Assessing E-CHAIM ionospheric model with the SuperDARN radars

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Abstract

The Empirical-Canadian High Arctic Ionospheric Model (E-CHAIM) has been shown to reasonably reproduce important general features of the electron density distribution in the high-latitude ionosphere such as solar cycle and seasonal variations of the F layer peak and the location of the ionospheric trough. The utility of the model for practical applications, such as predictions of HF radio wave propagation, is less clear. In this study, we consider ground-scatter (GS) data for three SuperDARN radars at various latitudes to compare the observed skip distance against ray tracings based on E-CHAIM predictions. Monthly-averaged GS band locations in 2010-2018 are computed for every half-hour of the day, and are correlated with modelled skip distances. We show that the agreement is better during summer months and we discuss the quality of predictions at various latitudes.

PHYSICS AND ENGINEERING PHYSICS

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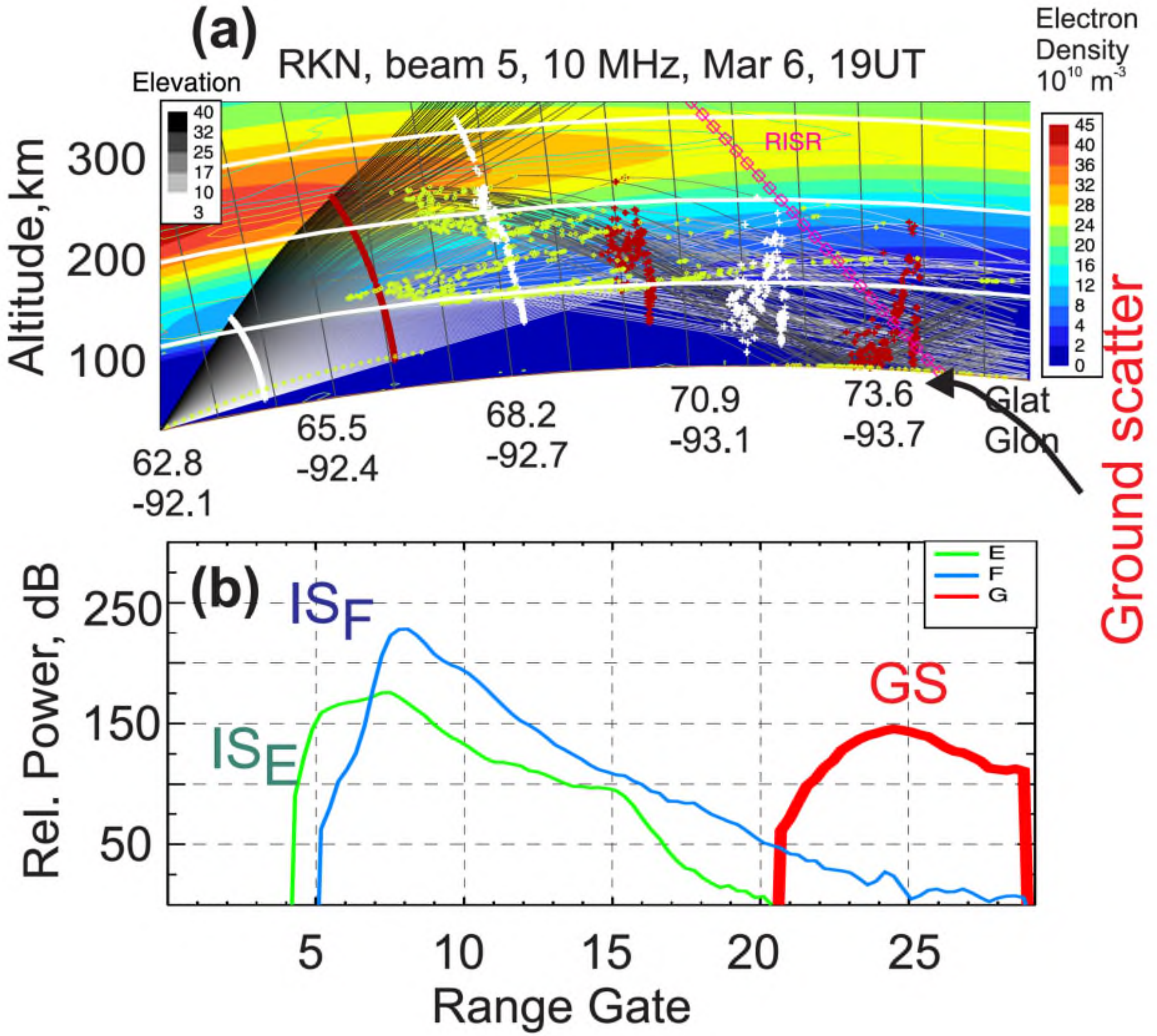
Objectives

1. Determine whether ground scatter in SuperDARN HF observations can be used for testing E-CHAIM model

2. Focus on long-term trends, not on individual events

3. Conclude what can be said on trends given by E-CHAIM model

Ray-tracing modeling

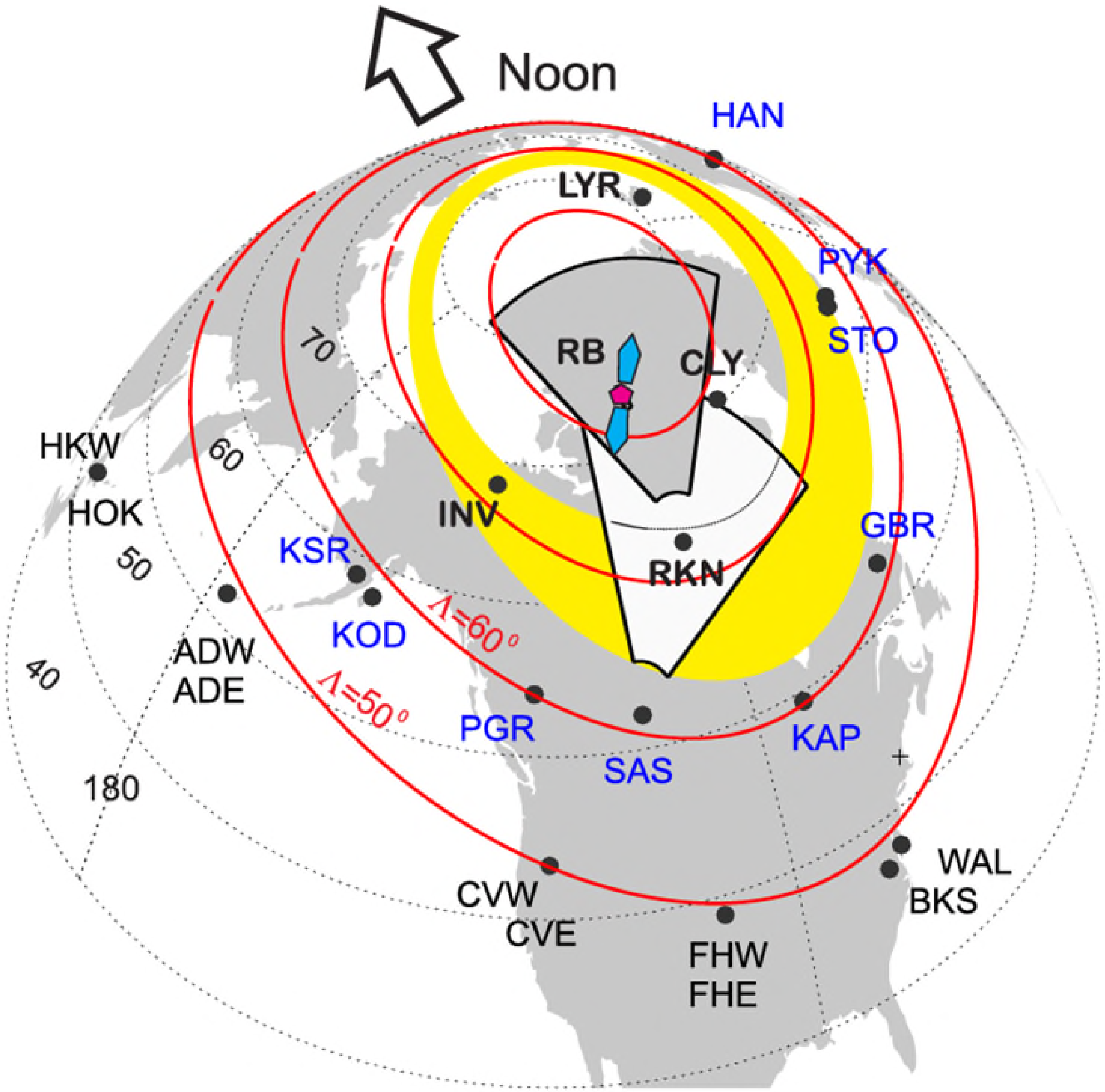


(a) Ray tracing for 10 MHz radio waves transmitted at Rankin Inlet. The 2-D electron density distribution is given by E-CHAIM (Themens et al., 2017) for 19 UT on 6 March 2016.

