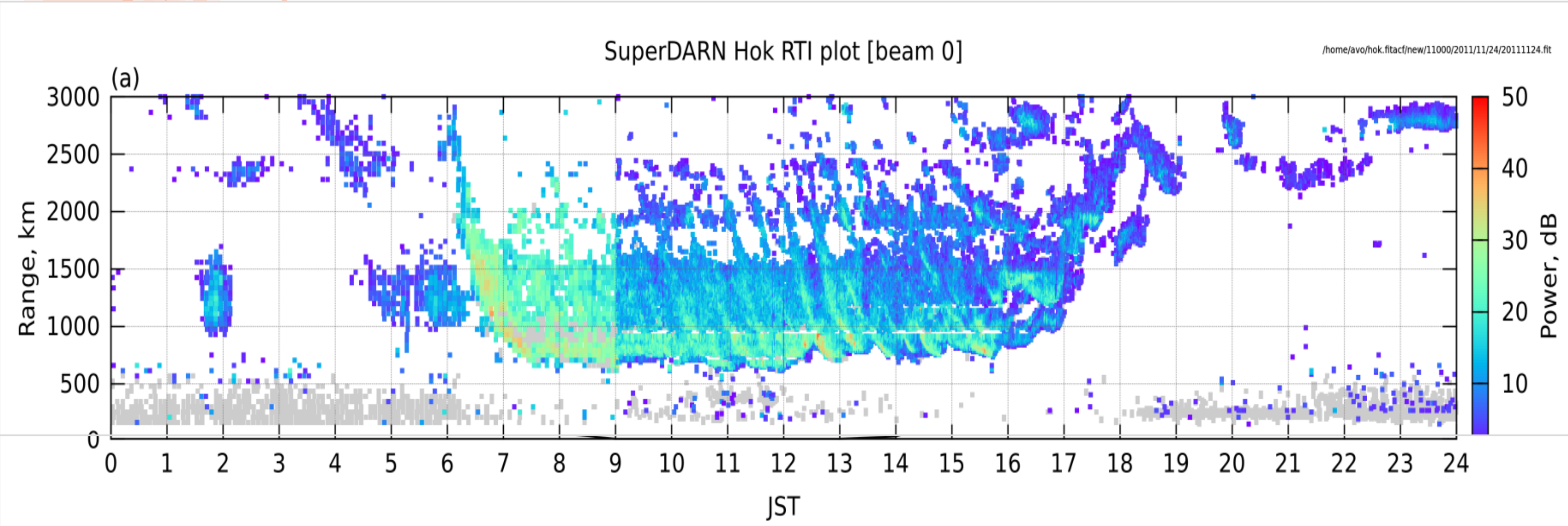
Model of several ground backscatter echo parameters calculated using IRI for SuperDARN Hokkaido radar: comparison with observations



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OUTLINE

Introduction

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2. **SuperDARN Hokkaido radar GB model**
    - Diurnal and seasonal variations of GB signal characteristics
    - Application of the model
3. **Comparison with observational data**

Conclusion

1. Technique for HF GB simulation

The technique is based on waveguide approach. Scattered field in the Earth–ionosphere waveguide can be expressed by series of eigen functions

$$E_j(\vec{r},t) = \mathrm{Re}\left\{ \frac{A}{y\sqrt{\sin\theta}} \sum_n (\gamma_n)^{-1/2} I_{nj}(\varphi) P_{nj}(\vec{r}) A_{nj}(\vec{r}) g_0(t-\tau_n(\vec{r})) e^{i\Phi_{nj}(\vec{r})-i\omega_0 t} \right\}$$

where $A_n(\vec{r})$, $\Phi_n(\vec{r})$ and $\tau_n(\vec{r})$ are amplitude, phase and delay of the eigen function of the waveguide, $g_0(t)$ is an envelope of the pulse, $I_n(\varphi)$ and $P_n(\vec{r})$ are excitation and receiving coefficients, n is a number of eigen function.

The mode structure of the received signal is determined using the “stationary condition”

$$L_n^{\pm}(\vec{r}, f) = \frac{1}{2\pi}(\Phi_n^{\pm}(\vec{r}) - \Phi_{n+1}^{\pm}(\vec{r})) = l^{\pm}$$

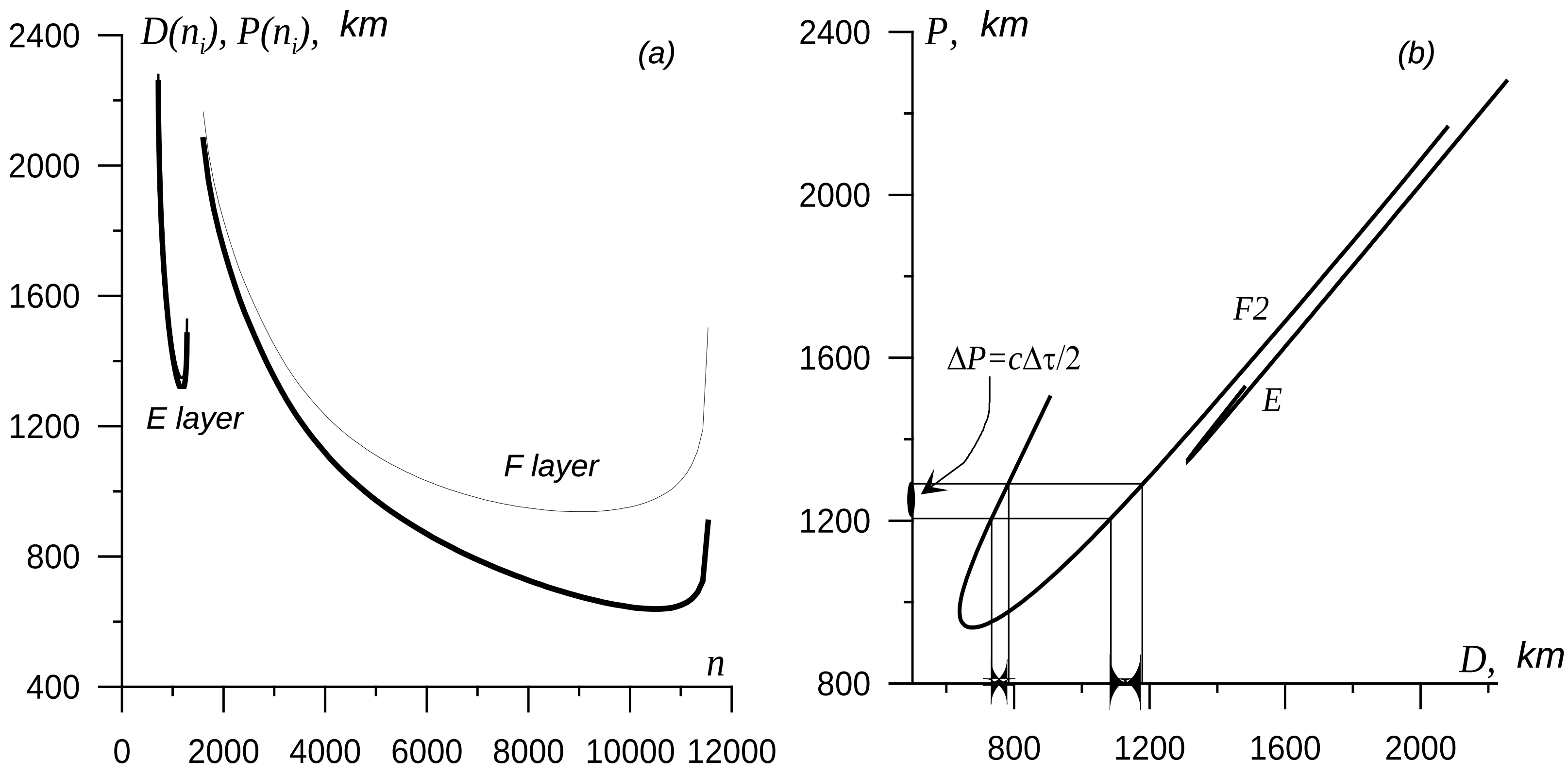
The relation between excitation coefficient and scattering coefficient $\sigma(\alpha_i, \alpha_s)$ of the rough ground surface is given by

