Plasma Structures in the High-Latitude Ionosphere

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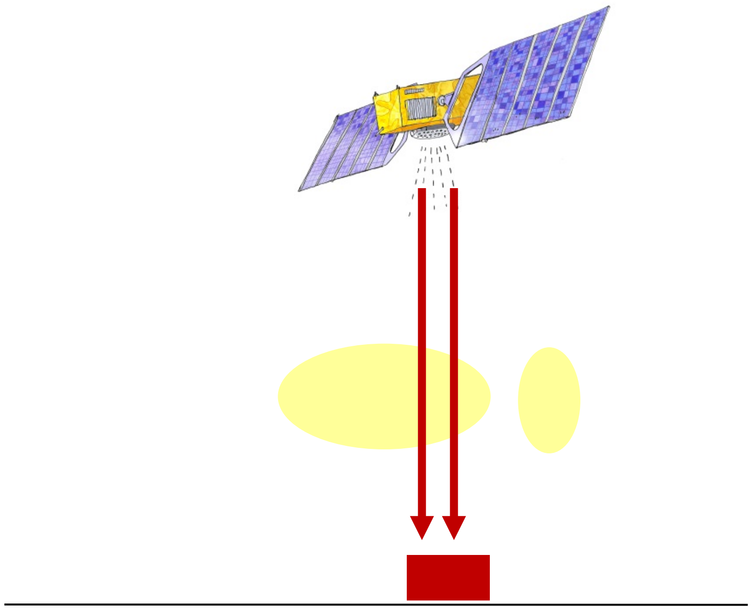
The High-Latitude Ionosphere

Highly Structured

Small scale structures associated with large scale structures



Large scale structures vary:

- Season
- Solar cycle
- Geomagnetic activity
- Solar wind conditions
- Location, UT

Relative importance is a more open question

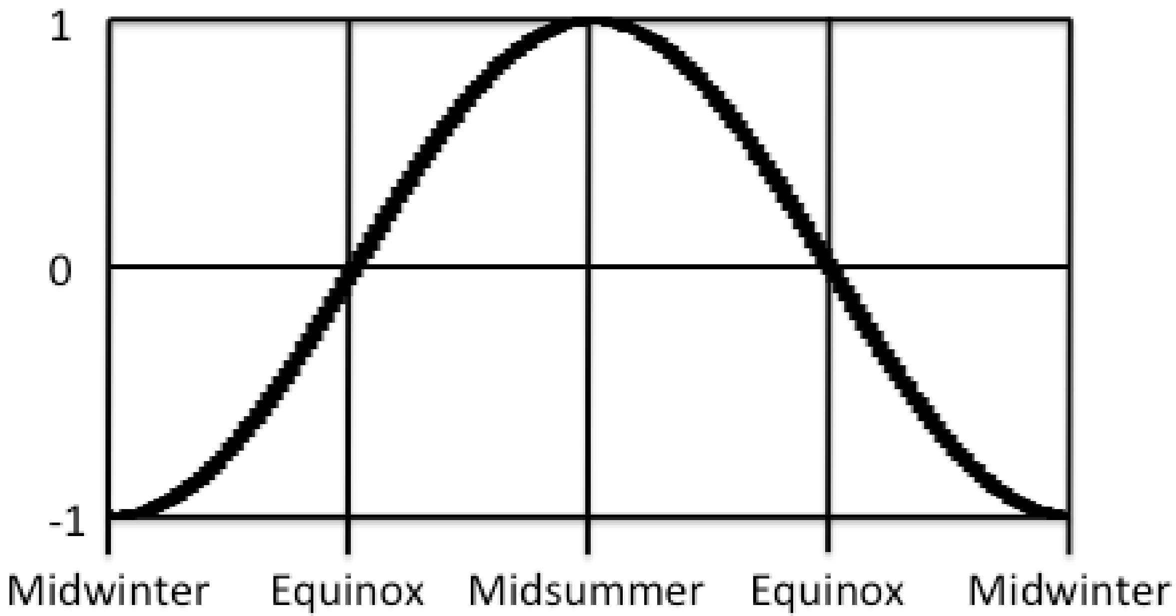
Generalised Linear Modelling

Dependant Variable: Amount of plasma structuring

Independ SSN)

ST)

ex)