(b) Expected power of 10 MHz echoes from various heights as a function of RKN range gate Arbitrary units were used.

E region (below 120 km, green
F region (above 120 km, blue
Ground scatter, red

SuperDARN HF radars (10-12 MHz) in the Northern Hemisphere



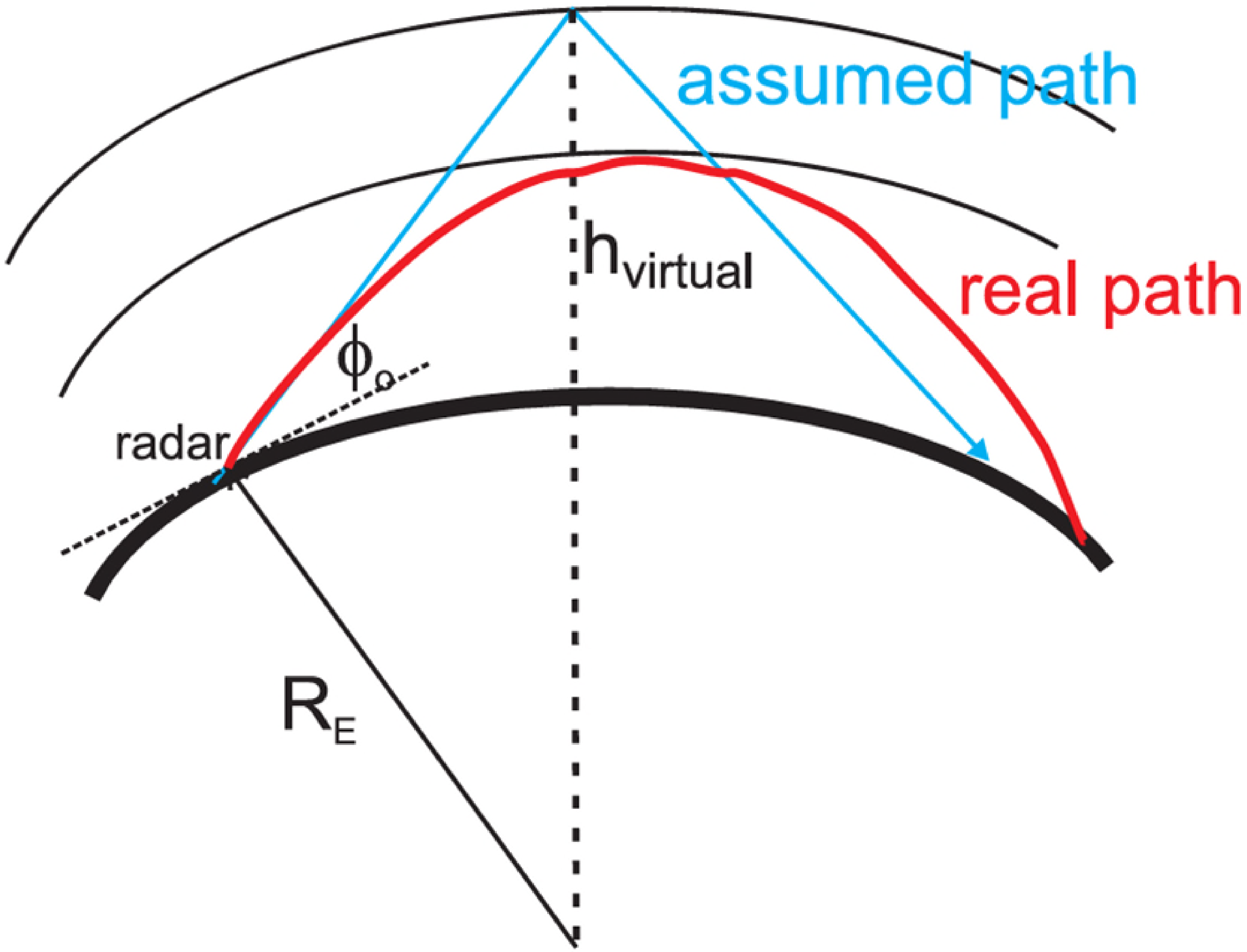
Selected:

Saskatoon (auroral oval)

&

Rankin Inlet (polar cap)

Some problems with SuperDARN mapping



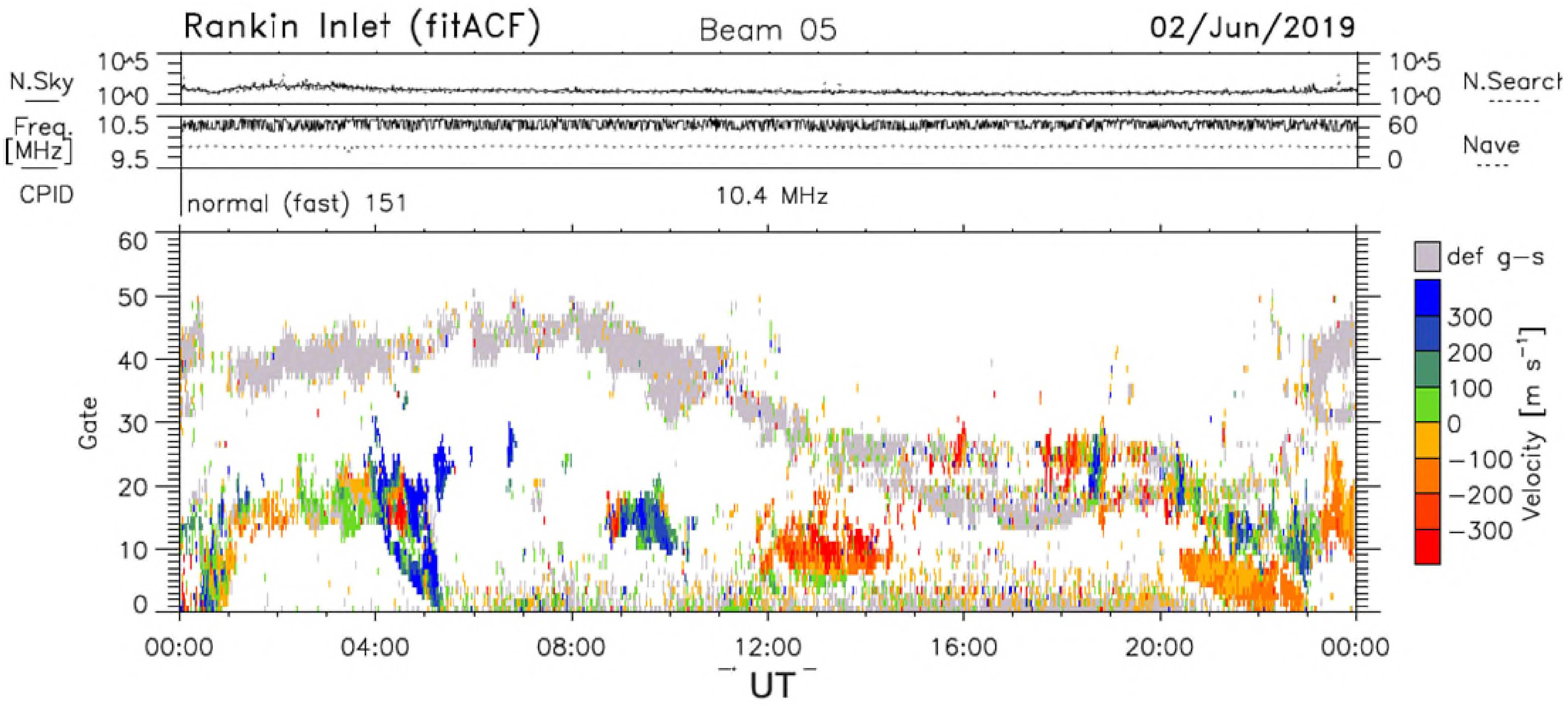
1. While mapping echo location, SuperDARN is using the model for the virtual height $h_{virtual}$

Improved method (Greenwald et al., 2017) of mapping using elevation angle data has not been implemented for routine measurements.