$$I_n(\varphi) = \frac{C_n}{ka^3} c A_i \sqrt{\frac{\gamma(\alpha_i, \alpha_s) S \cos\alpha_i}{4\pi}} e^{-iZ_n}$$

Here S is a square of the scattering area, A_i is amplitude of the incident field, α_i and α_s are incidence and scattering angles accordingly. For calculation of scattered field amplitude analytical formulation of scattering coefficient is also needed

$$\gamma(\alpha_i, \alpha_s) = 4\pi k^4 \cos^2\alpha_i \cos^2\alpha_s |\mu|^2 W(-k(\sin\alpha_i + \sin\alpha_s))$$

1. Technique for HF GB simulation

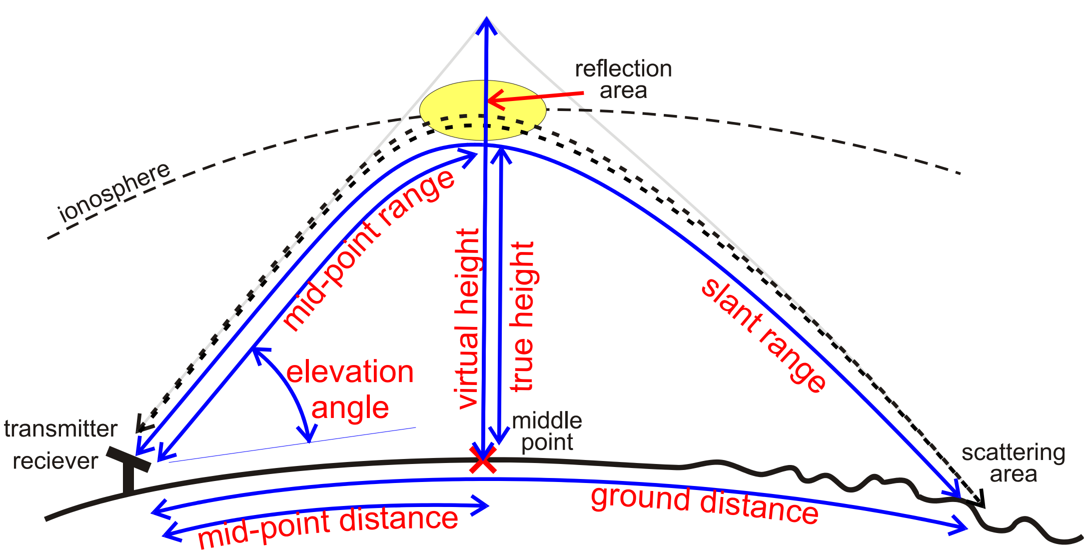


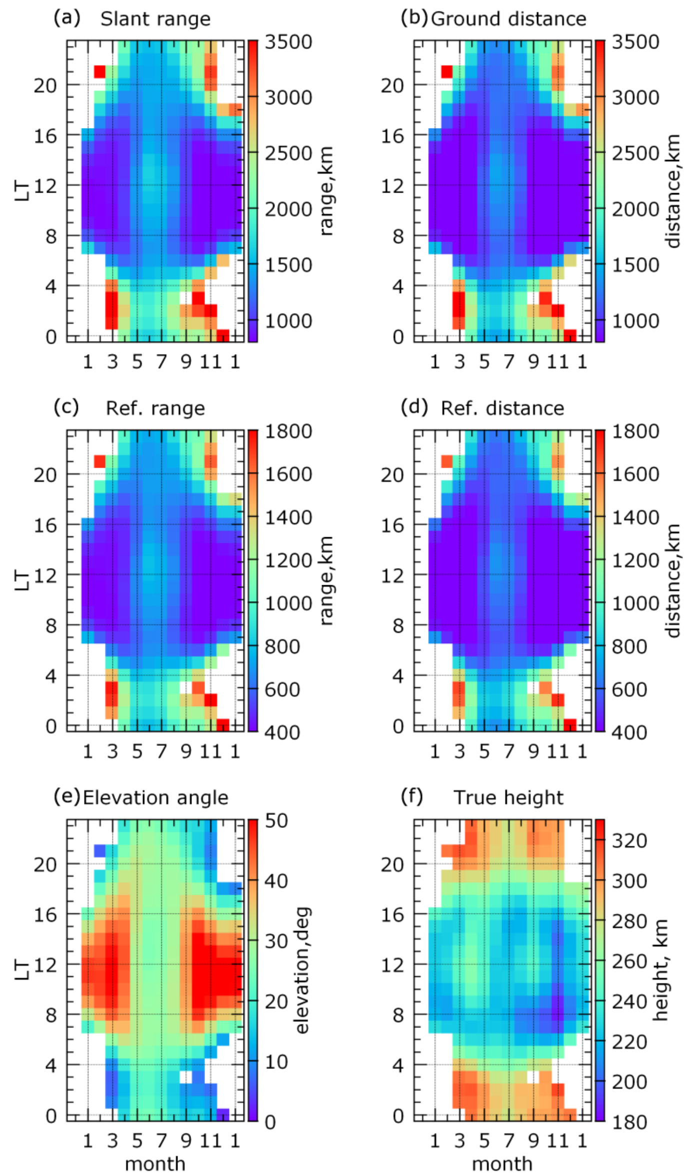
Dependencies of the ground range D and group range P from the number of eigen function (a) and corresponding dependence P(D) (b)

2. SuperDARN Hokkaido radar GB model

Diurnal and seasonal variations of the calculated characteristics of 1-hop ground backscatter from F2-layer, beam #0 at 11 MHz in 2013

