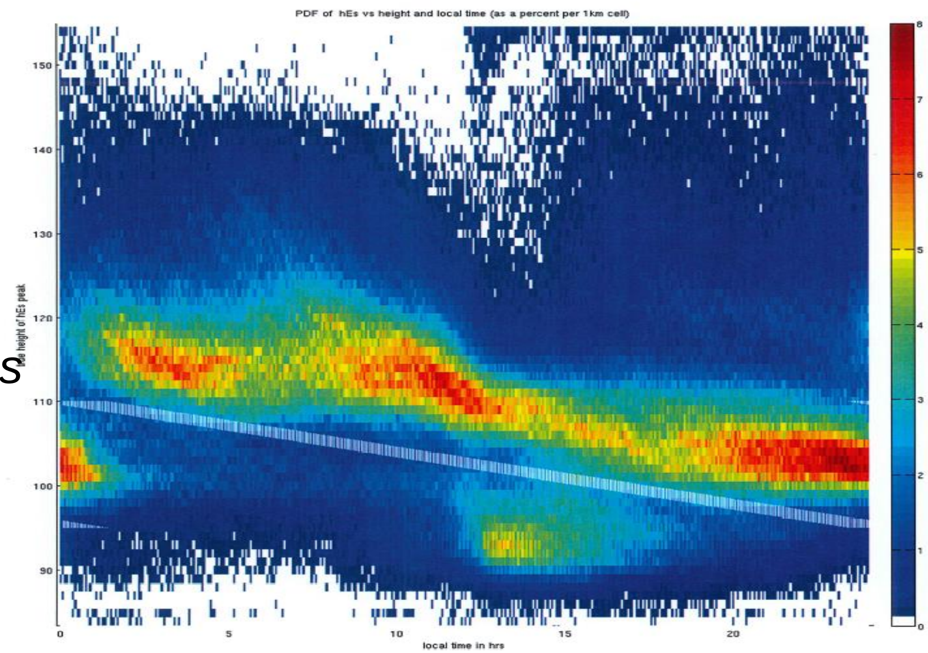
its sometimes just a bit complicated ie sometimes there are more than one layer

eg {Conceptually a dominant descending Tidal ion layer and in addition

a lower residual Es layer ,

see Mathews,1998) }

An area and day averaged pdf for hEs presented as number density verse height and local time of day.
This is based on all measurements of hEs over (2016).
Over-plotted (the white lines) are the positions of the model hEs-separator between high and low Es (low occurrence minima)



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eg {Conceptually a dominant descending Tidal ion layer and in addition

a lower residual Es layer (left over from past/patchy Es activity, see Mathews,1998) }

We can use the accumulation of data in local time to create a common

high low separator curve AND separately in real time

estimate mean 2 height of high Es (TILs) above separator AND

estimate mean 1 height of low Es data (res Es) below separator AND

estimate mean 0 height of all Es data (for when high/low separation isn't a good model)

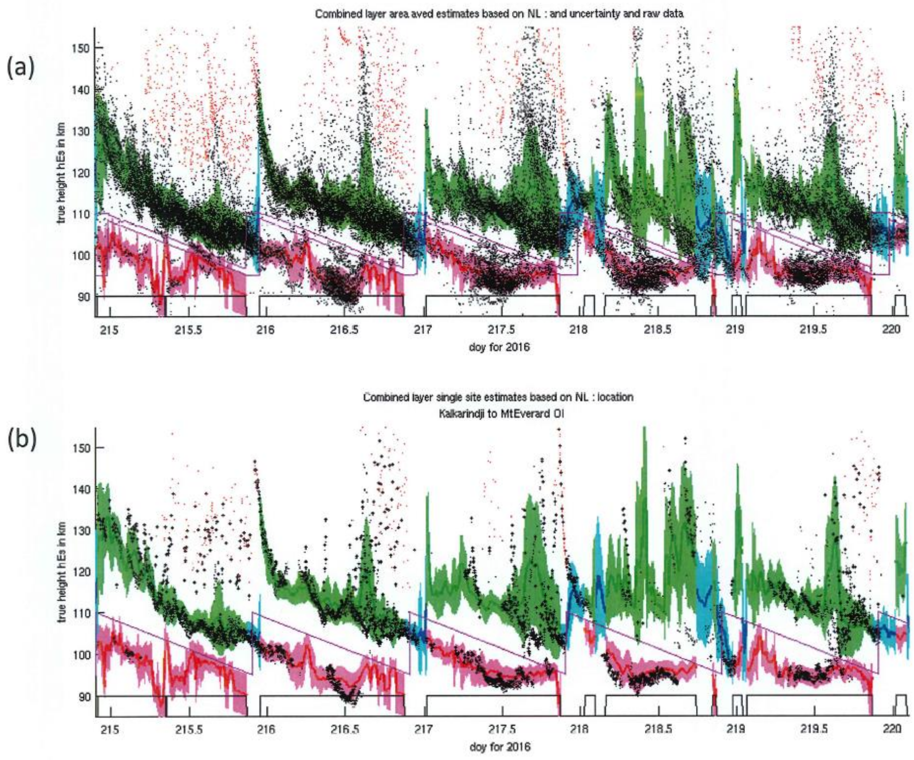
Modelling hEs (height and delay)(2)