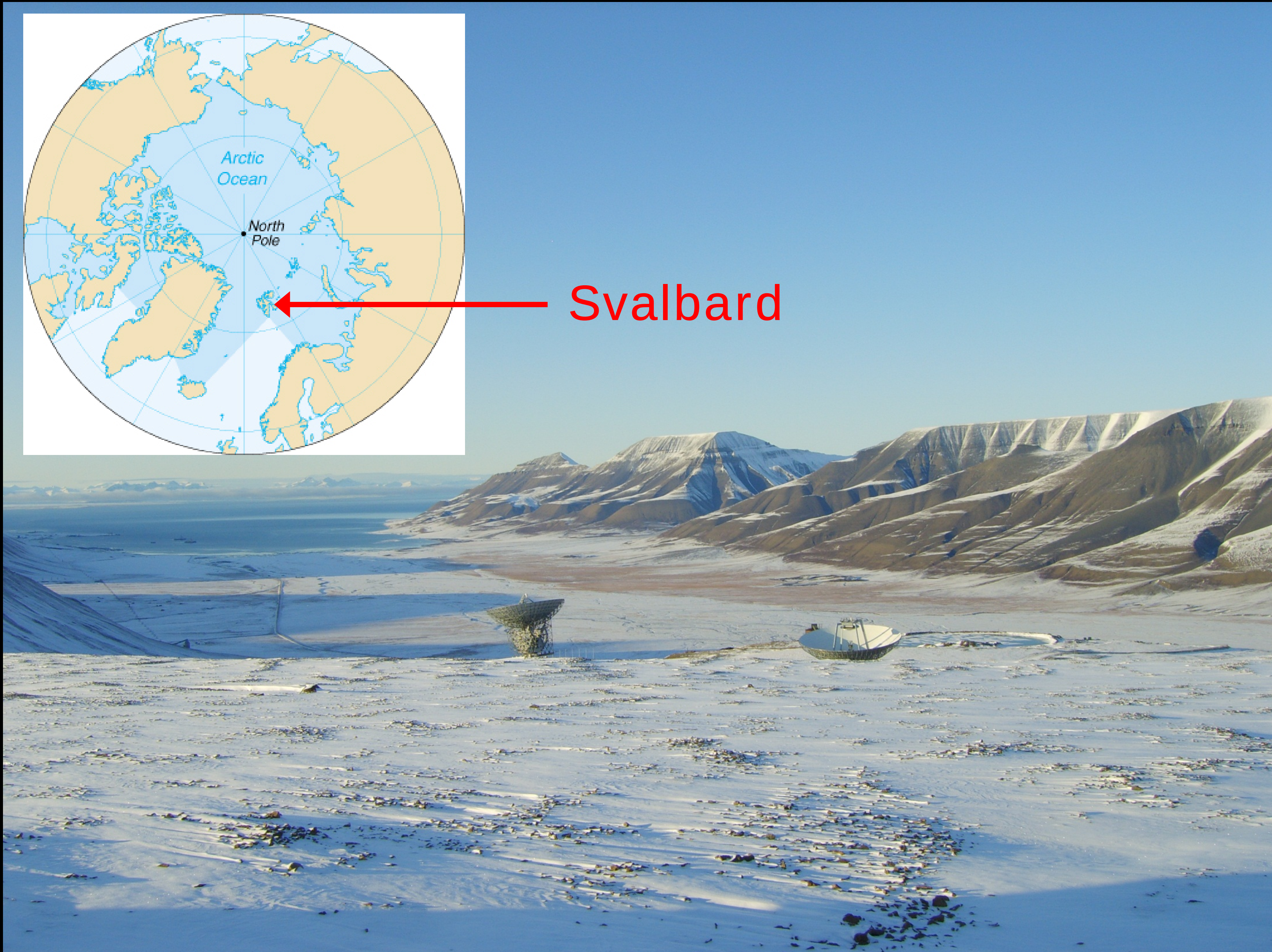
Modelling

Test statis

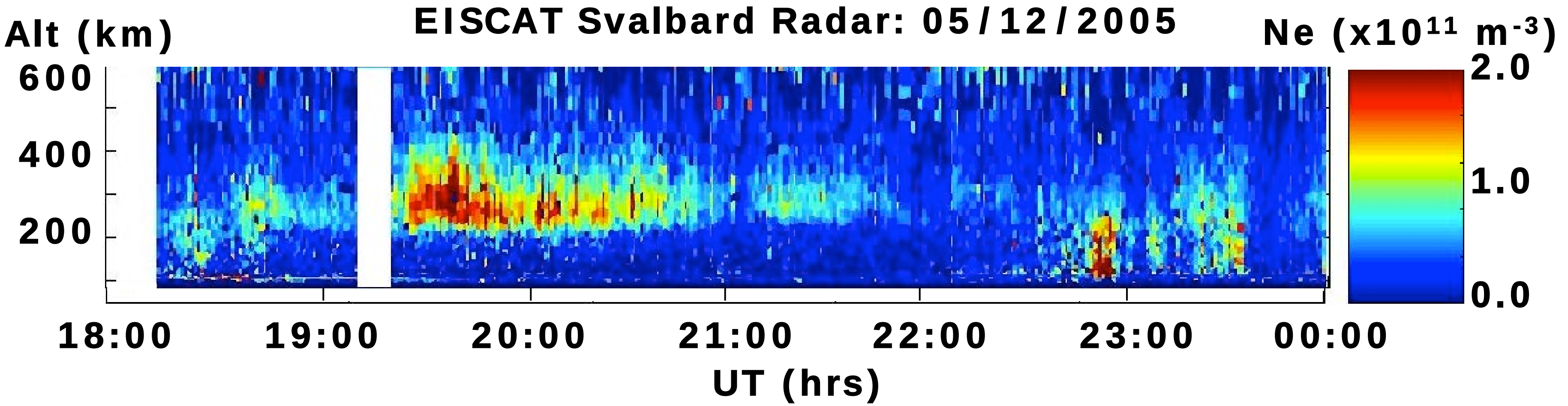
Add most significant parameter

Continue until nothing else is significant at the 5 % level

Acknowledgements: Kp, AE, PCI, SSN & F10.7 obtained from UKSSDC. IMF obtained from CDAWeb

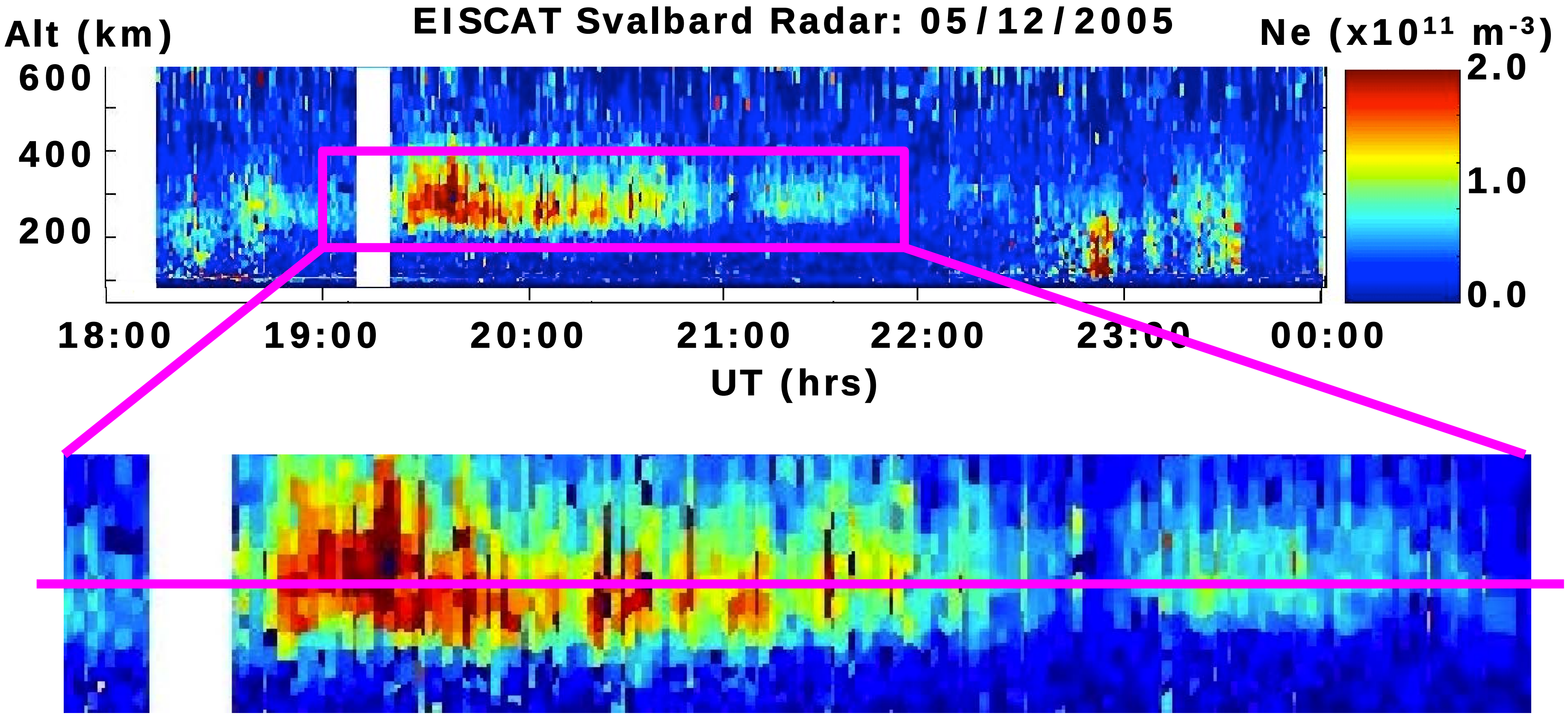

Arctic
Ocean
North
Pole
Svalbard

Structuring Ratio



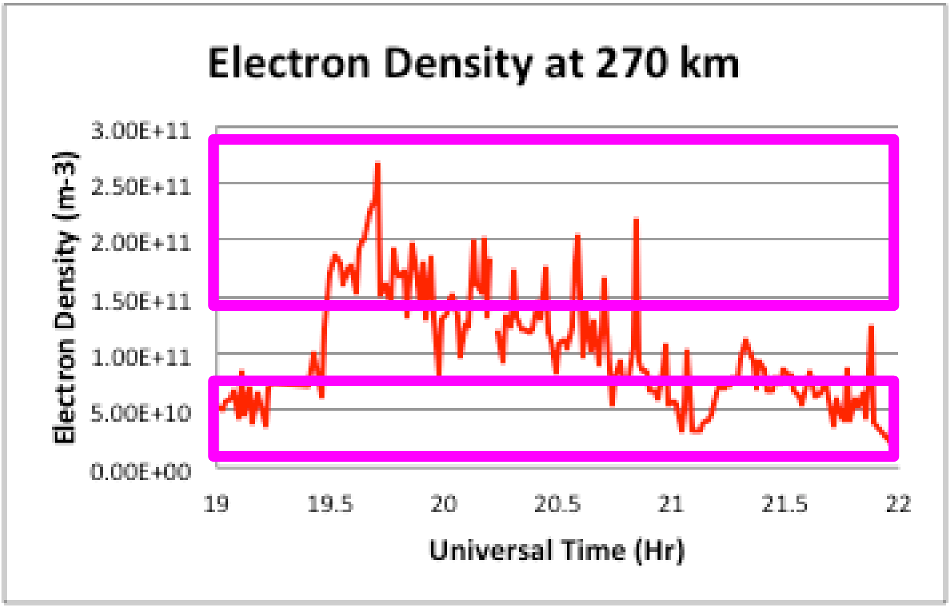
How highly structured is this plasma?