2. Ground scatter identification is not always reliable

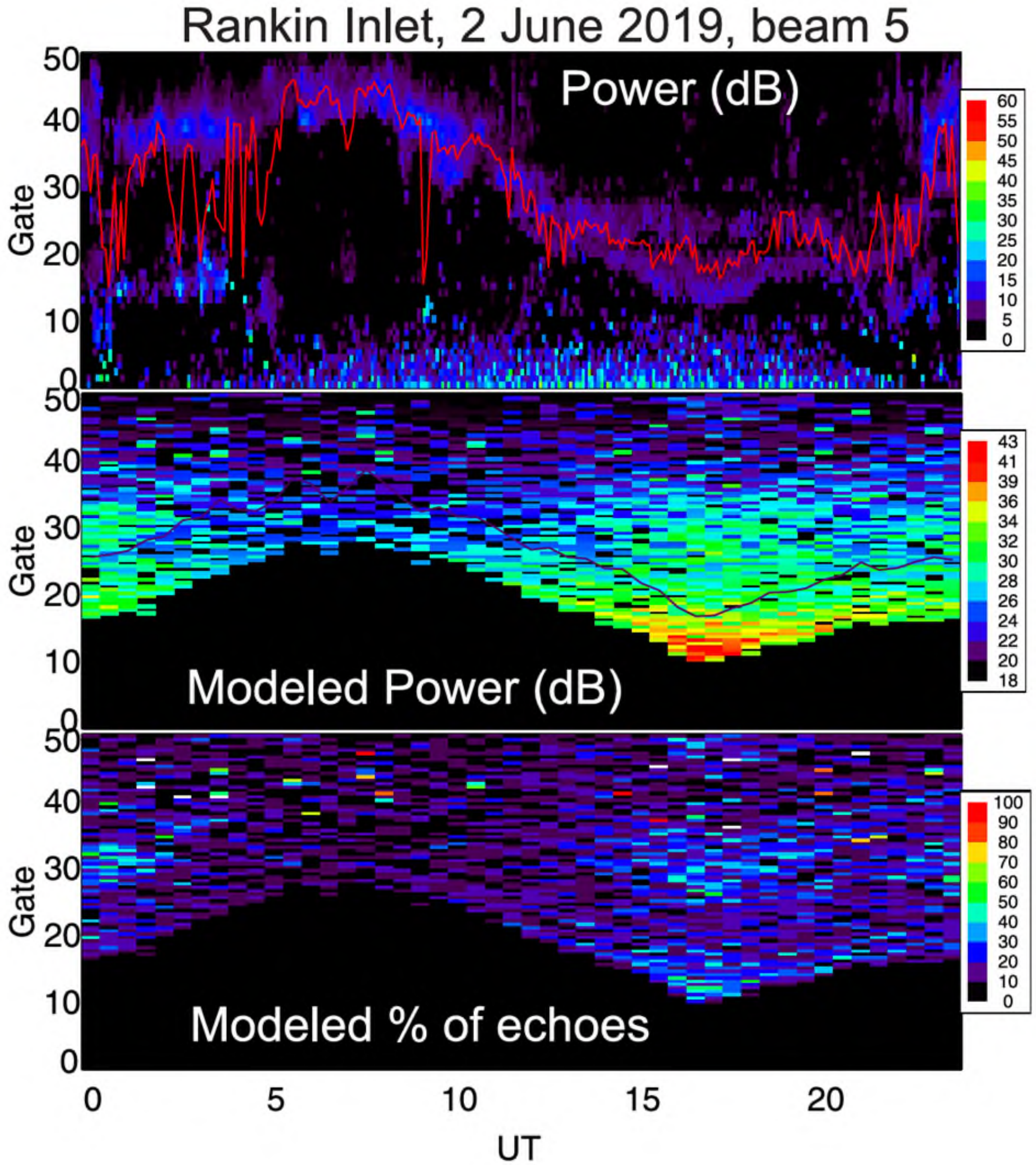
3. HF radio waves are very sensitive to 3-D electron density distribution

Rankin Inlet observations,02 Jun2019, Ionospheric &Ground Scatter



Ground scatter (G-S) is shown in grey

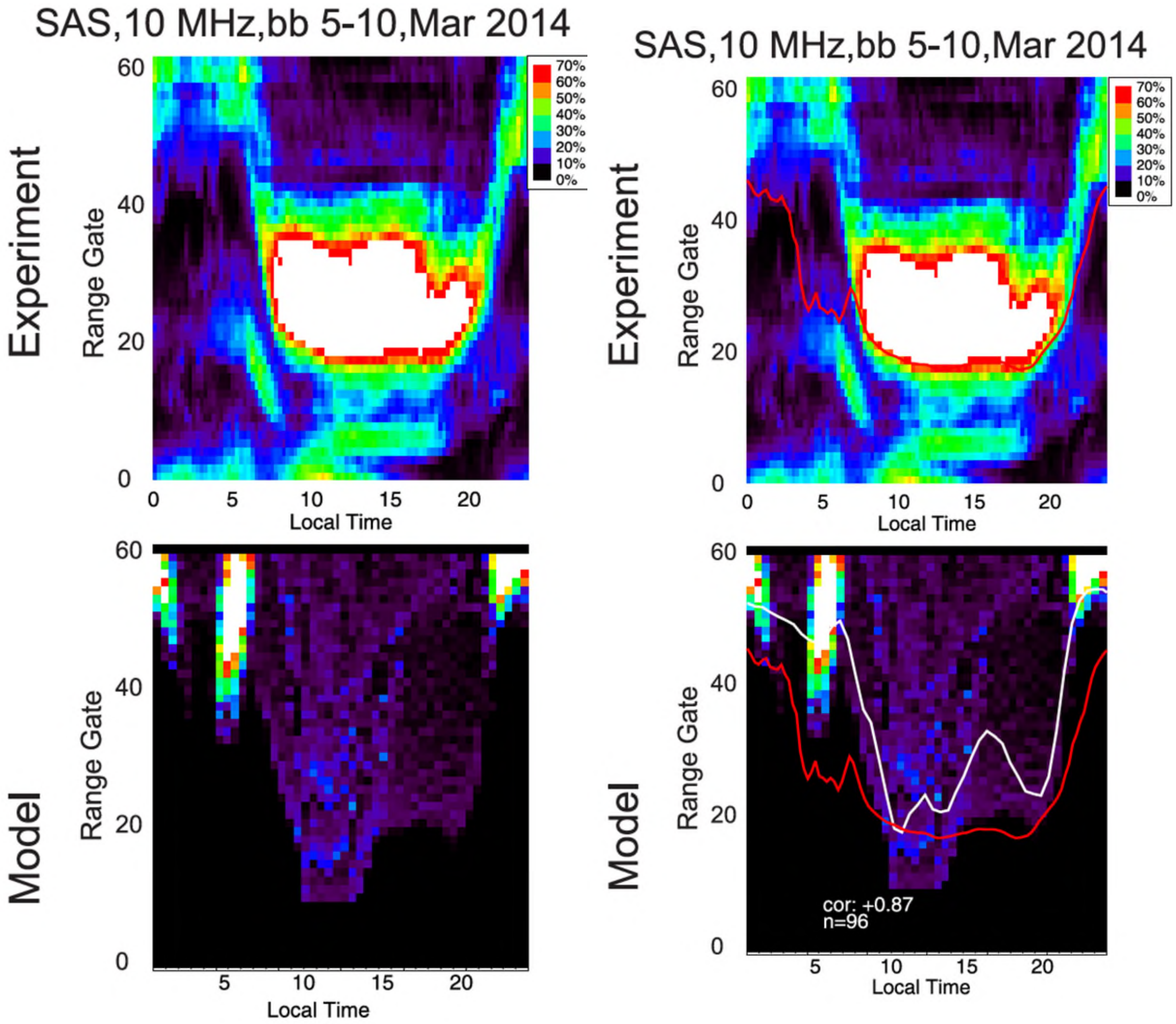
Comparison for an individual event (02 June 2019), summer case