Second, we create a criteria for when

two distinctly separate layers have been observed (nL =2)

Or if the data is inseparable (nL = 1) Criteria based on hes2- σhEs2 & hes1 +σhEs1

(a) Area average hEs +-1sigma high (green) and low (red) and common(blue) estimate and group of hEs samples
(b) Similar hEs+-1sigma
Centred on a single site (Kal-Mt Everard OI)



Third, we create an estimate for hEs

derived from mean & std from nearby data

(and relaxed toward spatial ave when

enough data isn't available)

Modelling hEs (height and delay)(3)

So what can we do with all this real time data?

Build a reliable data driven model of hEs (nL =1 or nL =2 part of the estimation process)

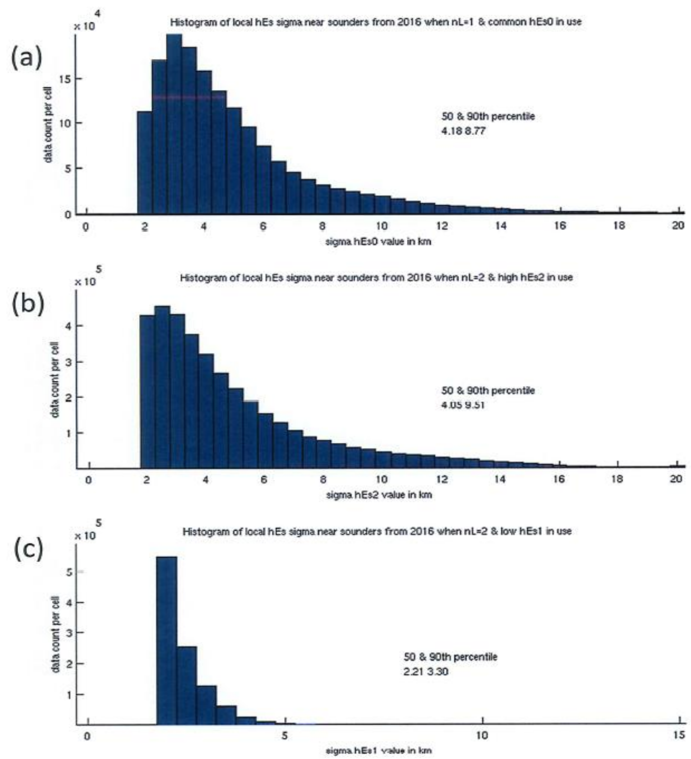
Varying in space and time, where the residual uncertainty