Structuring Ratio



Peak Altitude: 270 km

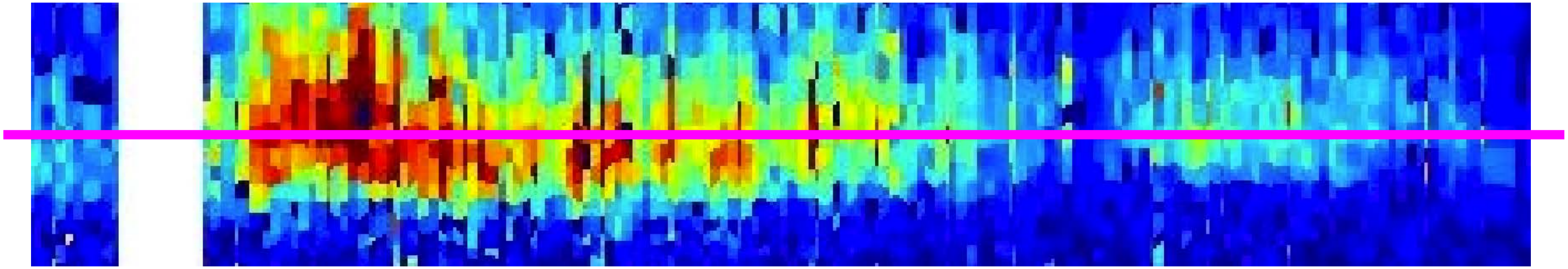
Structuring Ratio



Larger Ne: 1.8×10^{11} m^{-3}

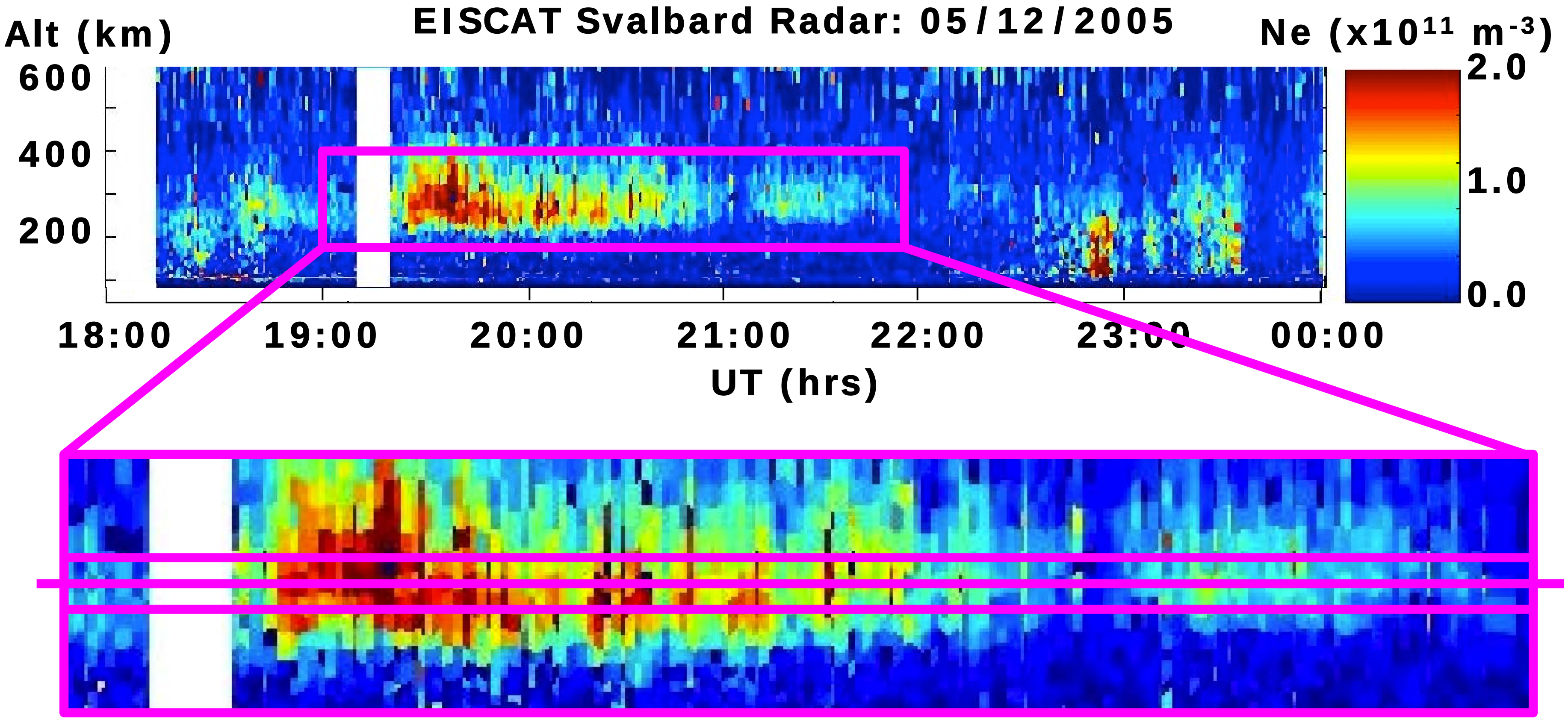
Smaller Ne: 0.5×10^{11} m^{-3}

Structuring Ratio: 3.6



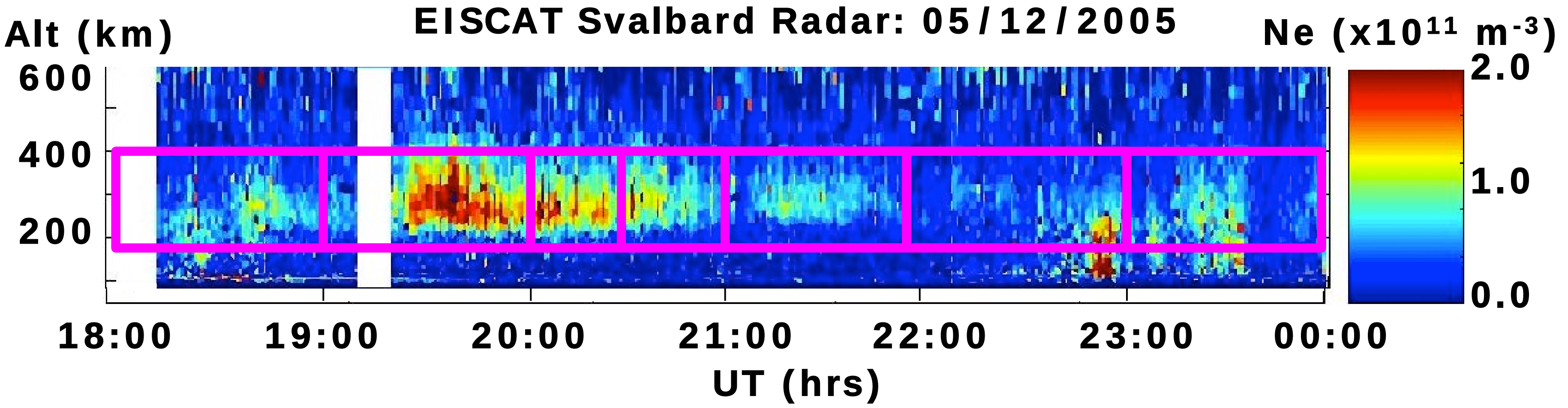
Peak Altitude: 270 km

Structuring Ratio



Peak Altitude: 270 km

Structuring Ratio

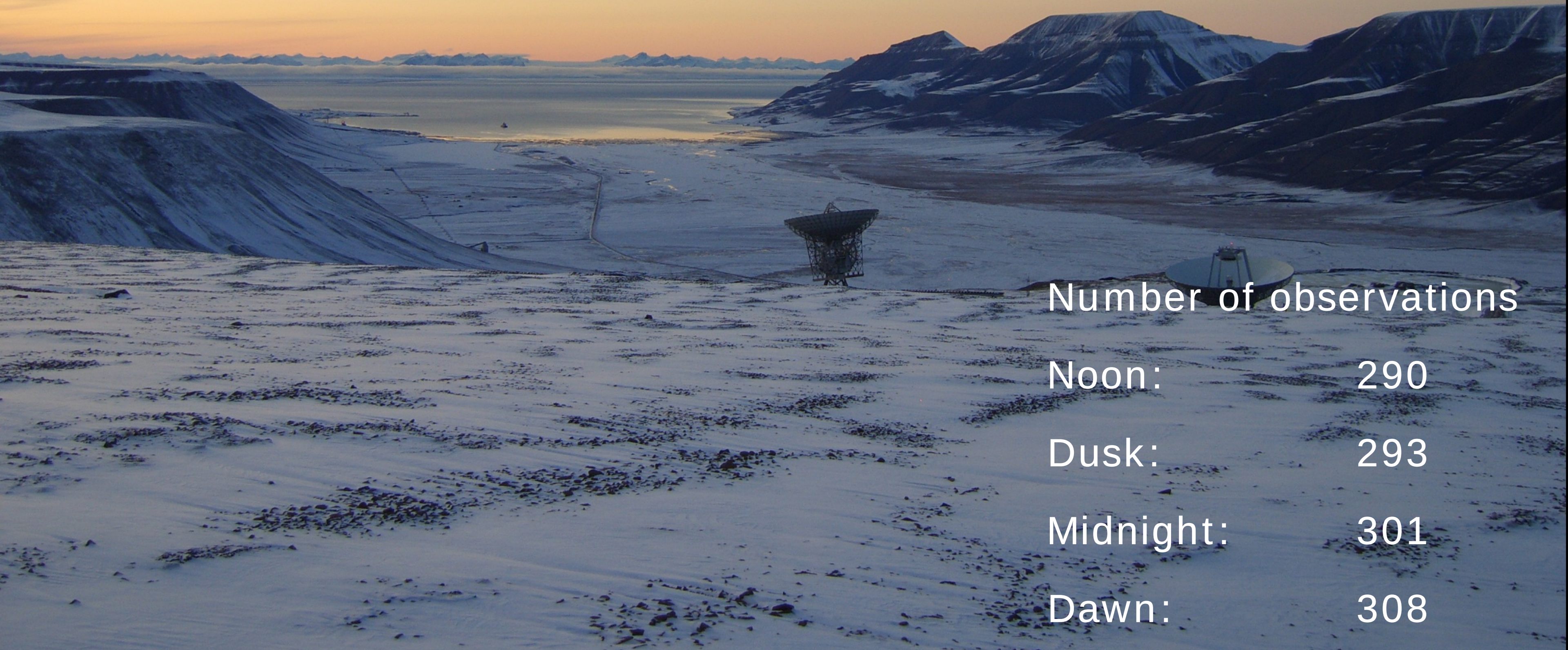


Time Intervals: 3 hours