Observed ground scatter bands at 10 MHz

Model Power prediction in dB

Model Occurrence Rate prediction in %

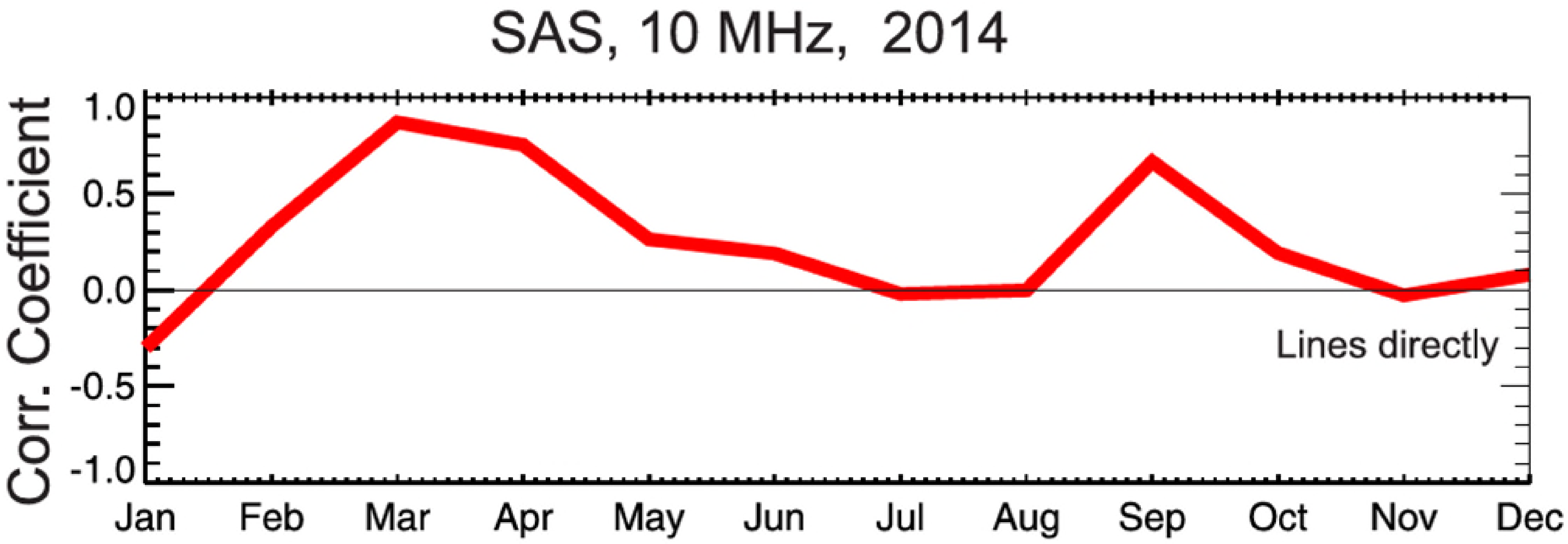


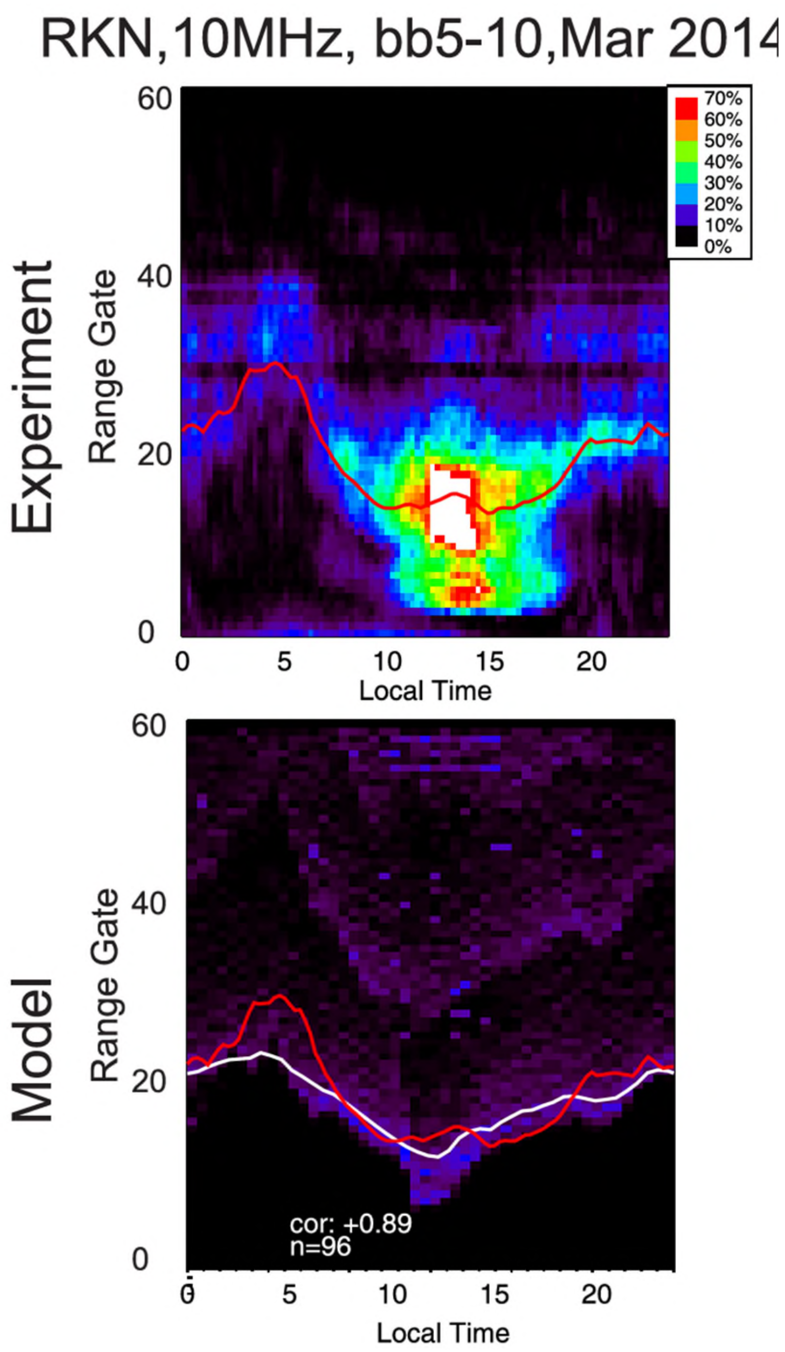
Saskatoon

Experiment and modeling

Monthly-averaged ground scatter echo bands with 15-min resolution, 10 MHz

Estimated band location comparison- lines directly


SAS, 10 MHz, 2014
Corr. Coefficient
1.0
0.5
0.0
-0.5
-1.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lines directly