between the model and the data is (eg over a year, 2016) typically quite small …

Histogram of hEs std
All data all sites 2016
(a) hEs0 (50-90p = ***4&9****km)*

(b) hEs2(50-90p = ***4&9****km)*

(c) hEs1(50-90p = ***2&3****km)*



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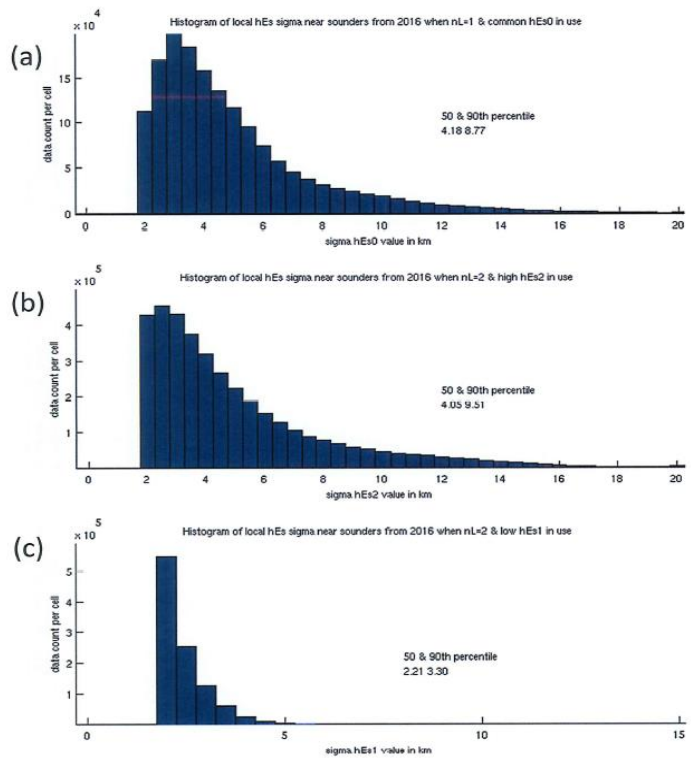


Oblique delay at any time and frequency is subsequently derived by assuming Es propagation is a mirror and combining this (when appropriate) with the excess delay of propagating through part of the normal E layer on the way to the Es path apogee!

Modelling foEs (1)
(the amplitude of eN in Es layer or the HF freq reflected)

So what can we do with all this real time foEs data?

First, we observe sometimes that foEs is not so much sporadic as just misunderstood!

(sometimes Es unobserved by our sounders ie missing foEs measurement is not zero foEs but foEs unobserved below some measurement threshold, fB , see ISR measurements)

Secondly, we observe that the best way to model (represent) foEs is not as a single deterministic value but as a set of stable and smooth parameters describing its statistical spread of values

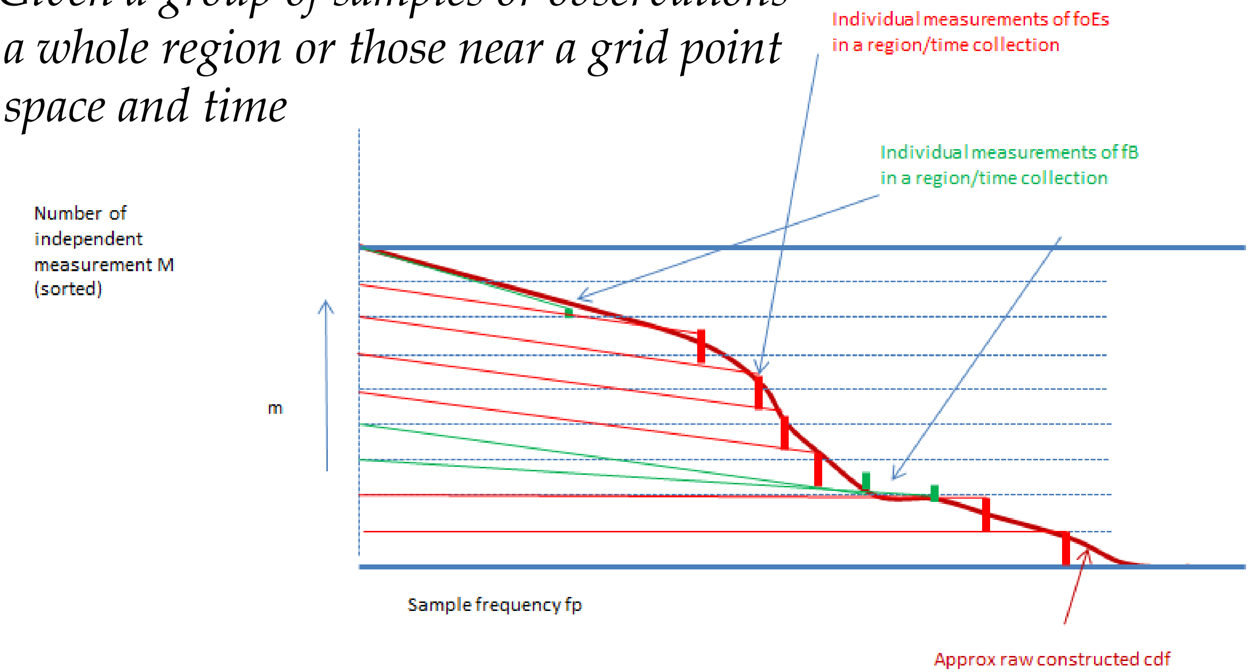
(ie idea of its cloudiness suggests modelling the probability distribution shape not single values!)