EISCAT Svalbard Radar

Six hours of quasi-continuous observations in noon (06-12 UT), dusk (12-18 UT), midnight (18-00 UT) or dawn (00-06 UT) sector

Archive data: 1997-2013

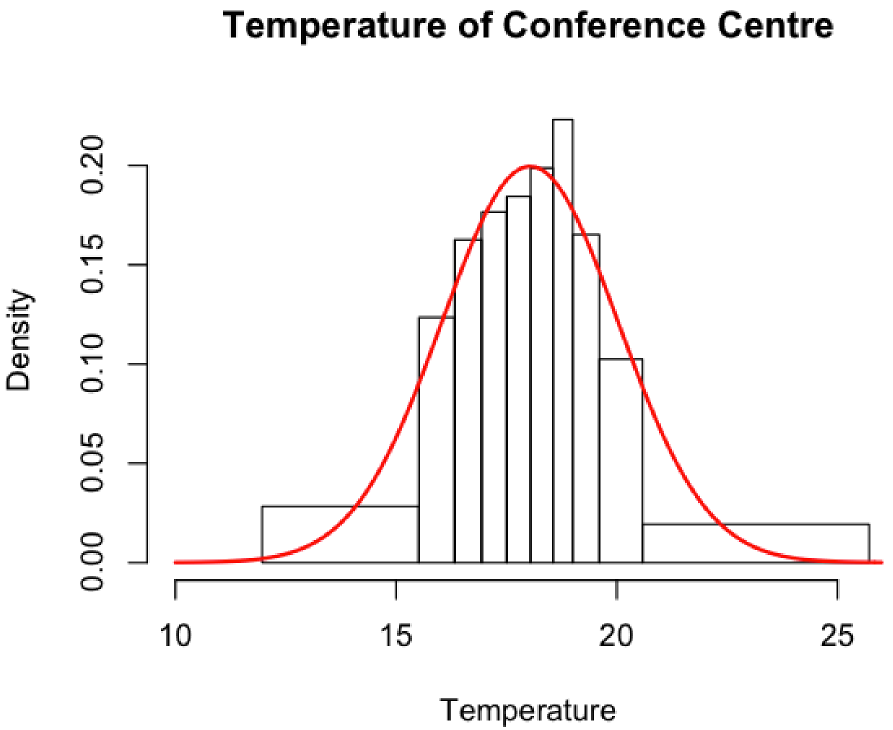


Number of observations

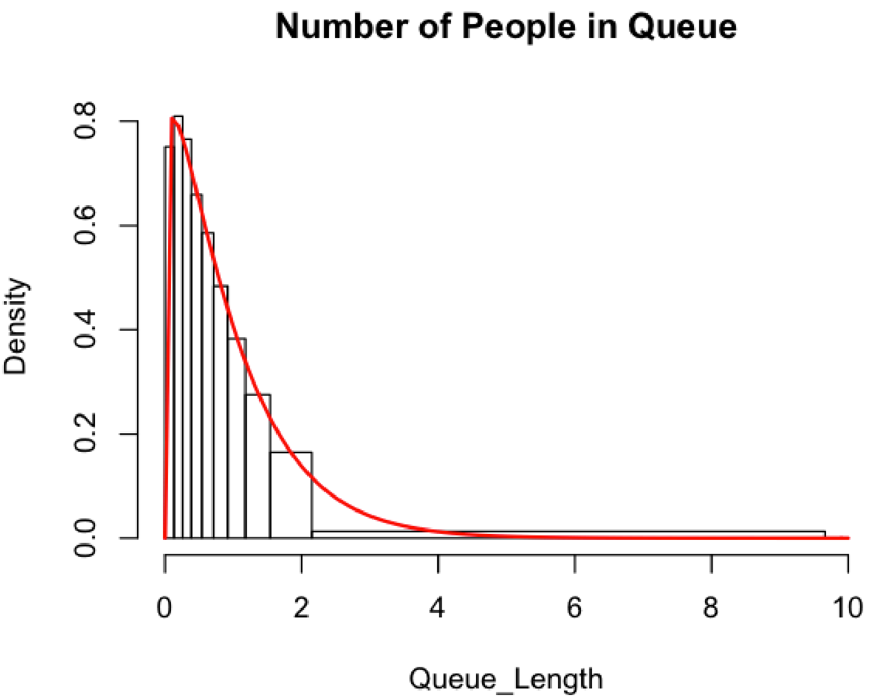
Noon:	290
Dusk:	293
Midnight:	301
Dawn:	308

Acknowledgements: EISCAT data obtained from the EISCAT Archive at the STFC Rutherford Appleton Laboratory