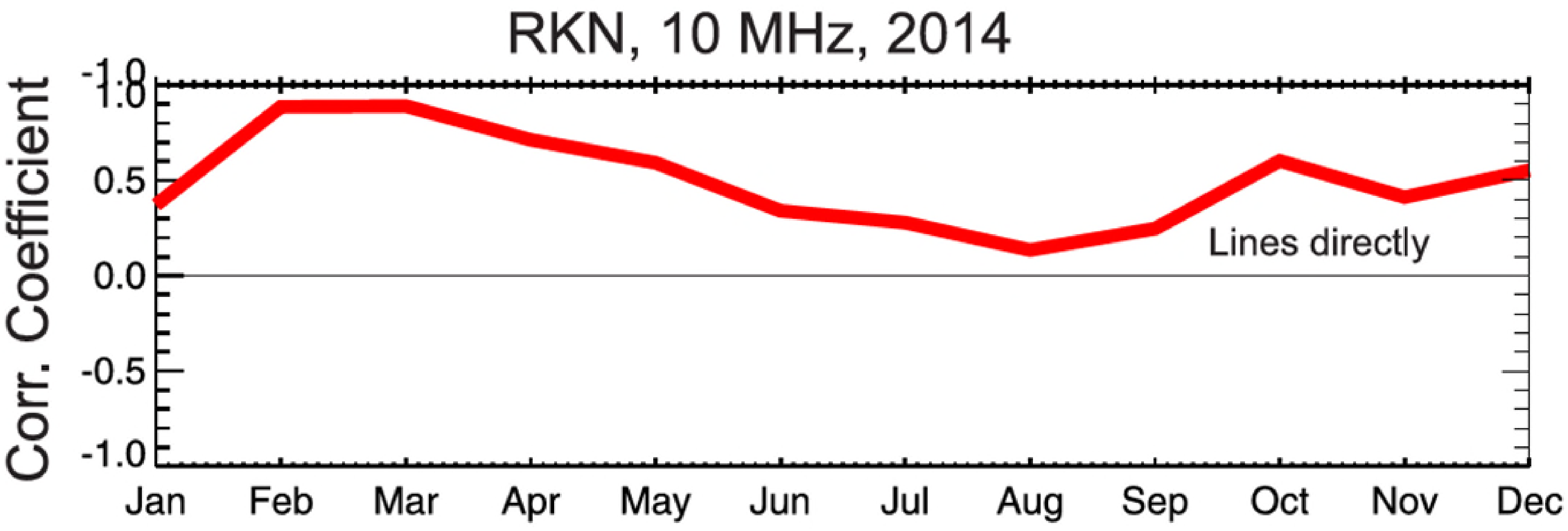


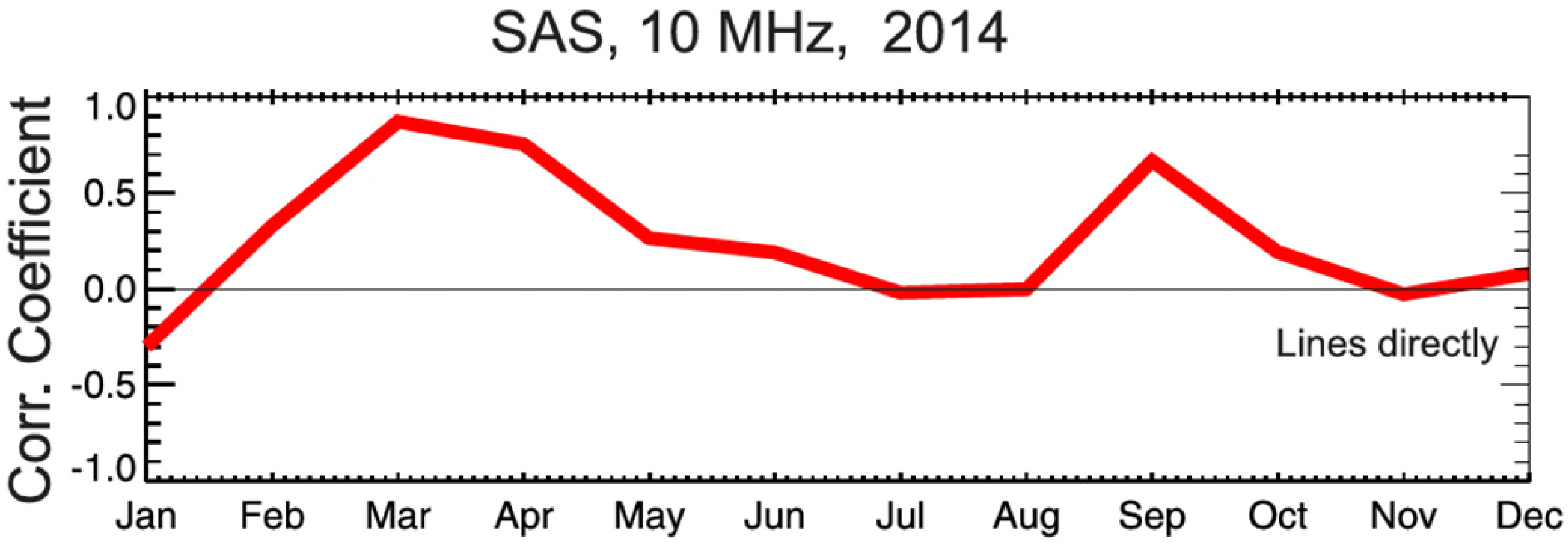
Rankin Inlet

Experiment and modeling

Monthly-averaged Ground scatter echo bands with 15-min resolution, 10 MHz

Estimated band location comparison- lines directly


RKN, 10 MHz, 2014
Corr. Coefficient
1.0
0.5
0.0
-0.5
-1.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lines directly


SAS, 10 MHz, 2014
Corr. Coefficient
1.0
0.5
0.0
-0.5
-1.0
Jan
Feb
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May
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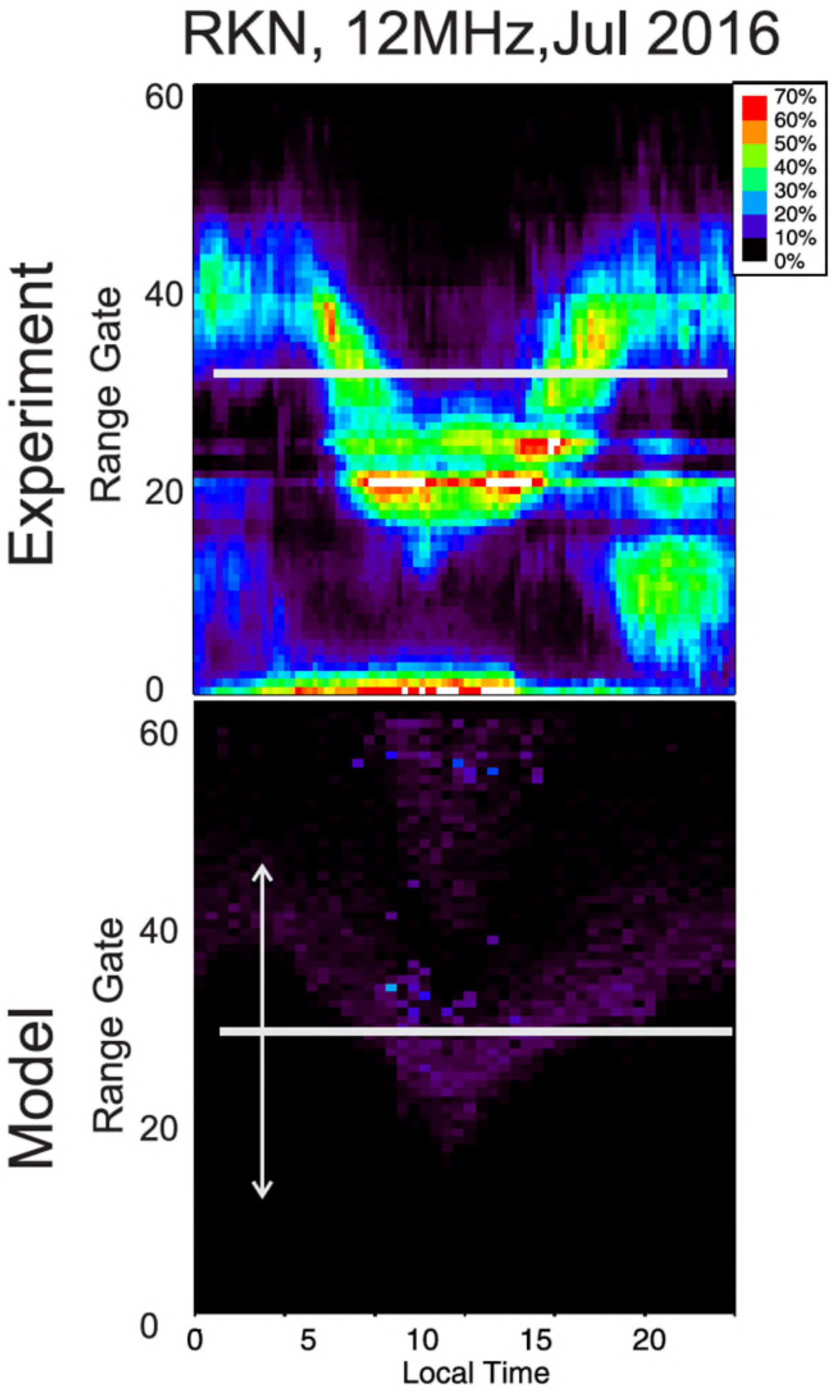
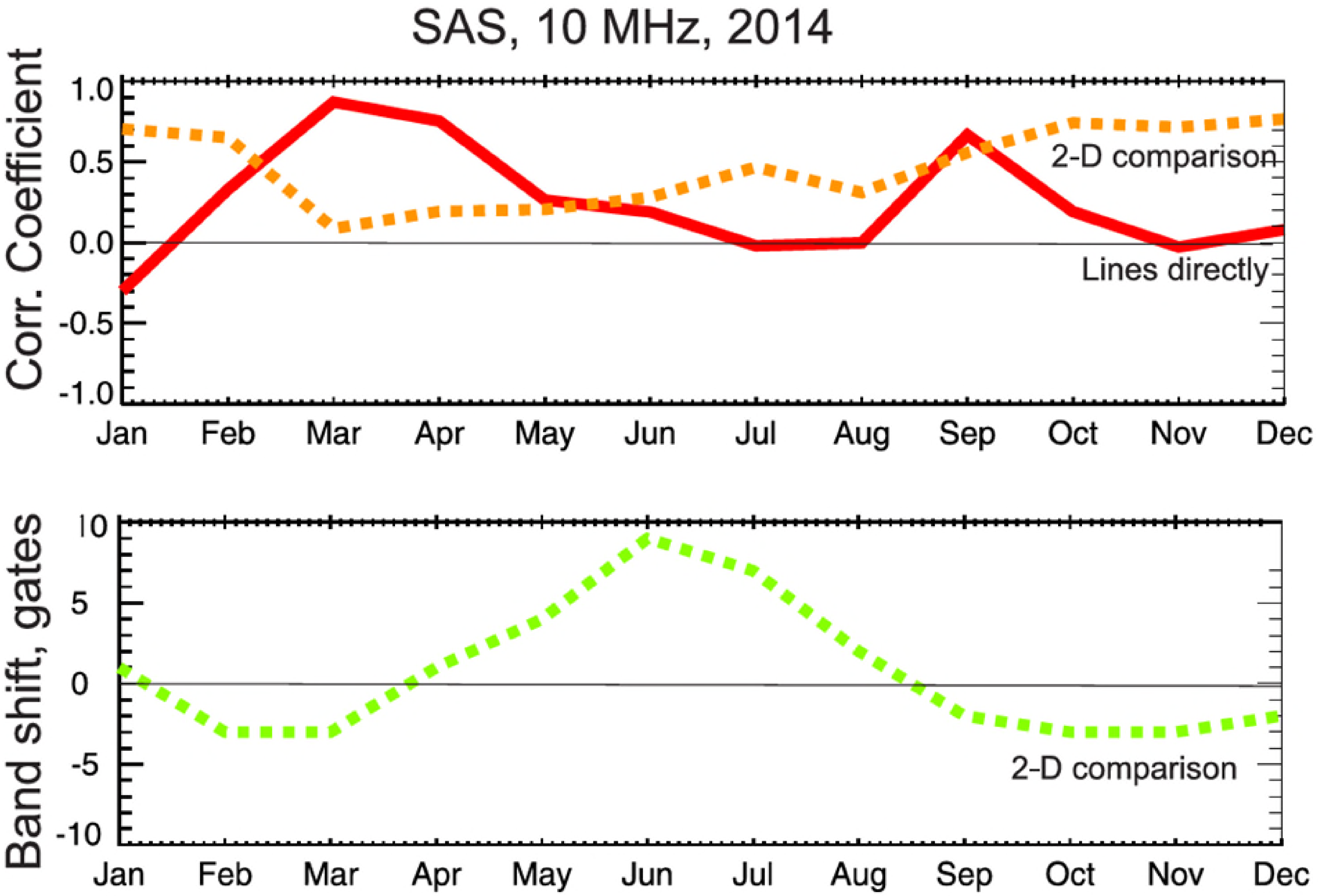
Sep
Oct
Nov
Dec
Lines directly