An example of the cumulative distribution function of pfoEs vs freq for a set of measurements is

Modelling foEs (2)

(a cdf for foEs, fp90, fp50 & fp10 ie freq where <10% of observations are greater and 90% are below)

Given a group of samples or observations eg a whole region or those near a grid point In space and time



A conceptual schematic of multiple sounder measurements producing a cdf of foEs including measurements with no visible foEs (but a blanketed frequency fB).

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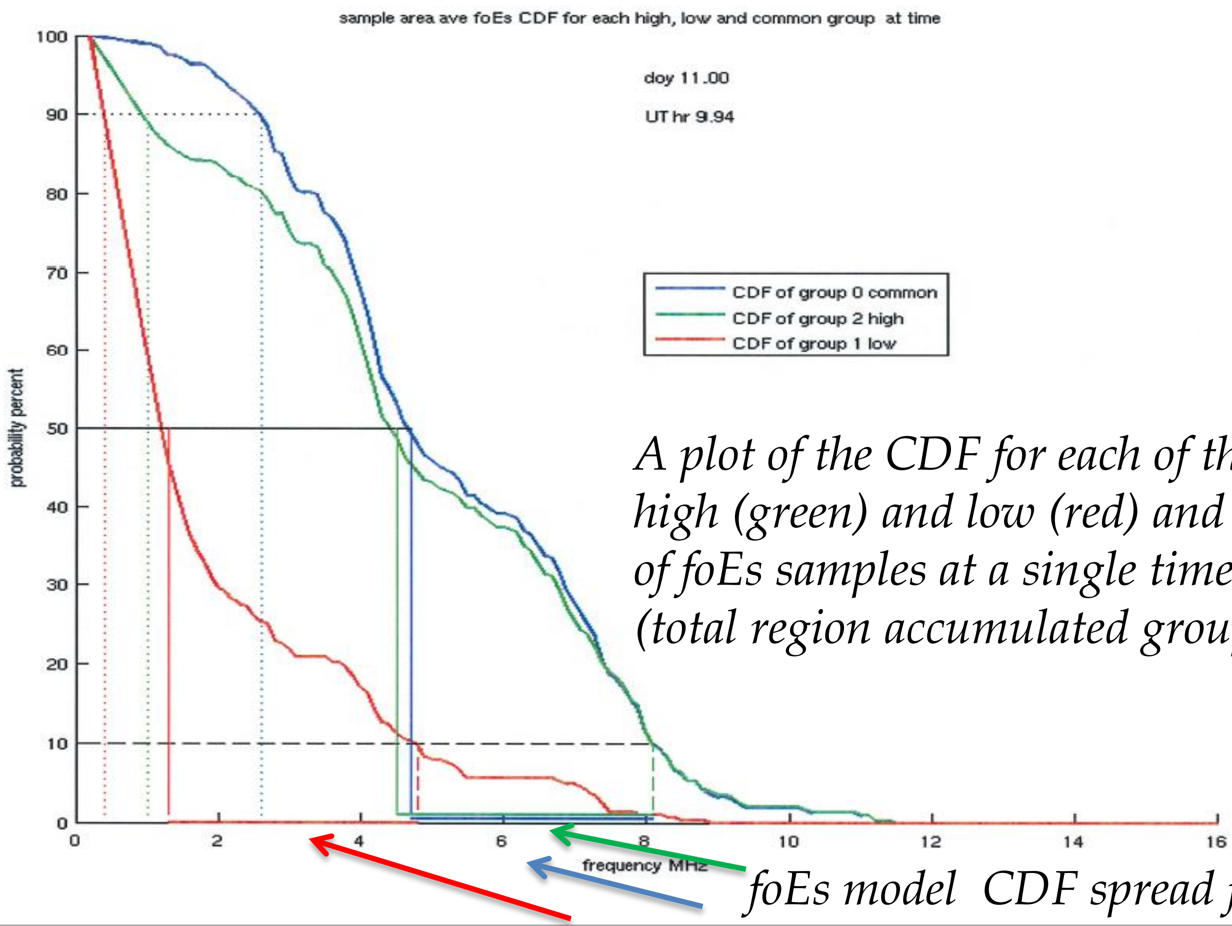