Distributional Form



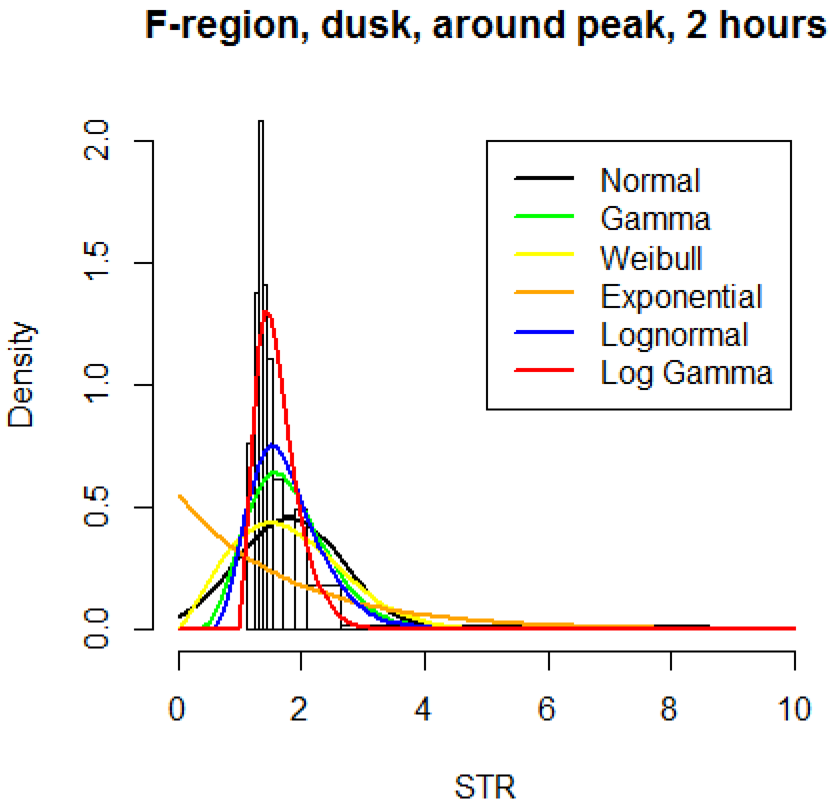
Normal distribution

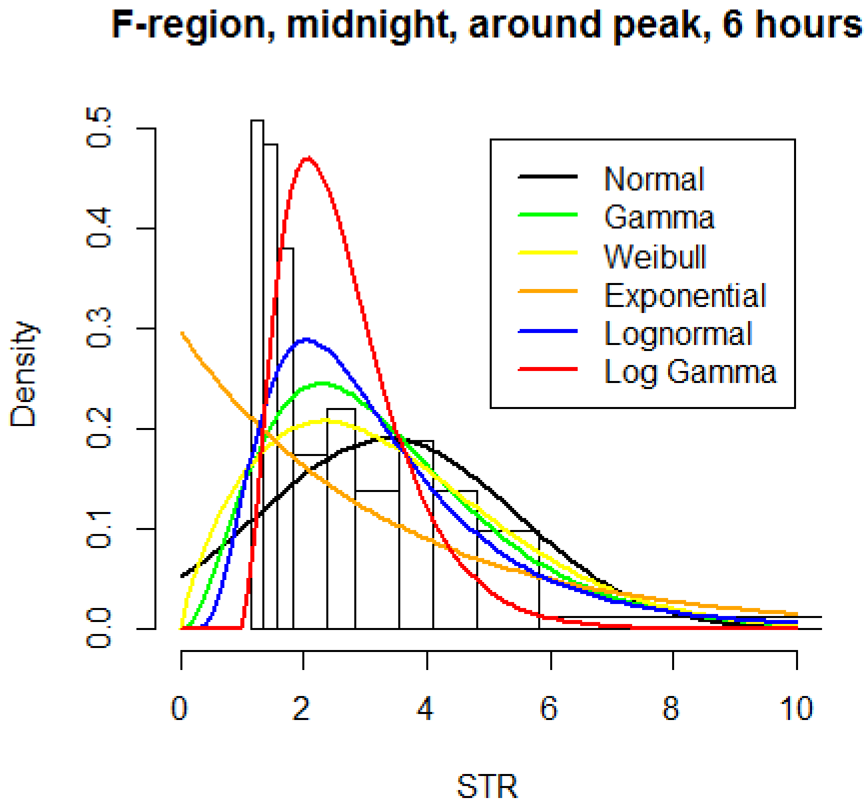


Weibull distribution

Tried: Normal, Gamma, Exponential, Weibull, Lognormal & Log Gamma distributions

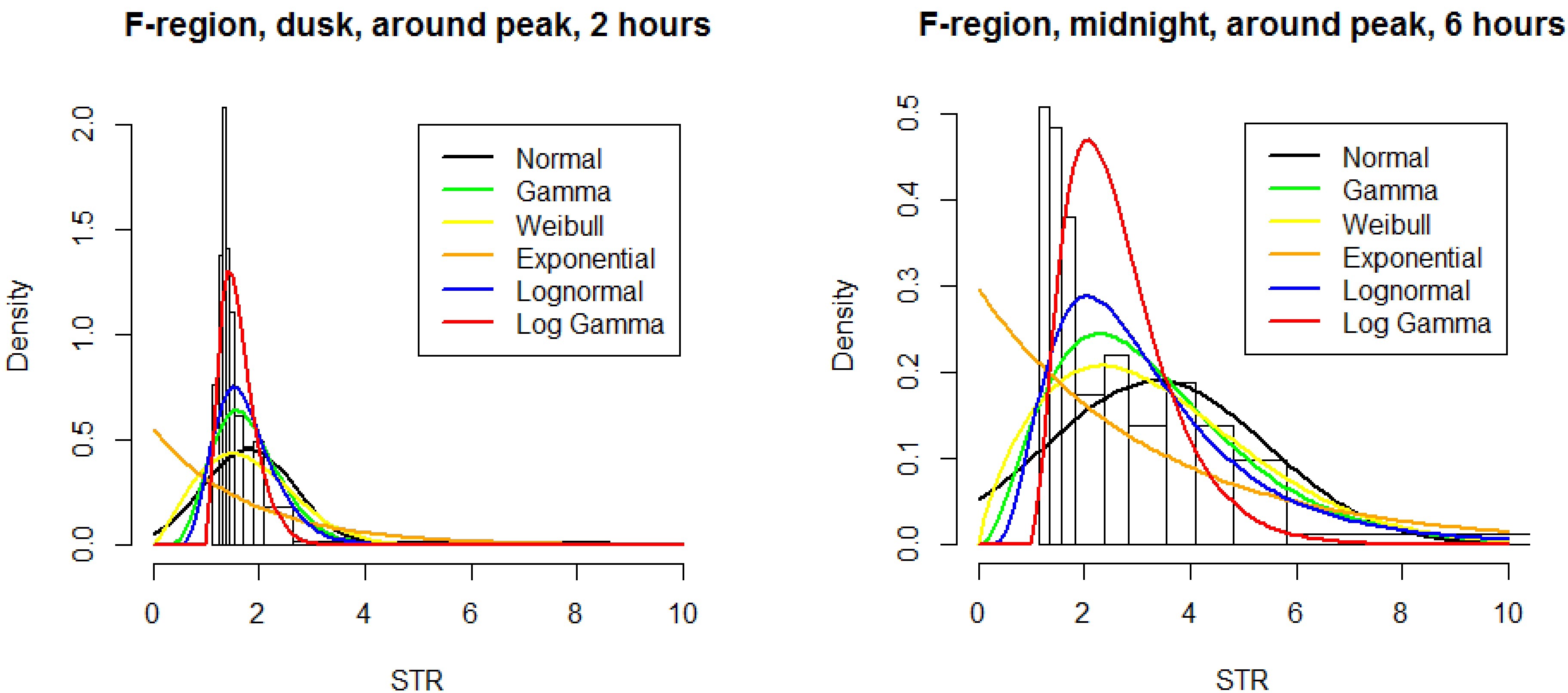
Distributional Form





Log Gamma fits best, but does not fit everywhere

Distributional Form



Expect Chi-sq ~1 per degree of freedom

Inspect all plots: If Chi-sq more than x3 expected value, or less than x1/3 expected value, reject