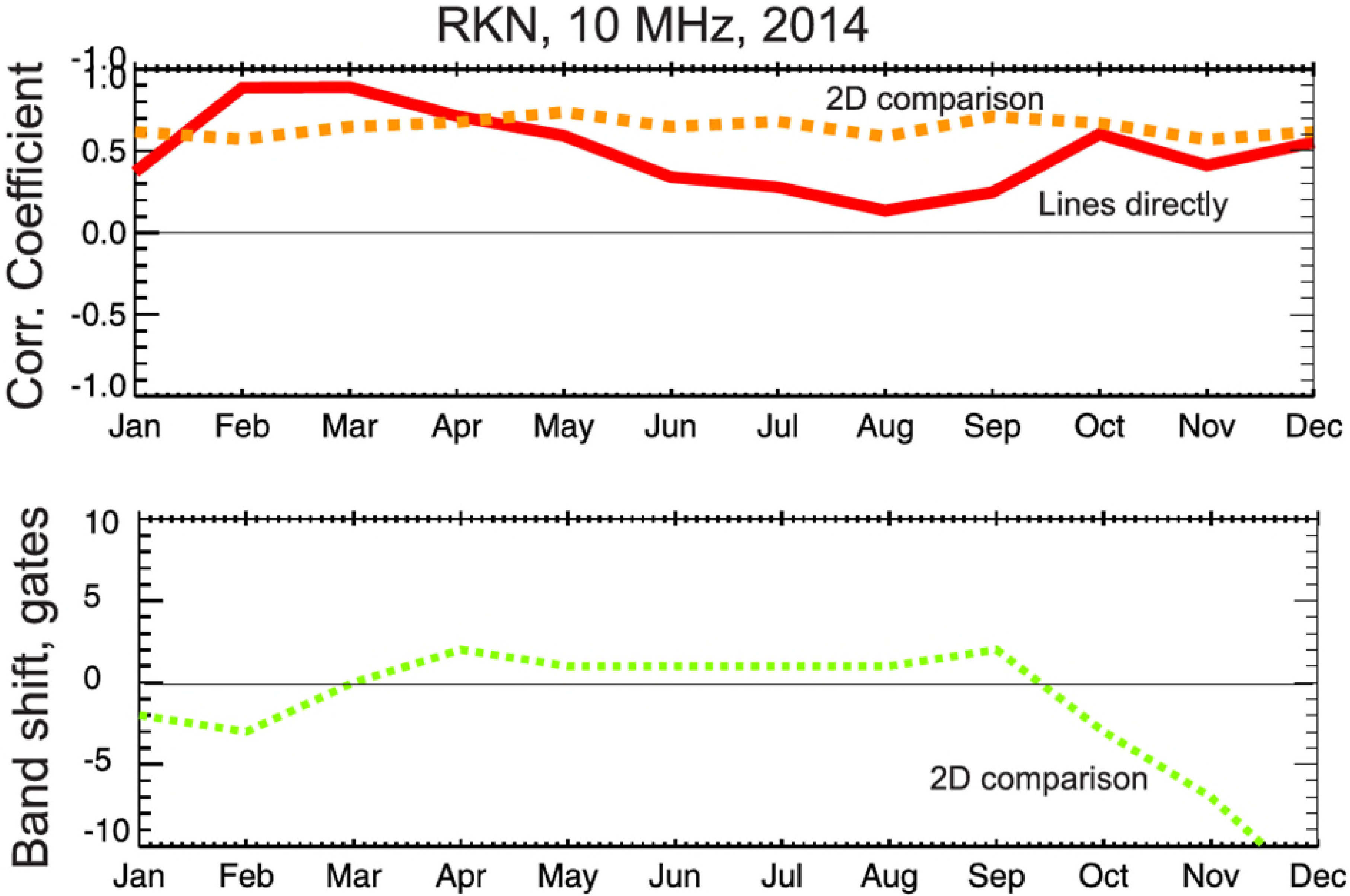


A different way of assessing:

2-D pattern correlation

Considered correlation of diurnal variations at all range gates by allowing some range gate shift for a modeled distribution. Selected the optimal gate separation.


SAS, 10 MHz, 2014
Corr. Coefficient
1.0
0.5
0.0
-0.5
-1.0
2-D comparison
Lines directly
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Band shift, gates
10
5
0
-5
-10
2-D comparison
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