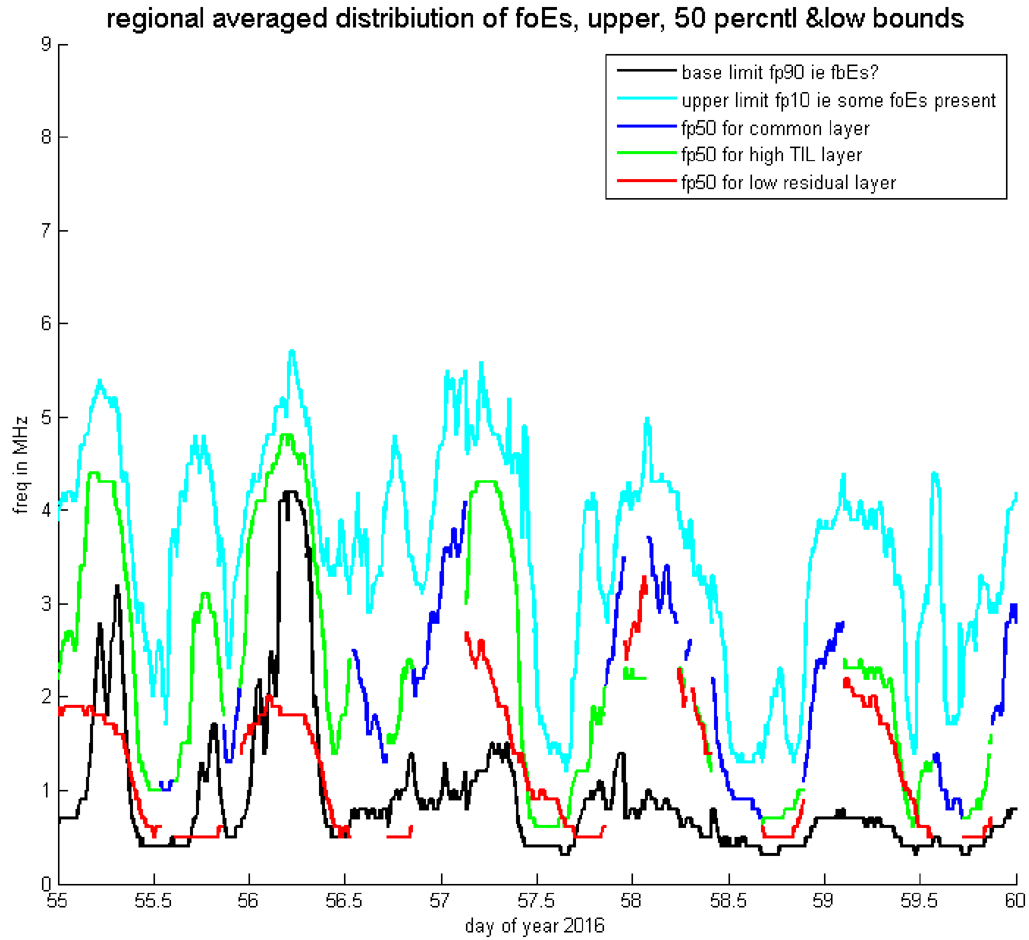
A plot of the CDF for each of the high (green) and low (red) and common(blue) group of foEs samples at a single time in 2016 (total region accumulated groups of foEs samples).

foEs model CDF spread for each layer

Modelling foEs (3)

Spread as a fn of time (lag) & space & layer & season

Example of foEs variation wrt time (area averaged sample).