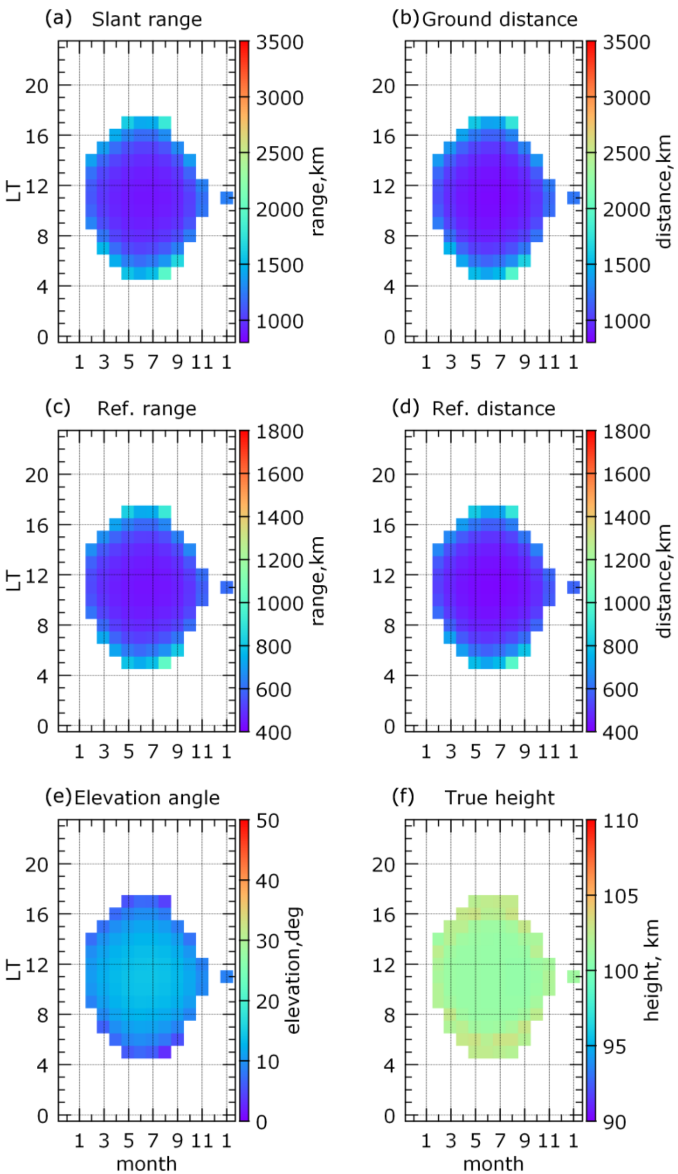
(a) minimum slant range,
(b) corresponding ground distance,
(c) mid-point range (ref. range),
(d) mid-point distance (ref. range),
(e) elevation angle,
(f) true height