RKN, 10 MHz, 2014
Corr. Coefficient
-1.0
1.0
0.5
0.0
-0.5
-1.0
2D comparison
Lines directly
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Band shift, gates
10
5
0
-5
-10
2D comparison
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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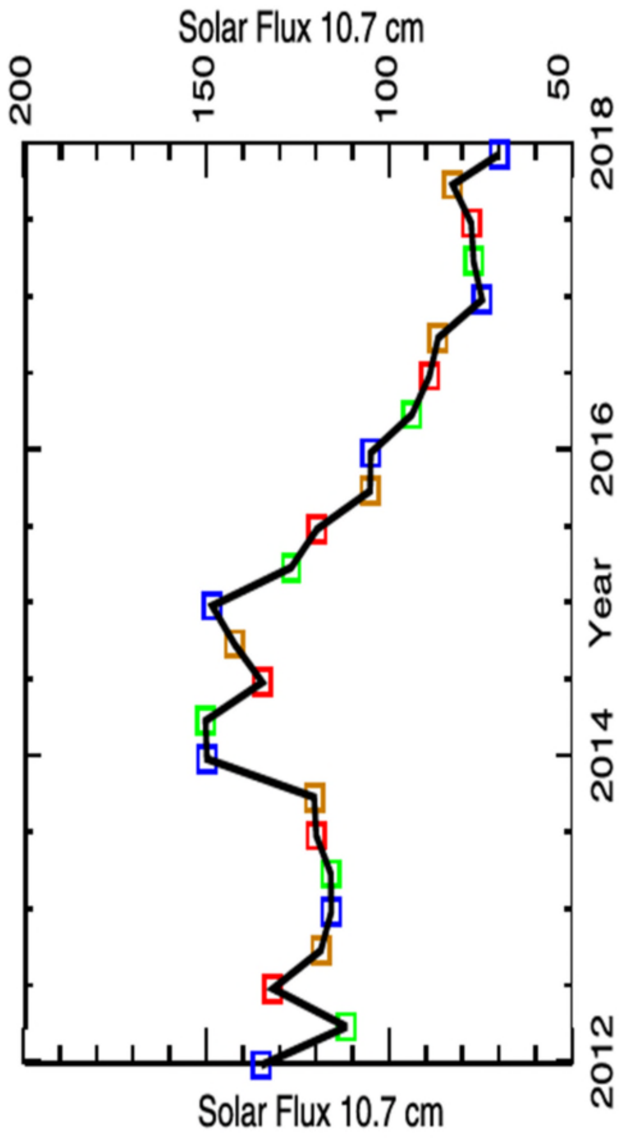
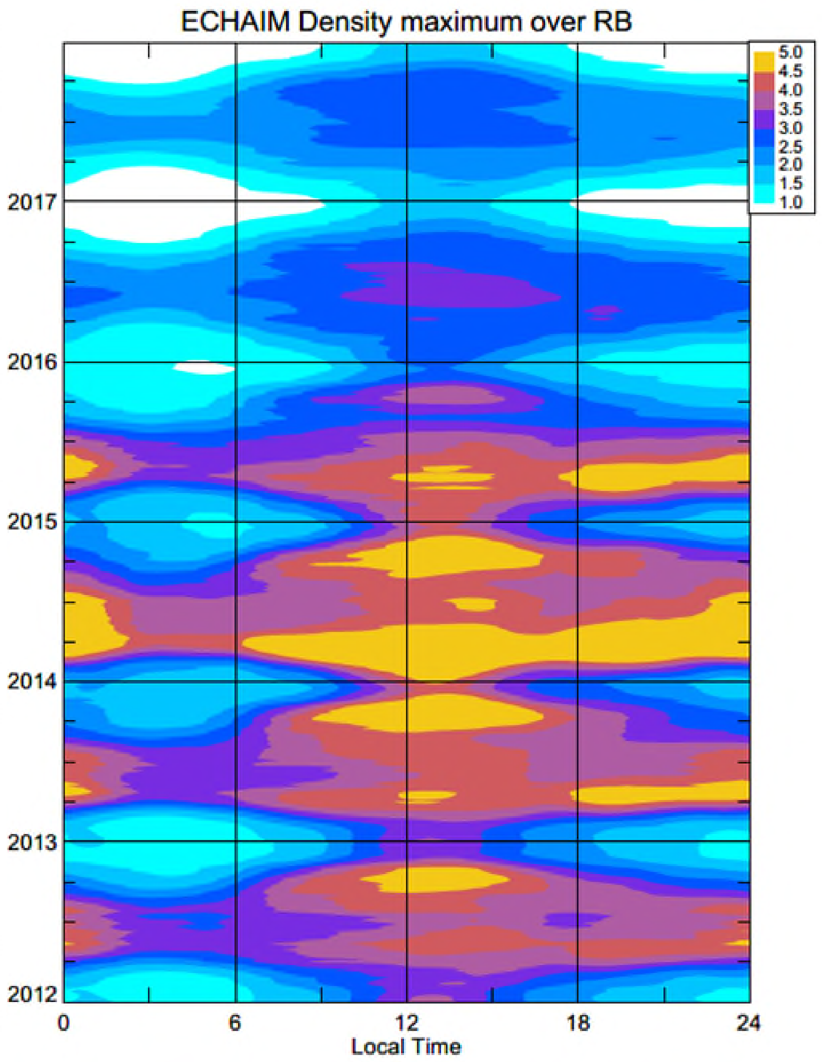
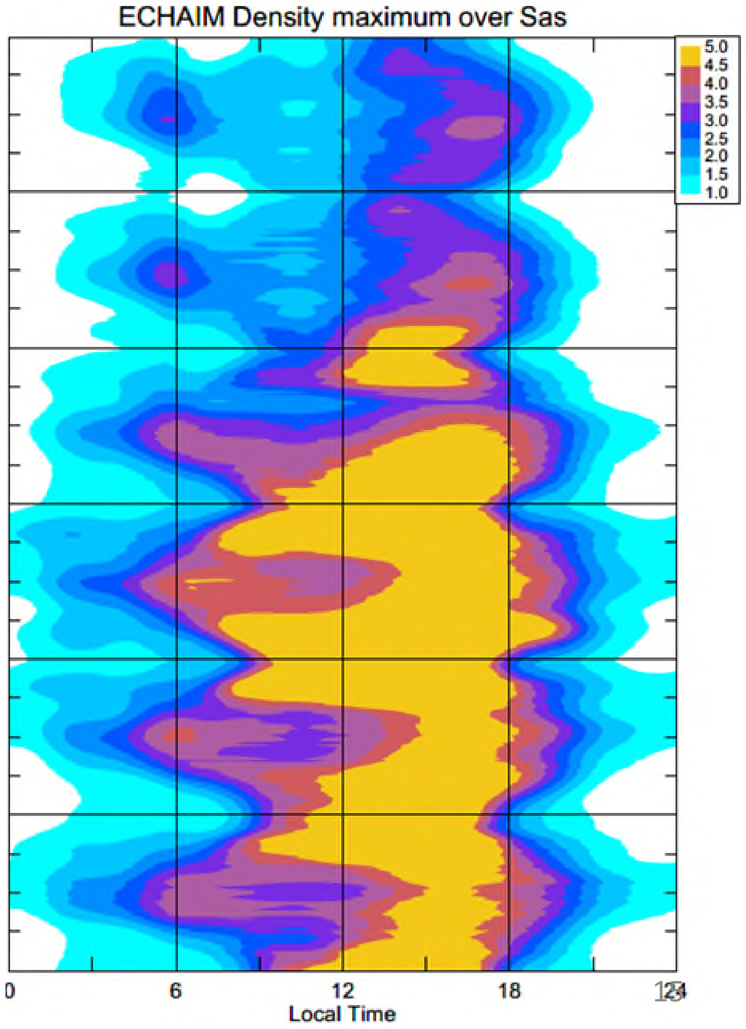
Oct
Nov
Dec

Long-term trends

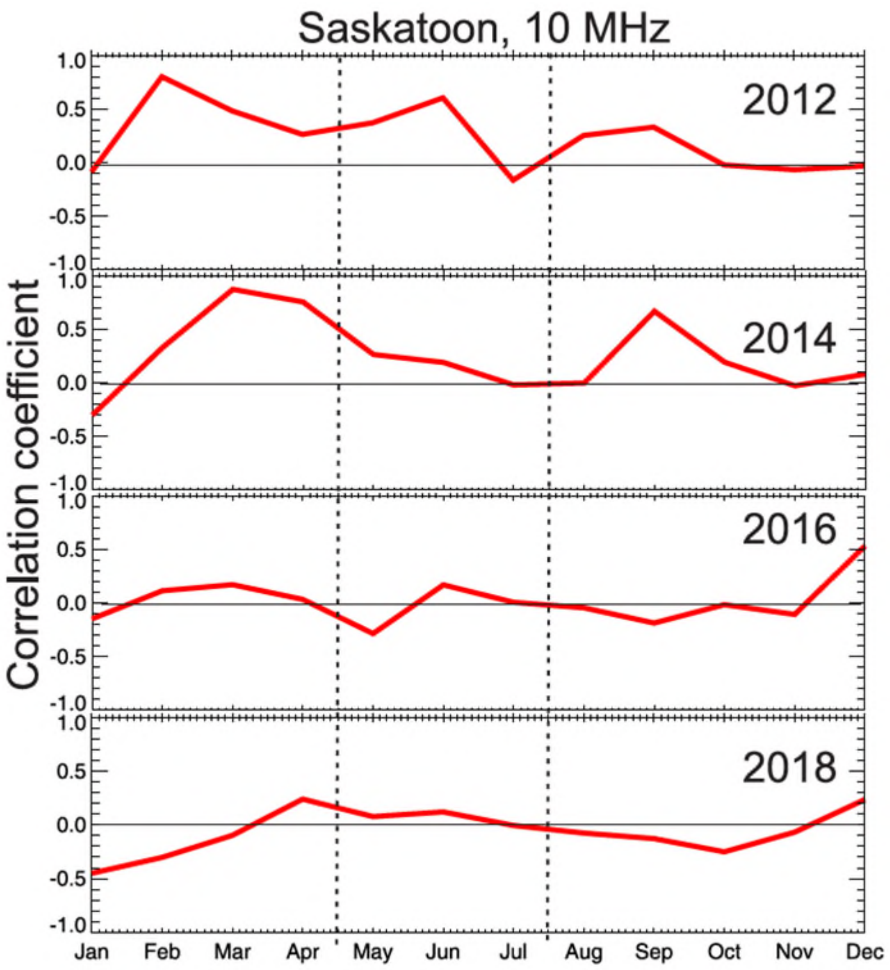
E-CHAIM NmF2 variations for the RKN and SAS viewing zones