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Example of foEs variation wrt time
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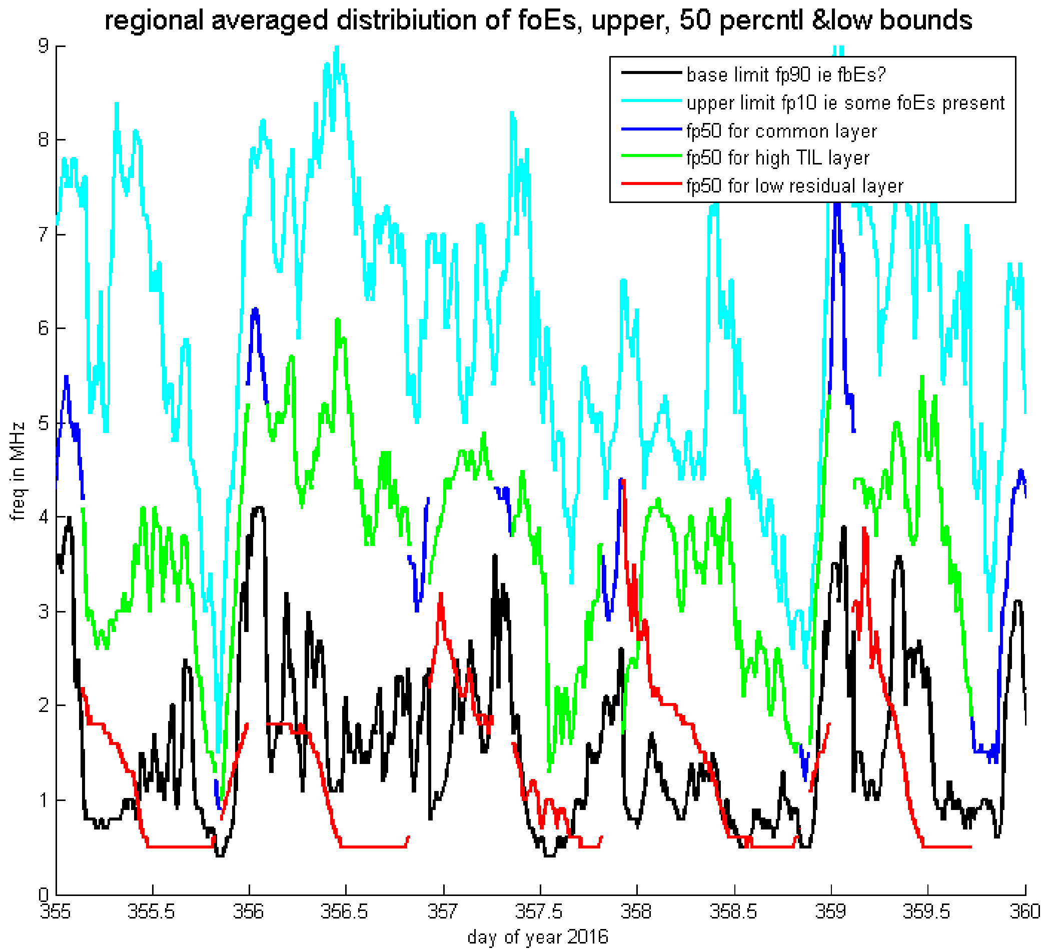
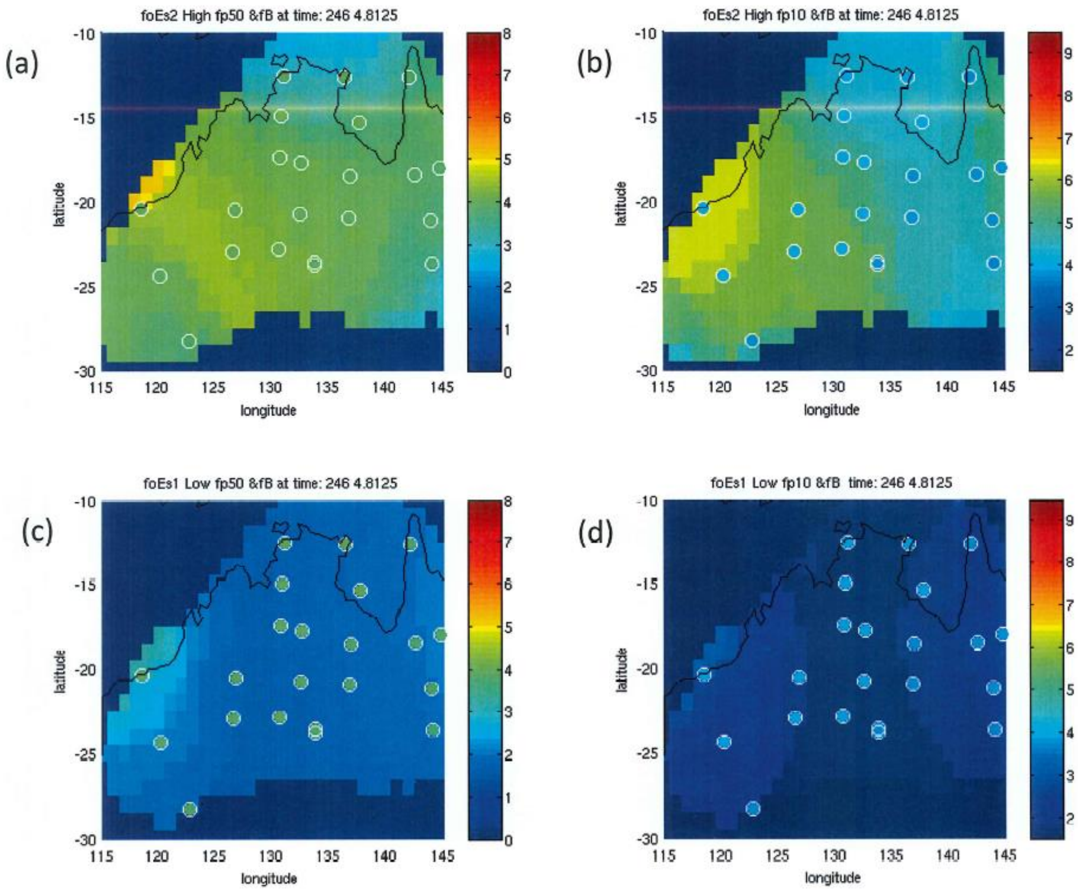
SUMMERTIME