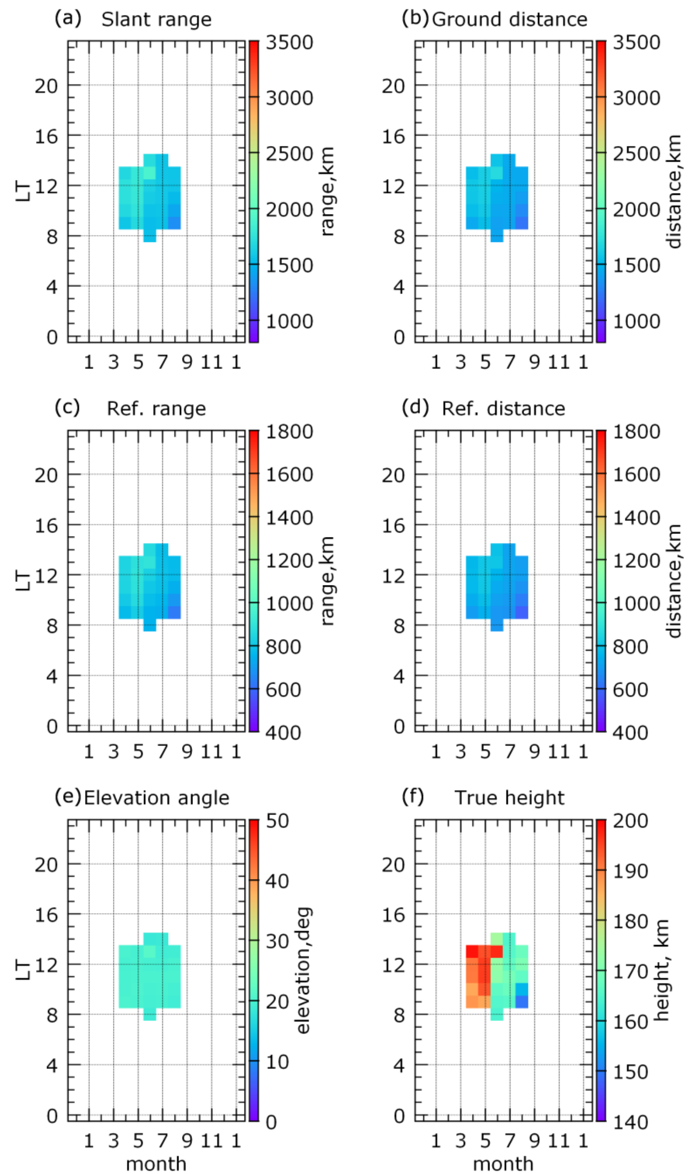


2. SuperDARN Hokkaido radar GB model

1−hop ground backscatter from E−layer, beam #0 at 11 MHz in 2013

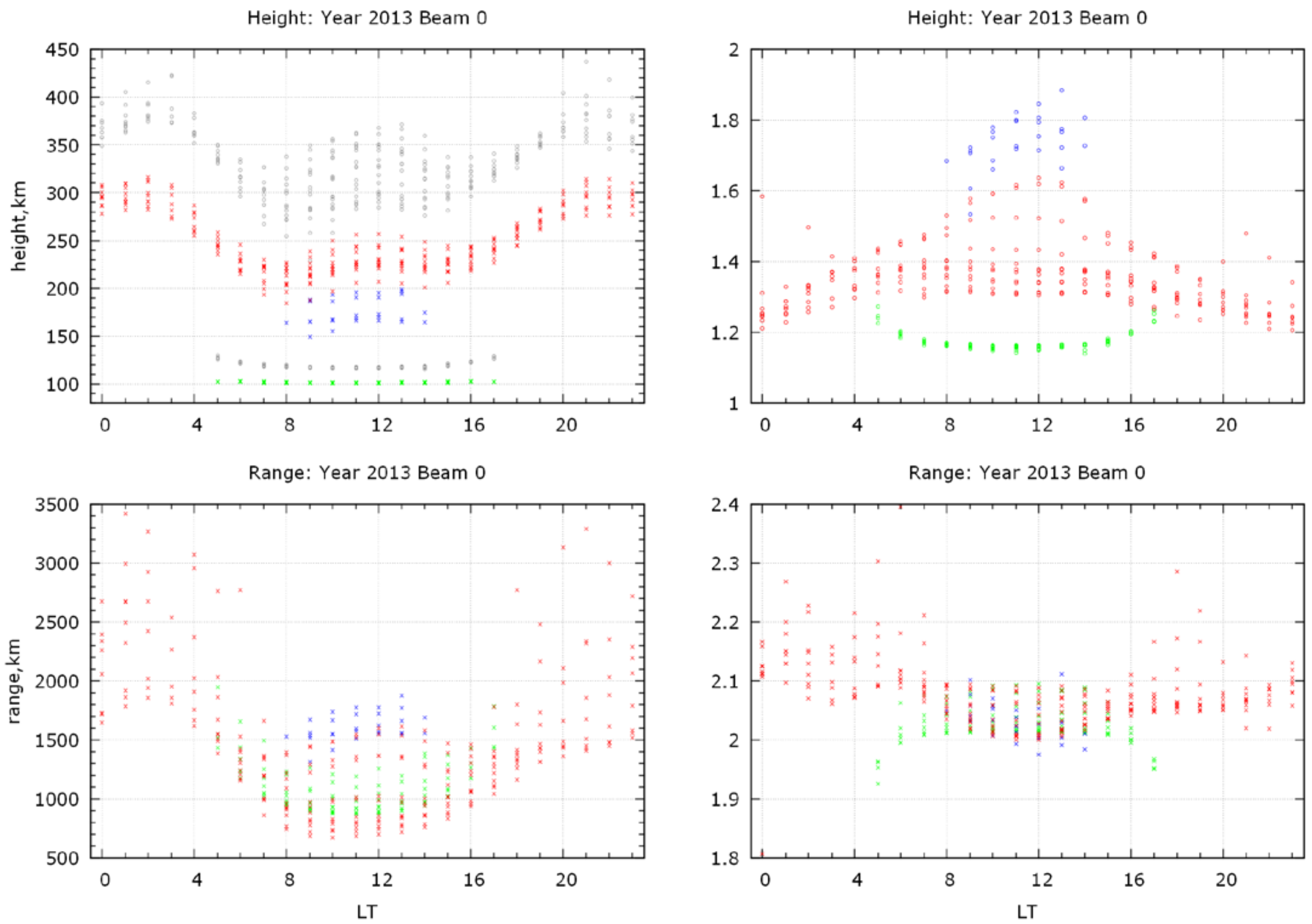


1−hop ground backscatter from F1−layer, beam #0 at 11 MHz in 2013



2. SuperDARN Hokkaido radar GB model

True height and slant range for F2, F1 and E-layer GB echoes



2. SuperDARN Hokkaido radar GB model

How can we use the model for mapping?

Calculated additional parameters from GB model for F2-layer

(a) mid-point range to full range ratio,

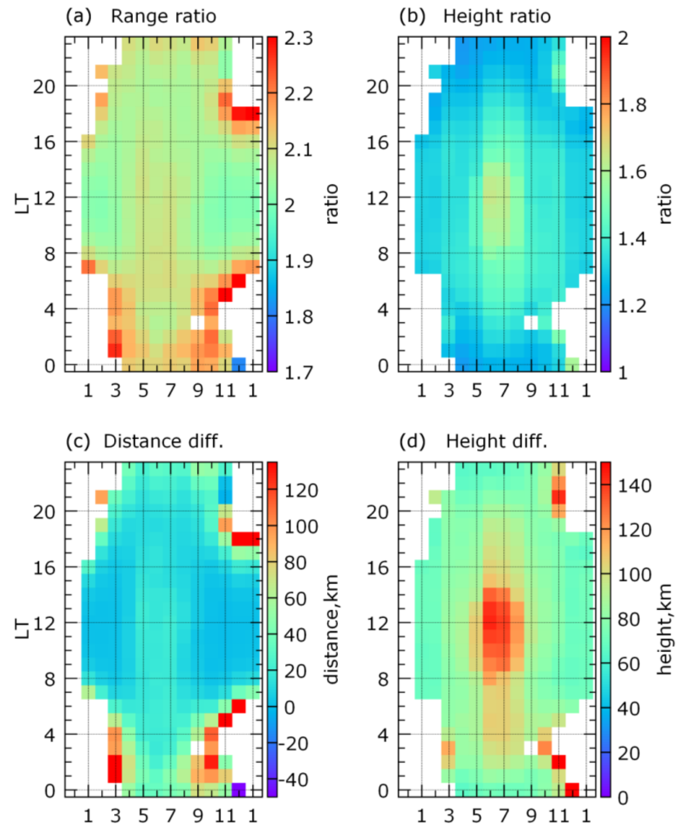
(b) virtual to true height ratio,

(c) difference between calculated (1) and model mid-point distance,

(d) difference between virtual (2) and true height

$$D_{m.p.} = r_0 arctg\left[\frac{\frac{P}{2}\cos\alpha}{r_0 + \frac{P}{2}\sin\alpha}\right] \quad (1)$$

$$h_{virt} = \sqrt{2r_0 P_{m.p.}\sin\alpha + r_0^2 + P_{m.p.}^2} - r_0 \quad (2)$$