Link Function

	Link Function	Form of equation
Identity	$X\beta = \mu$	$\log(STR) = a + b \cdot x$
Inverse	$X\beta = \mu^{-1}$	$\log(STR) = \frac{1}{a + b \cdot x}$
Log	$X\beta = \ln(\mu)$	$\log(STR) = a \cdot x^{b}$

Find which produces, on average, the most statistically significant results

$$Significance\_Index = (4 \cdot Sig\_0.01\%) + (3 \cdot Sig\_0.1\%) + (2 \cdot Sig\_1\%) + (1 \cdot Sig\_5\%)$$

Generalised Linear Modelling

Dependant Variable: Amount of plasma structuring

Independent Variables: Solar activity (F10.7 Solar Flux & SSN)

Solar wind (IMF: Bx, By & Bz)

Geomagnetic activity (Kp, AE)

Plasma convection (Polar cap index)

Season (days from midwinter)

Modelling Method

Test statistical significance of all parameters

Number of Models

3 x 7 x 4 x 2 = 168

Acknowledgements: Kp, AE, PCI, SSN & F10.7 obtained from UKSSDC. IMF obtained from CDAWeb

Relative Importance of Geophysical Parameters

Svalbard

Parameter	Importance
Season	5.0
F10.7	3.5
Dst (average)	3.4
PCI (average)	2.9
SSN	2.9
Kp (average)	2.8
IMF Bz (average)	1.7
IMF Bz (stdev)	1.6
IMF By (stdev)	1.4
PCI (stdev)	1.3
AE (stdev)	1.2
Dst (stdev)	1.2
AE (average)	1.0
IMF Bx (stdev)	0.7
IMF Bx (average)	0.4
Kp (stdev)	0.1
IMF By (average)	0.0

Importance

Significance better than ...

... 5%	Importance	1
... 1%	Importance	2
... 0.1%	Importance	3
... 0.01%	Importance	4
... 0.001%	Importance	5

Season is the most important parameter

Seasonal Variation

Parameter Estimate varies with altitude range and time range …

Altitude	Time						
	6-hr	5-hr	4-hr	3-hr	2-hr	1-hr	30-min
Peak	1.11±0.05	1.13±0.06	1.18±0.06	1.19±0.06	1.27±0.07	1.3±0.1	1.5±0.2
Around Peak	1.17±0.05	1.20±0.06	1.27±0.06	1.29±0.06	1.41±0.08	1.5±0.1	1.6±0.2
Height Integrated	1.33±0.07	1.41±0.08	1.47±0.09	1.56±0.09	1.8±0.1	2.1±0.1	2.4±0.2

F region, dusk

… but this can be largely explained by the variation in the amount of structuring

Altitude	Time						
	6-hr	5-hr	4-hr	3-hr	2-hr	1-hr	30-min
Peak	2.33±0.12	2.22±0.11	2.17±0.11	2.06±0.11	1.97±0.11	1.97±0.13	2.25±0.33
Around Peak	2.18±0.07	2.08±0.06	2.03±0.07	1.90±0.05	1.81±0.05	1.77±0.06	2.04±0.23
Height Integrated	1.90±0.05	1.83±0.05	1.79±0.05	1.68±0.03	1.60±0.03	1.48±0.03	1.41±0.02

F region, dusk

Seasonal Variation

Variation with sector and region shows significant differences

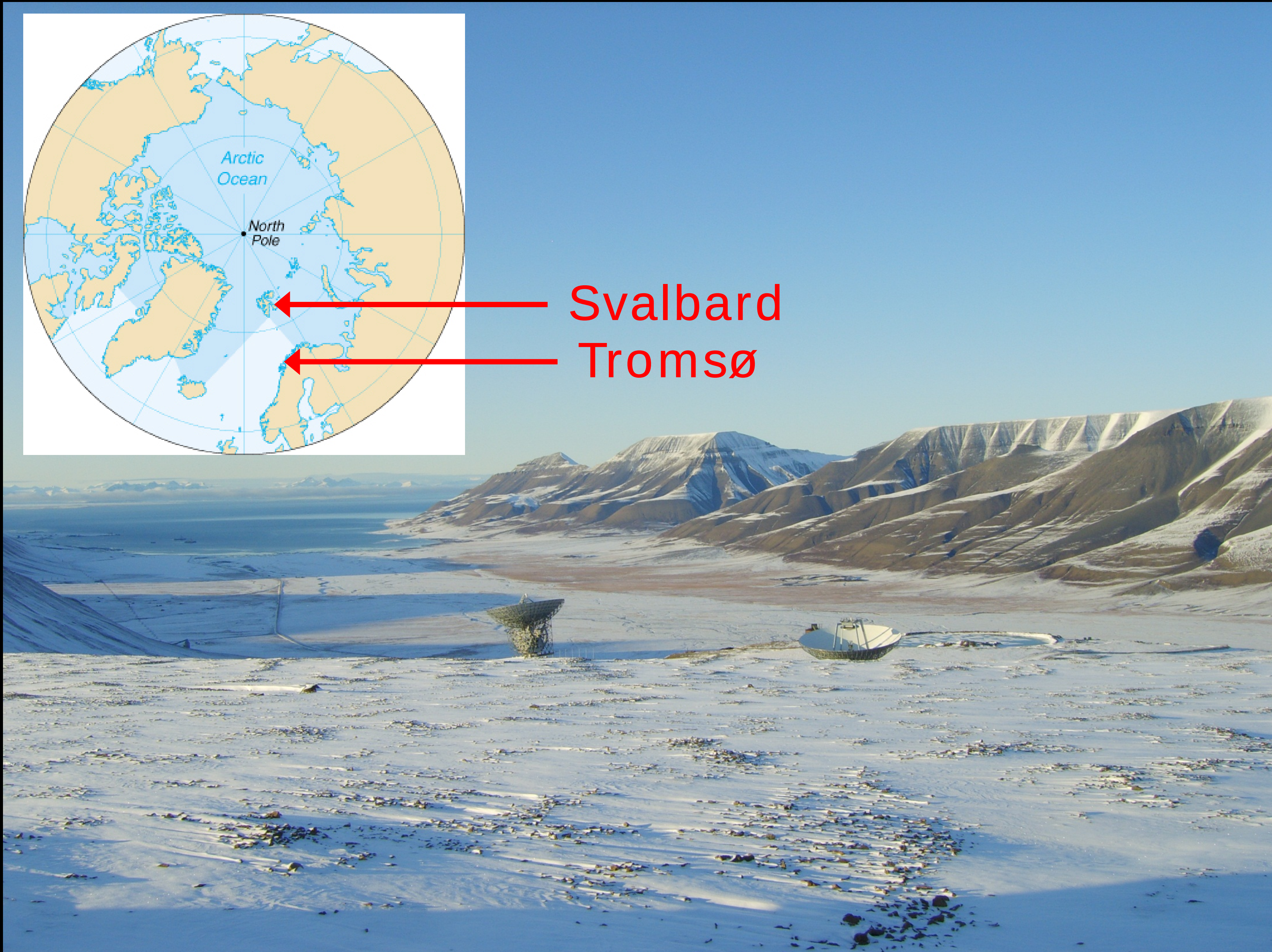
3 hour, around peak

Sector	F-region	E-region
Dusk	1.29±0.06	0.63±0.05
Midnight	1.01±0.05	0.36±0.03
Dawn	0.77±0.04	-0.70±0.05

5 hour, TEC

Sector	F-region	E-region
Dusk	1.40±0.08	0.51±0.04
Noon	1.08±0.09	0.35±0.04

Different dependence upon season at different MLT and regions


Arctic
Ocean
North
Pole
Svalbard
Tromsø

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Kp (average)	2.8
IMF Bz (average)	1.7
IMF Bz (stdev)	1.6
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PCI (stdev)	1.3
AE (stdev)	1.2
Dst (stdev)	1.2
AE (average)	1.0
IMF Bx (stdev)	0.7
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Kp (stdev)	0.1
IMF By (average)	0.0