Modelling foEs (3)

Spread as a fn of time (lag) & space & layer & season

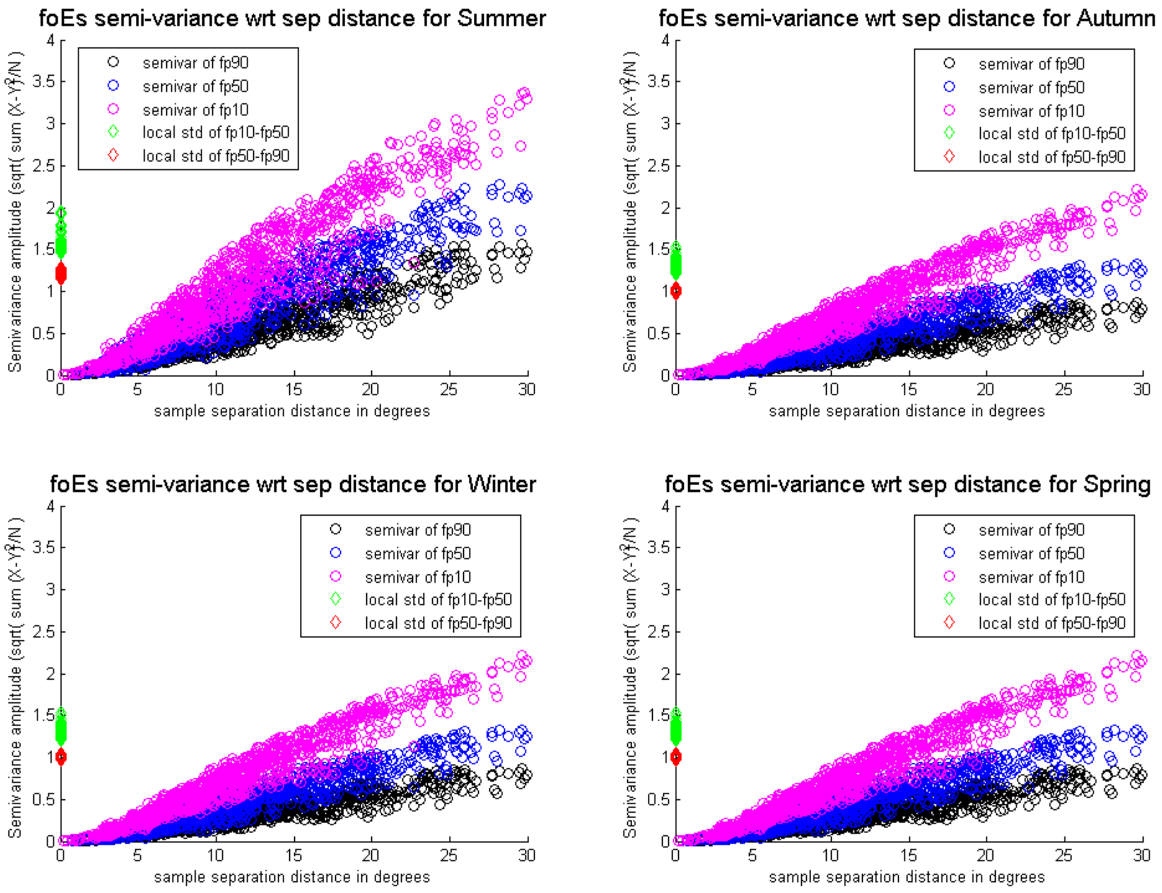
Now Spatial maps of
foEs high & (fp50&fp10)
low (fp50 &fp10)
ie variation wrt space



Modelling foEs (3)

Spread as a fn of time (lag) & space & layer & season

Now variation in Space & Time & Layer variations combined



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Summary

So what can we do with all this real time Es data?