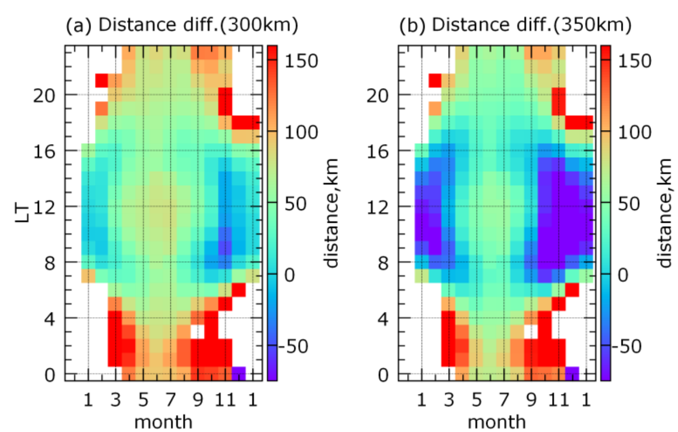


Mapping using fixed height

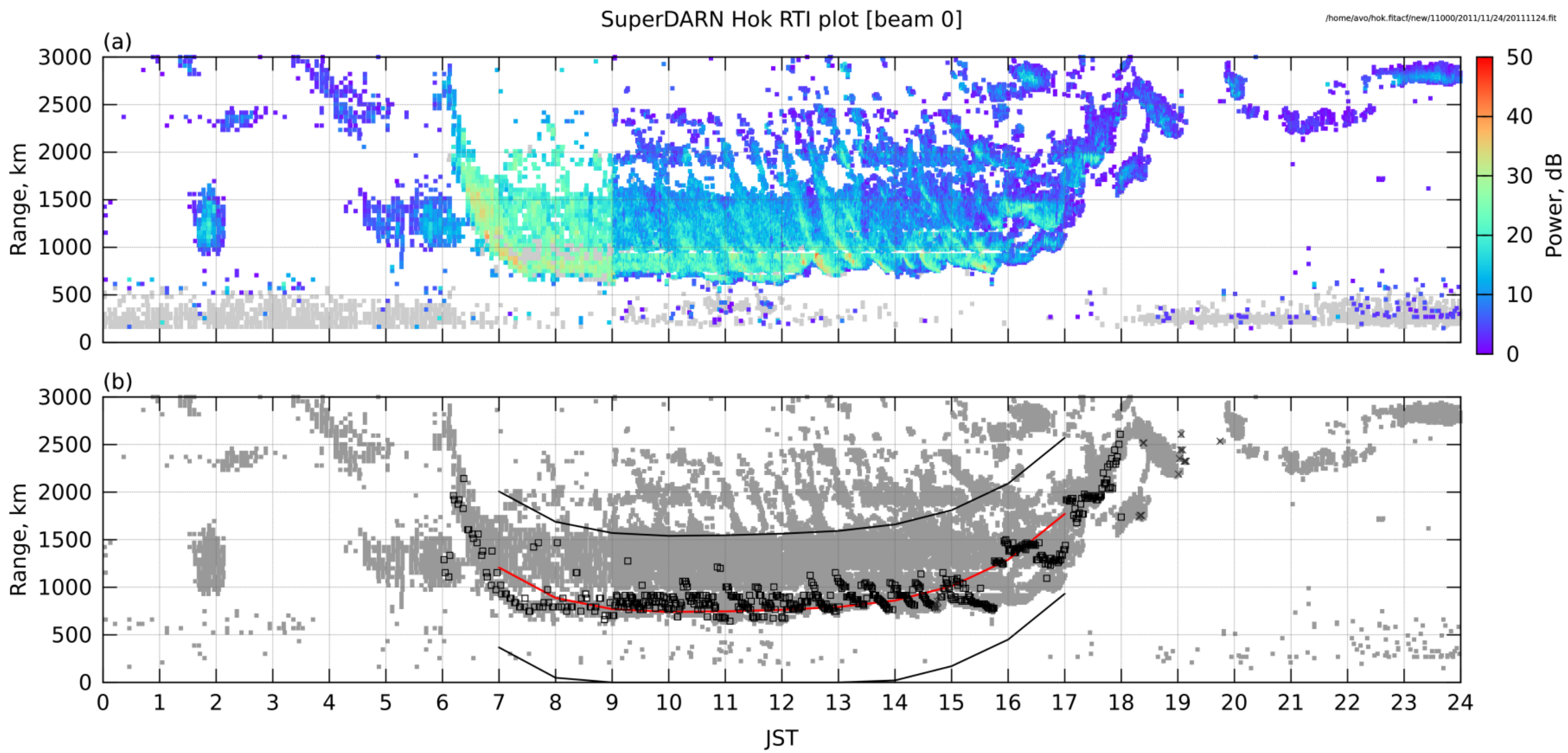
(a) 300 km,

(b) 350 km

$$D_{m.p.} = r_0 \arcsin\left[\frac{\sqrt{\frac{P^2}{4} - h^2}}{r_0}\right]$$



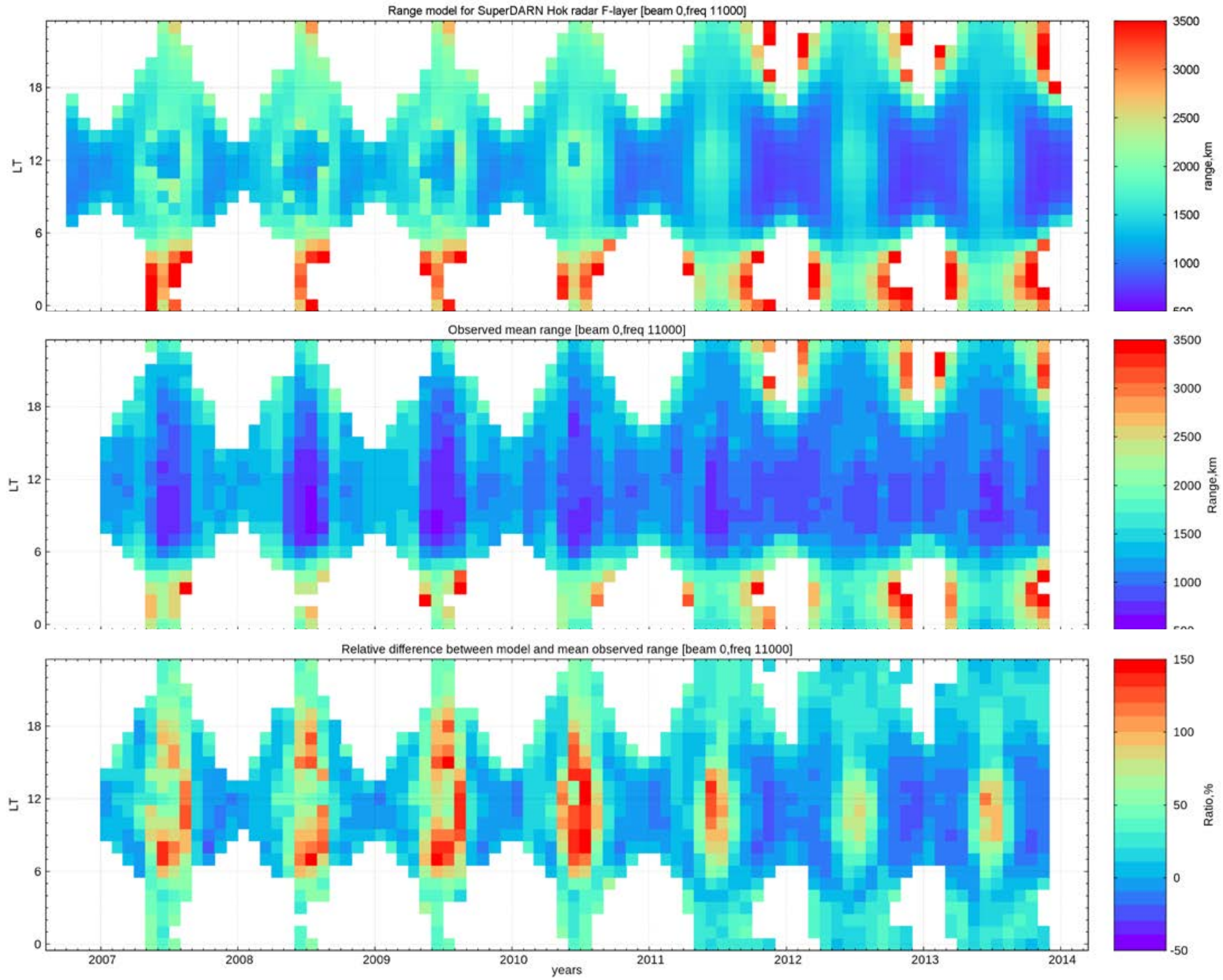
3. COMPARISON WITH OBSERVATIONAL DATA



1. **We calculate GB model prediction** **(red curve)** of minimum range (P_{GB}) for given date (November 24, 2011).
2. We find the **range corresponding to the peak power (black rectangulars)** within **P_{GB} ± 800 km (black curves).** Such way allows to exclude certainly irregular echoes (e.g. at winter nighttime) but don't affect the usual variations caused by ionospheric disturbances of different nature.
3. Whole dataset obtained by Hokkaido radar were processed in such way.