Tromsø

Parameter	Importance
Season	5.0
Dst (average)	2.6
PCI (average)	1.8
Kp (average)	1.3
F10.7	1.2
IMF By (stdev)	1.1
IMF Bz (average)	1.1
PCI (stdev)	0.9
AE (stdev)	0.8
IMF Bz (stdev)	0.8
Dst (stdev)	0.7
IMF Bx (stdev)	0.7
SSN	0.7
AE (average)	0.5
IMF Bx (average)	0.5
Kp (stdev)	0.4
IMF By (average)	0.3

Season still the most important parameter

Relative importance of other parameters changes

In the F-region 24 % of parameter estimates are significantly different

In the E-region 36 % of parameter estimates are significantly different

Relative Importance of Geophysical Parameters

Season: Parameter Estimate

F-region: Significantly different in 1 out of 31 cases

- Predict more structuring in winter than summer

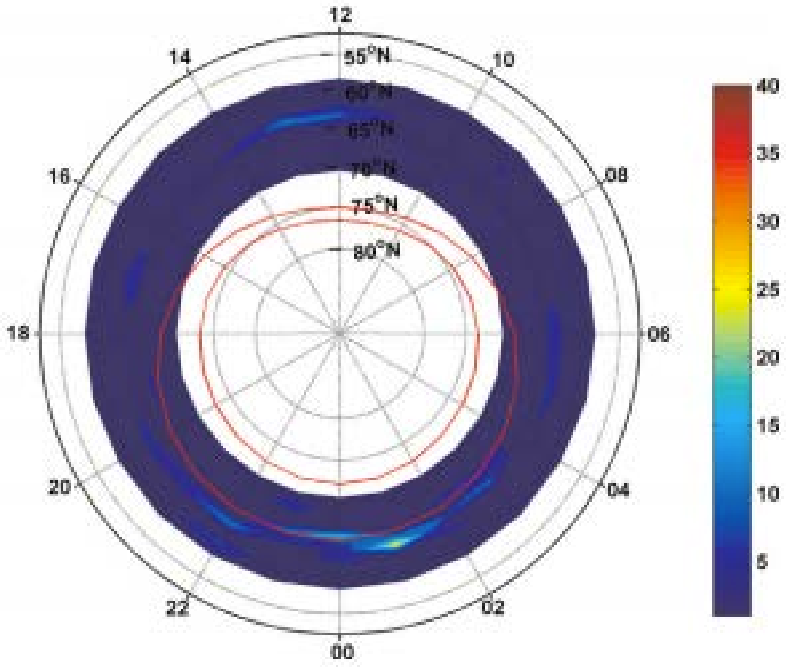
E-region: Significantly different in 9 out of 33 cases

- Predict more structuring in winter than summer
  - Where differences occur in the noon sector predict more variation in E-region than F-region
  - Where differences occur in the dawn sector predict less variation in E-region than F-region

Phase Scintillation

Data supplied by Nottingham Geospatial Institute

Occurrence of phase scintillation > 0.3

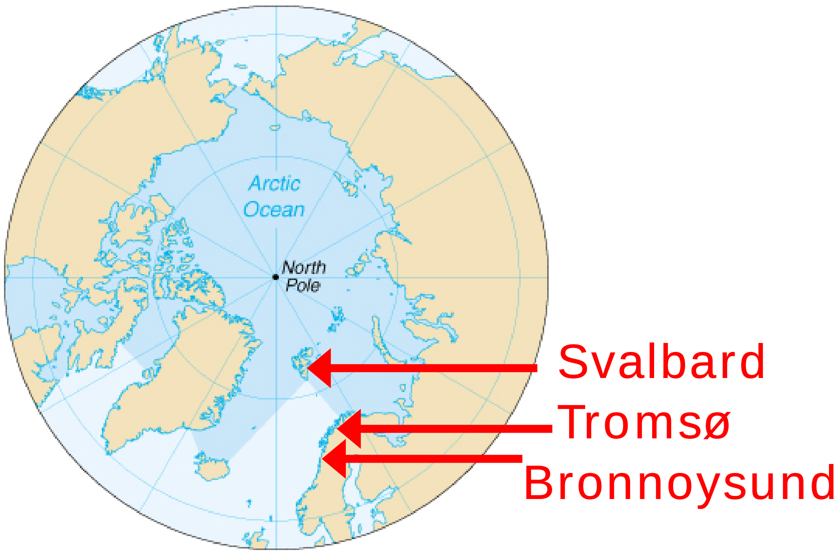


Sreeja & Aquino, JASTP, 2014
Data from 2011-2013

Binomial Model

1 year of data: 02.2012-01.2013

Restrict to El > 70 degrees



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PCI (stdev)	1.3
AE (stdev)	1.2
Dst (stdev)	1.2
AE (average)	1.0
IMF Bx (stdev)	0.7
IMF Bx (average)	0.4
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IMF By (average)	0.0

Tromsø

Parameter	Importance
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Dst (average)	2.6
PCI (average)	1.8
Kp (average)	1.3
F10.7	1.2
IMF By (stdev)	1.1
IMF Bz (average)	1.1
PCI (stdev)	0.9
AE (stdev)	0.8
IMF Bz (stdev)	0.8
Dst (stdev)	0.7
IMF Bx (stdev)	0.7
SSN	0.7
AE (average)	0.5
IMF Bx (average)	0.5
Kp (stdev)	0.4
IMF By (average)	0.3

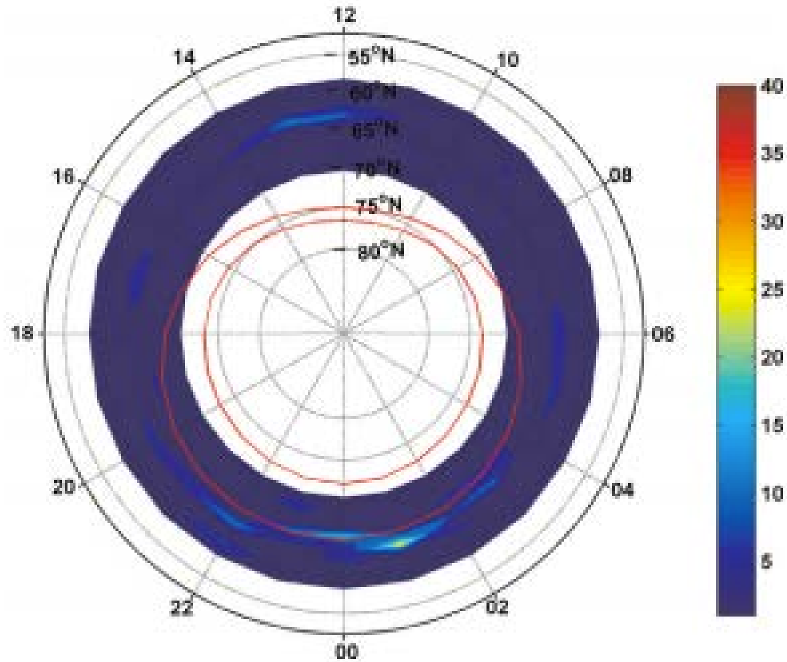
Bronnoysund

Parameter	Importance
F107	4.0
Solar Wind Density (average)	4.0
Season	3.8
SSN	3.0
Kp (average)	2.8
AE (average)	2.8
DST (average)	1.0
PCI (average)	0.5
Solar Wind Velocity (Average)	0.0
IMF Bz (average)	0.0
IMF By (average)	0.0
IMF Bx (average)]	0.0
IMF Abs(By) (average)	0.0