- Identify and exclude outliers *(in hEs & hence foEs)*
- Integrate VIS & OIS data into single common model.

- Make a highly reliable and robust estimate of hEs (in the au region)!
- Reliable describe the number of separate (or in common) hEs layers present!

- Reliably describe the distribution of foEs (in the au region over past 30 min)!

  (spread of foEs est can be large! eg typically 1-2 MHz)
- Integrate BSS Es LE data (finer scale foEs maps) is ongoing.

- With this model we find the hEs and foEs properties are smoothly varying in space and time!
- Developing a reliable model of fbEs and oblique path loss estimation is ongoing.

Conclusions

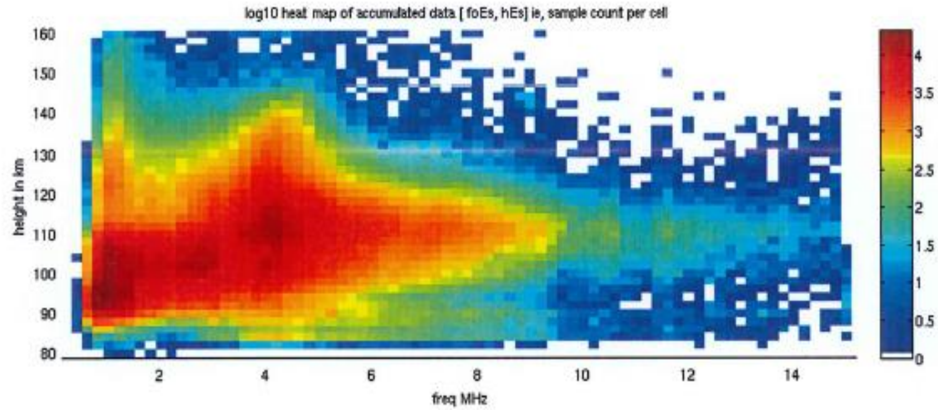
The greater part of Es variability is understood and represented, see movies below

Anticipation (15min pred) of Es effecting propagation does not need to be a nightmare!

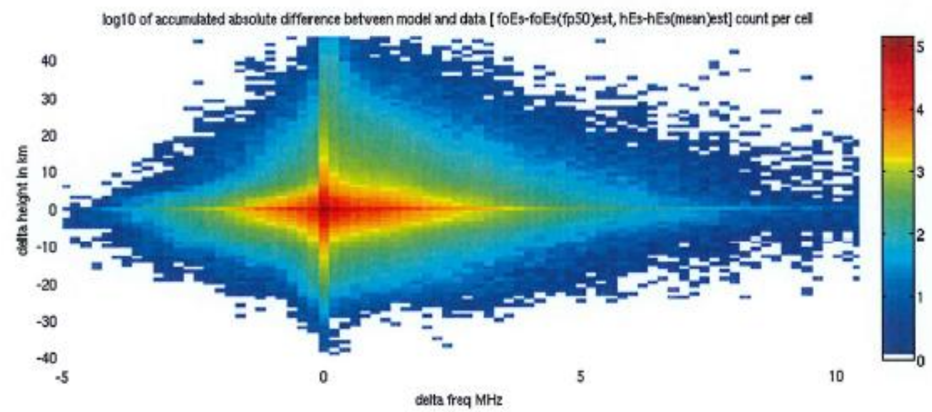
(a) Number density map of log10 of the binned sample count for foEs vs hEs data from all VIS &OIS sounder data from 2016

(b) the same data as panel (a) but with the x &y axis changed to represent the data binned w.r.t. to the model estimate i.e. $foEs_{obs}-foEs_{median\ est}$ vs $hEs_{obs}-hEs_{mean\ est}$

(a)



(b)



Example movies

The greater part of Es variability is understood and represented, see movies below

Anticipation (15min pred) of Es effecting propagation does not need to be a nightmare!

Es_movie1.mp4.avi

Es_movie2.mp4.avi

Es_movie3.mp4.avi

Es_movie4.mp4.avi