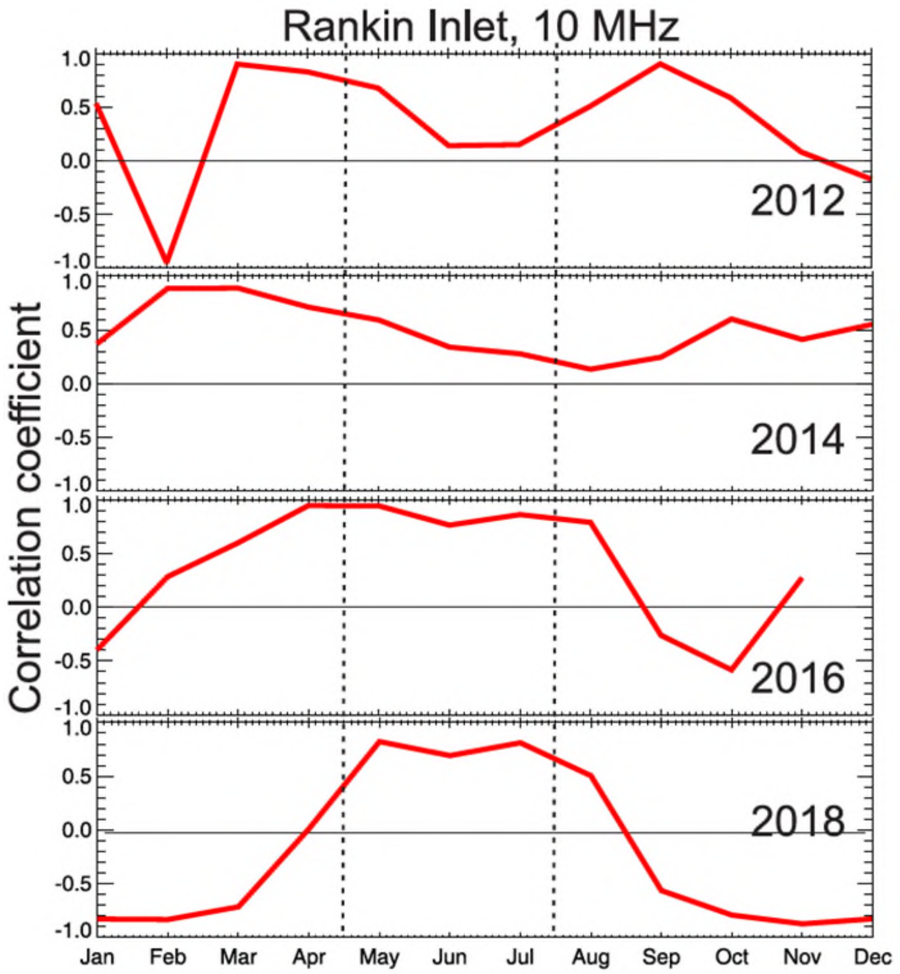






Correlation coefficients for average band location

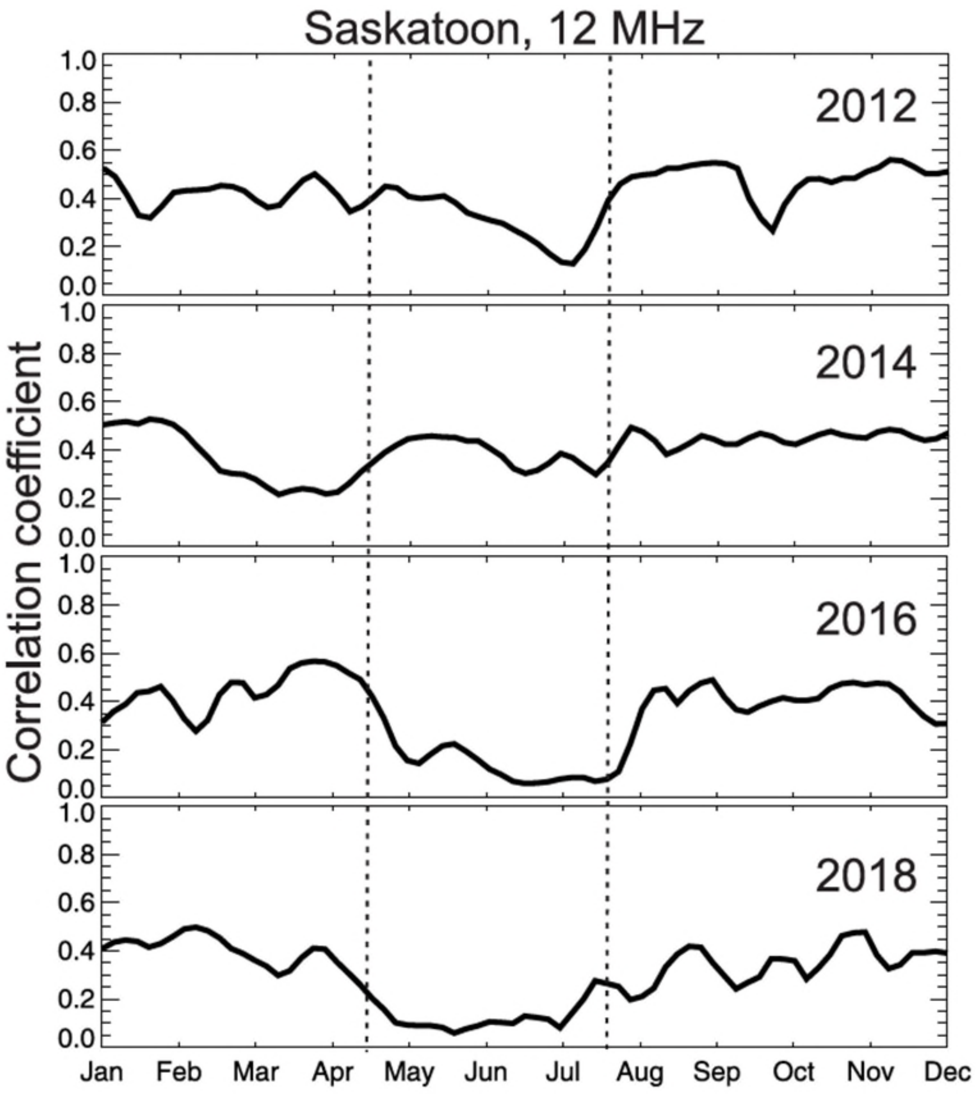


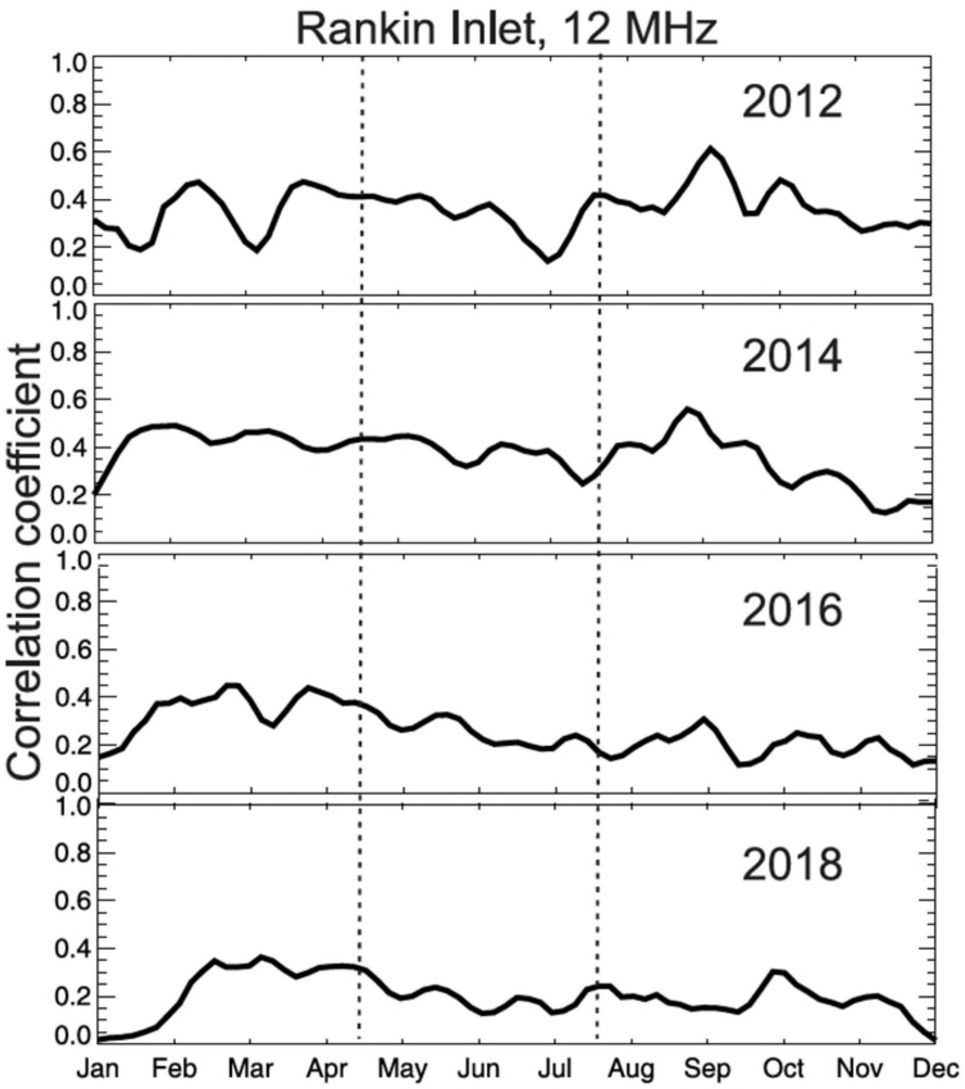


Auroral zone: Agreement deteriorates toward solar minimum in all seasons.

Polar Cap: Agreement deteriorates toward solar minimum in winter but improves in summer. Equinoctial maxima are changing to summer max, in agreement with NmF2

Correlation coefficients for 2-D patterns comparison





Auroral zone: Agreement deteriorates toward solar minimum in summer.

Polar Cap: Agreement deteriorates toward solar minimum in winter and somewhat in summer

Conclusions

1. Matching observed SuperDARN bands and predictions of the E-CHAIM model is doable but analysis is not straightforward owing to many factors affecting SuperDARN GS occurrence, e.g. presence of E region bands

2. Performed crude analysis shows that matching of predictions and observations are more successful for the polar cap

3. For the auroral zone: Agreement deteriorates toward solar minimum, stronger in summer

4. For the polar cap: Agreement deteriorates toward solar minimum in winter. Agreement is better for seasons with largest electron densities