Phase Scintillation

Data supplied by Nottingham Geospatial Institute

Occurrence of phase scintillation > 0.3



Sreeja & Aquino, JASTP, 2014
Data from 2011-2013

Binomial Model

1 year of data: 02.2012-01.2013

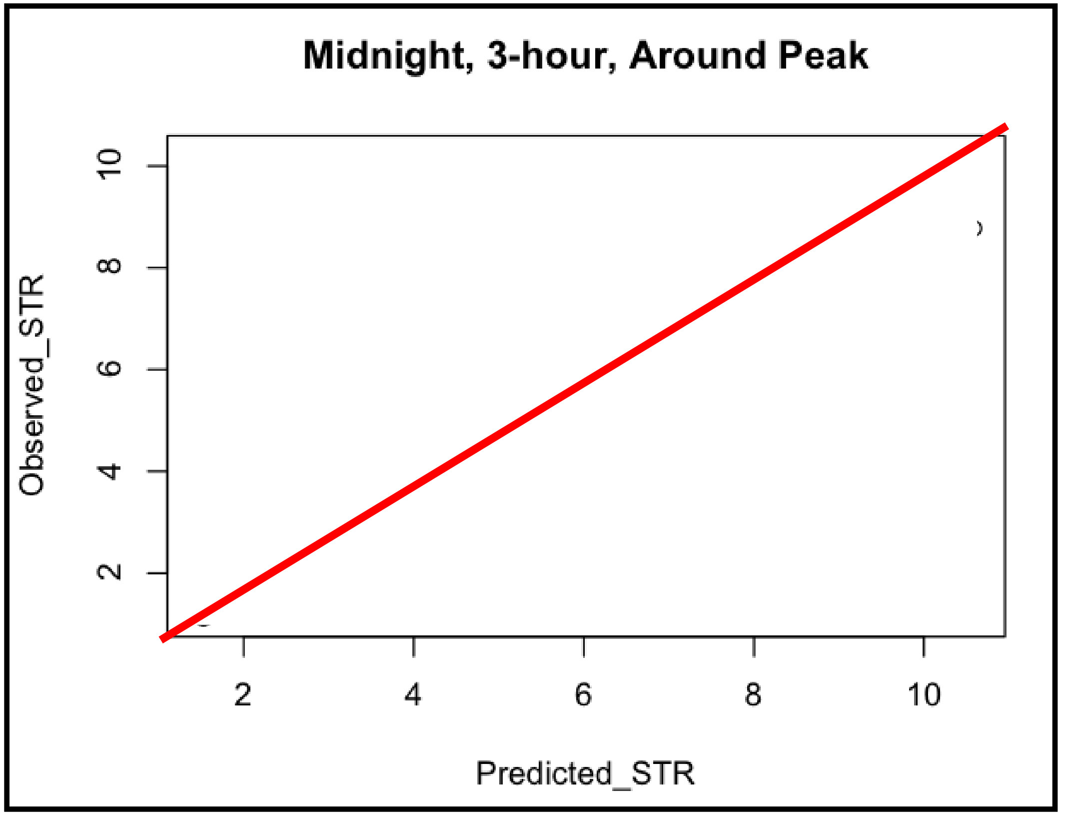
Restrict to El > 70 degrees

Sector	Parameter Estimate	Standard Error
Noon	0.035	0.003
Dusk	-0.028	0.014
Midnight	-0.032	0.011
Dawn	-0.063	0.010

Dusk & Midnight not significantly different; all other comparisons are significantly different

Model Results

$$\log(STR) = \frac{1}{1.28 \cdot Season - 0.09 \cdot IMF\_Bz\_Stdev + 2.36}$$



Seasonal Variation

EISCAT Svalbard Radar observations

Around solar maximum

IMF Bz predominantly negative

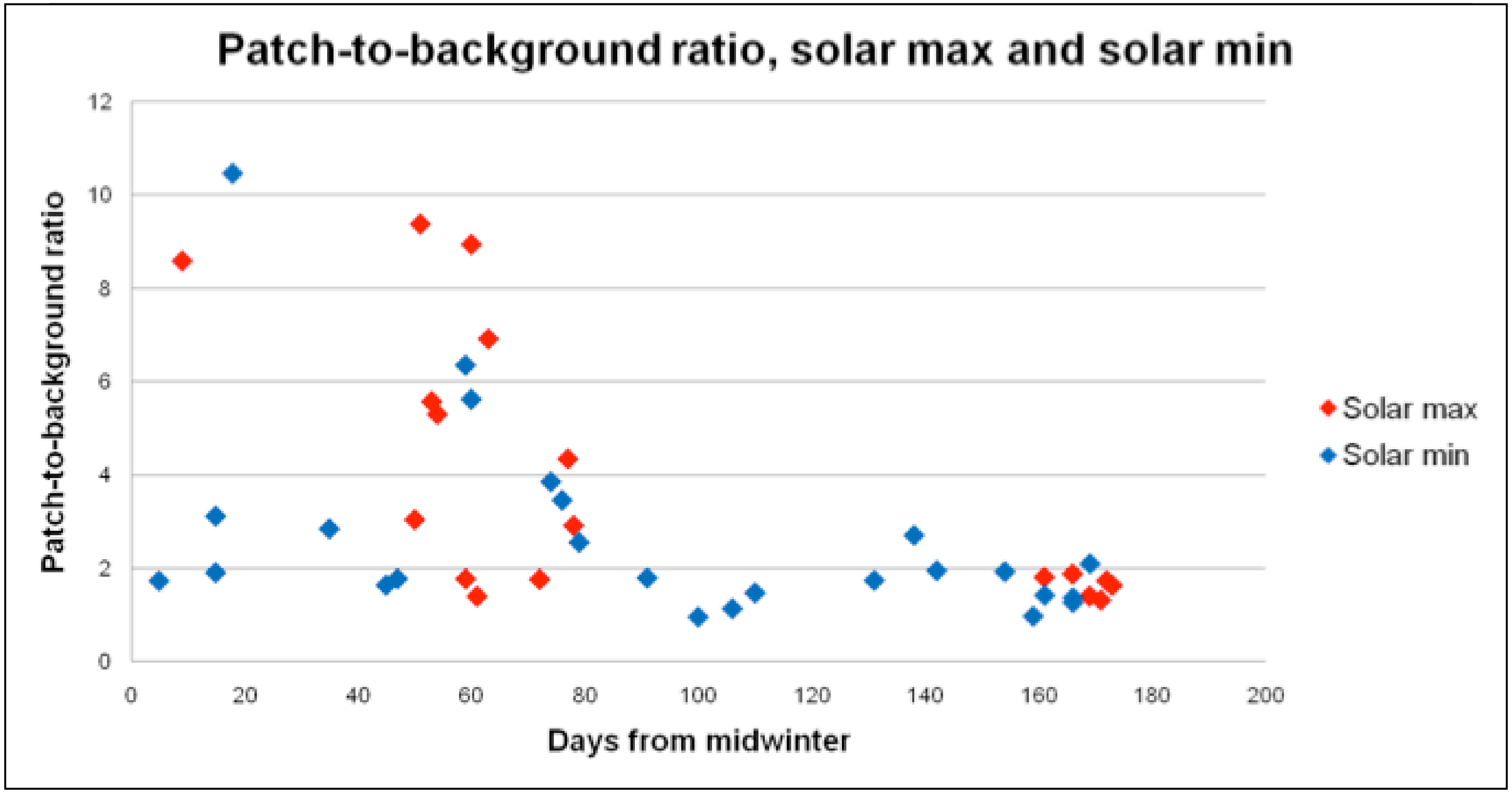
ESR in antisunward cross polar flow

ESR poleward of Harang discontinuity

No evidence of precipitation

42 studies from 6 years of data

Seasonal Variation



Relatively little variation between solar maximum & solar minimum

Enhancements weaker in summer

Next Steps: Statistical Models

Next steps: Model the ‘upper limit’

Next steps: Thermosphere (Amy Ronksley)

Comparison of thermospheric & ionospheric parameters using over a solar cycle of data

Look for statistically significant relationships between thermospheric and ionospheric parameters

Break statistical models into times of Sudden Stratospheric Warming (SSW) & non-Sudden Stratospheric Warming

Summary

Large scale structures

Season is the most significant parameter; the parameter estimate varies between sectors

Small scale structures

F10.7 is the most significant parameter; the parameter estimate varies between sectors

Thermosphere

Seems that at least one parameter is missing.

Next step: Include thermospheric parameters