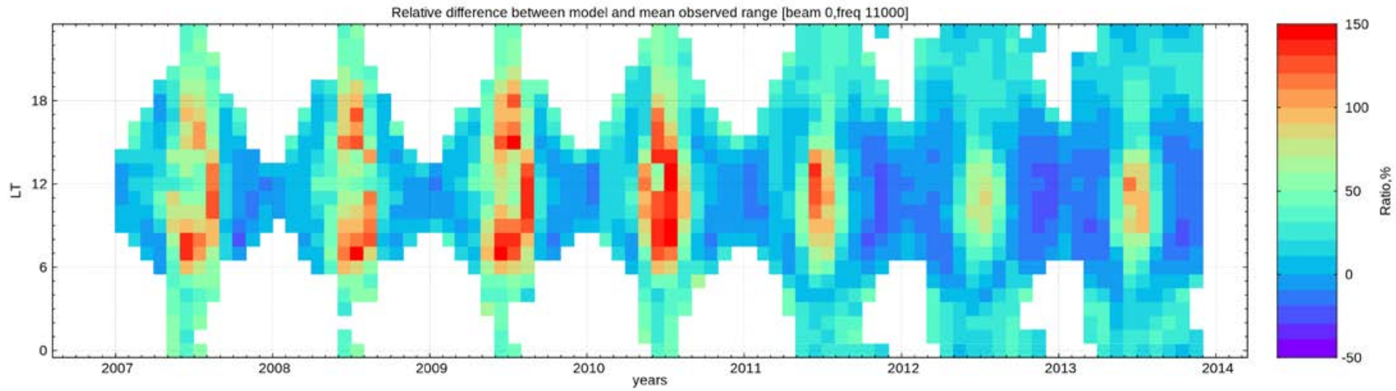
3. COMPARISON WITH OBSERVATIONAL DATA

Model and observed monthly mean minimum range and their relative difference for beam #0 and 11 MHz

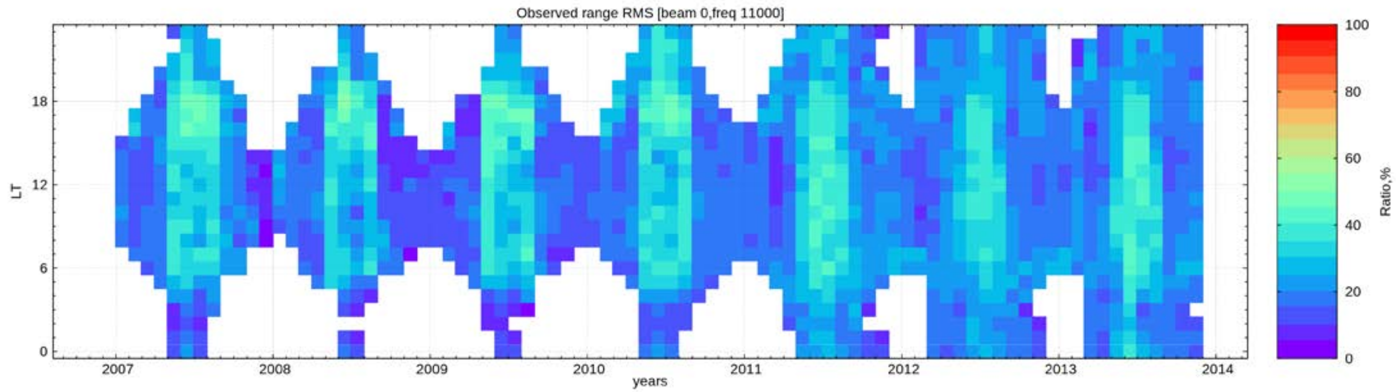


3. COMPARISON WITH OBSERVATIONAL DATA

Relative difference between GB model range and observed range



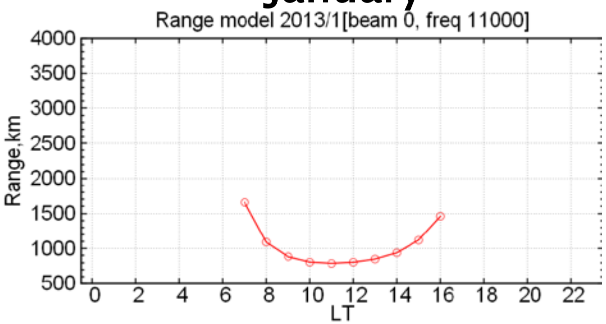
Observed relative RMS



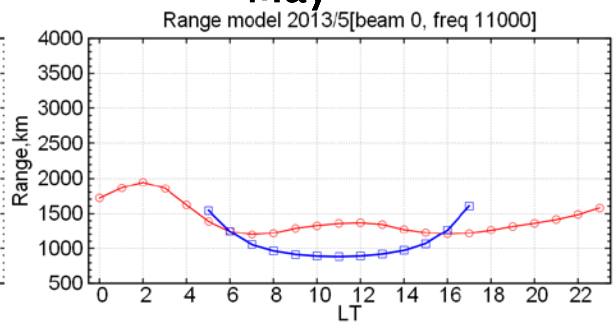
3. COMPARISON WITH OBSERVATIONAL DATA

Diurnal variations of F2 and E minimum range in 2013

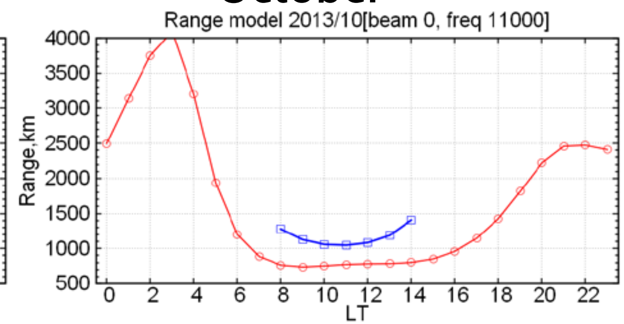
January



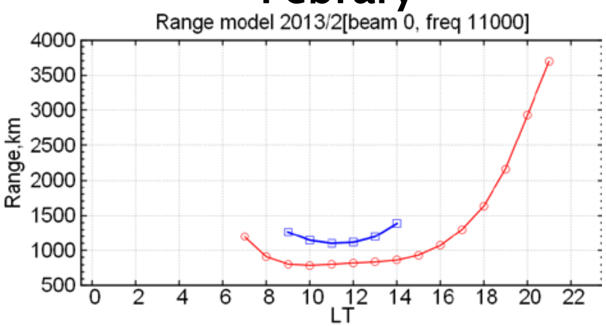
May



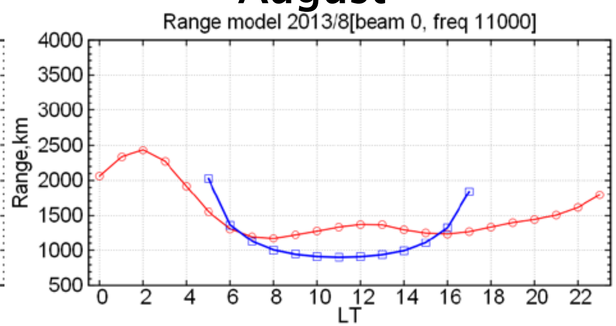
October



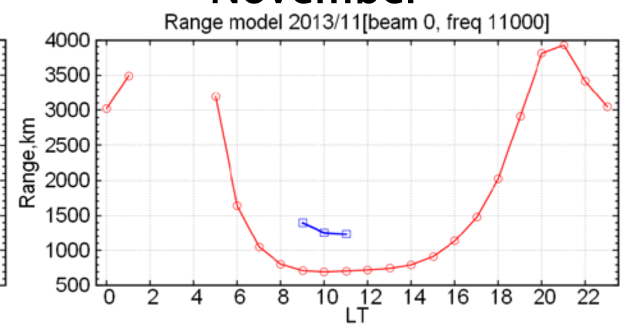
Febrary



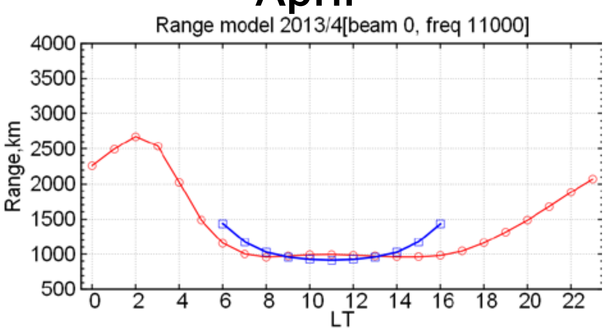
August



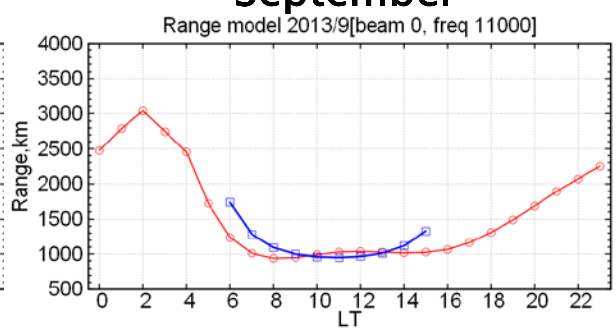
November



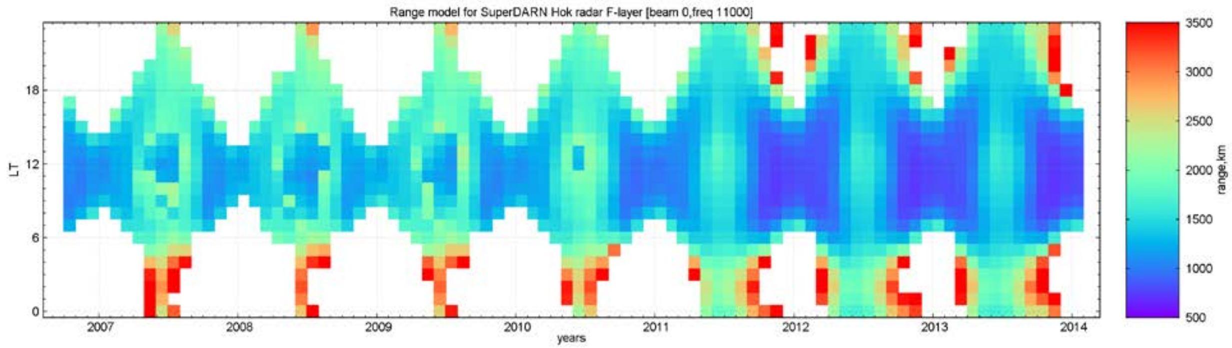
April



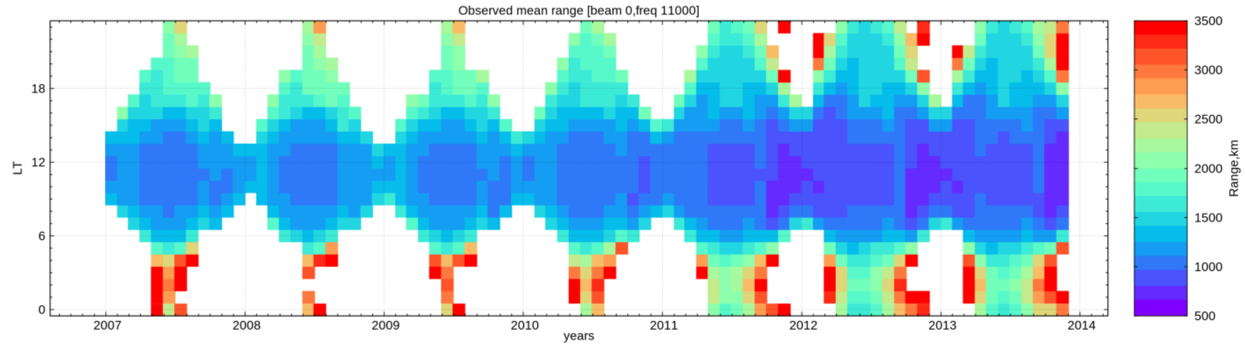
September



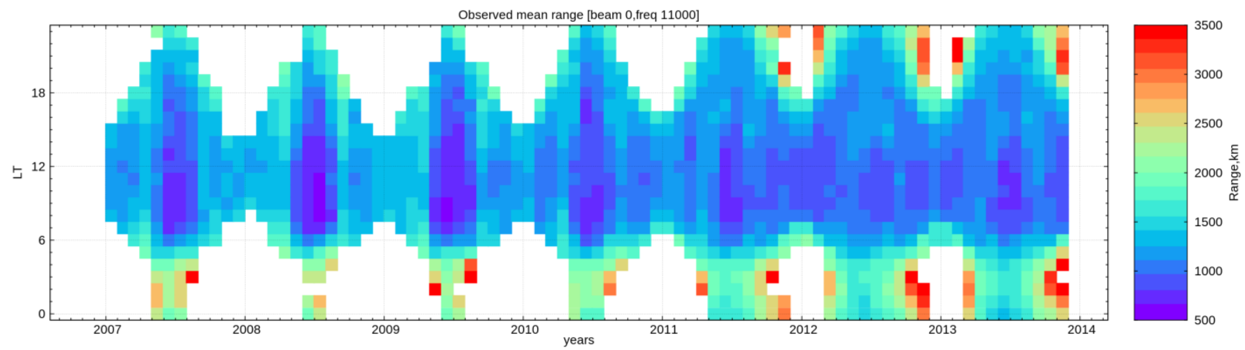
3. COMPARISON WITH OBSERVATIONAL DATA



Composite version of the GB model where E-layer range used instead of F2-layer range if smaller then the last one

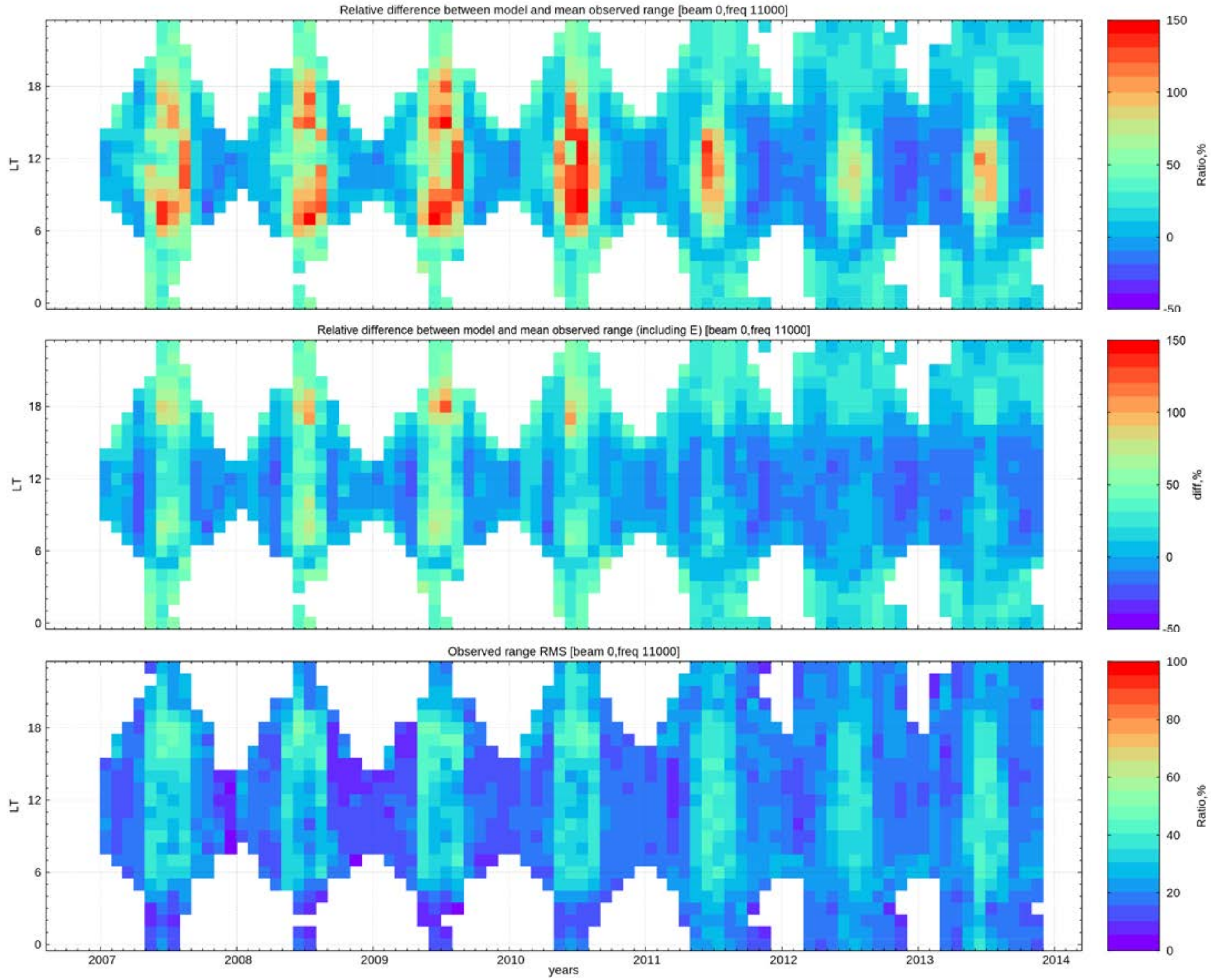


Observed minimum range



3. COMPARISON WITH OBSERVATIONAL DATA

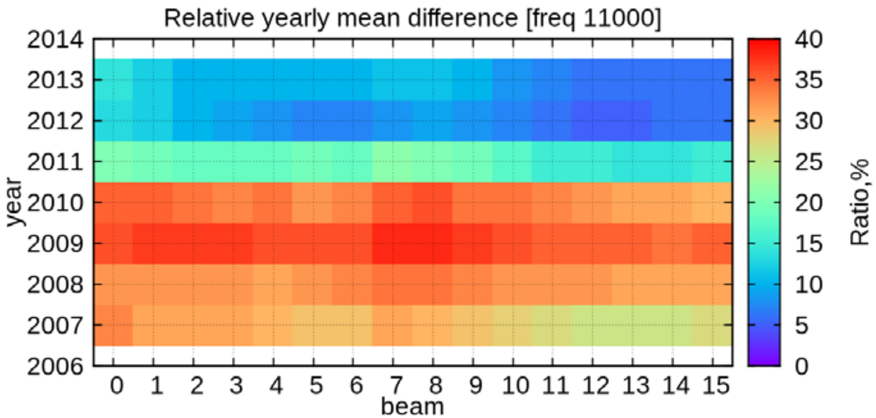
Relative difference between GB model (initial and composite) and observed range and observed RMS



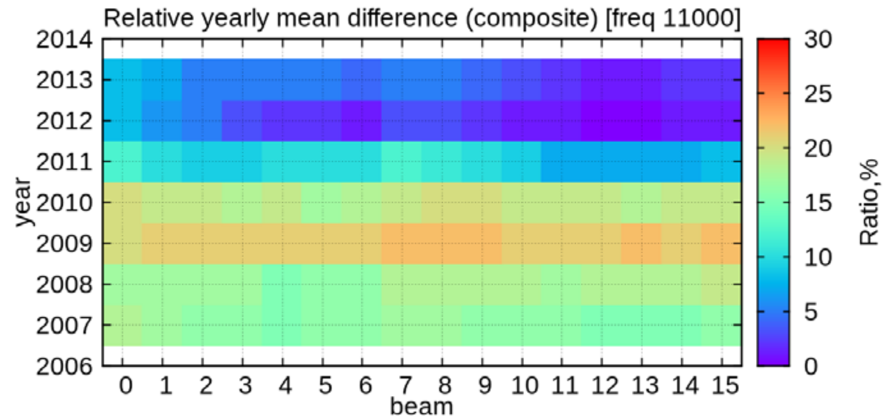
3. COMPARISON WITH OBSERVATIONAL DATA

Relative yearly mean difference

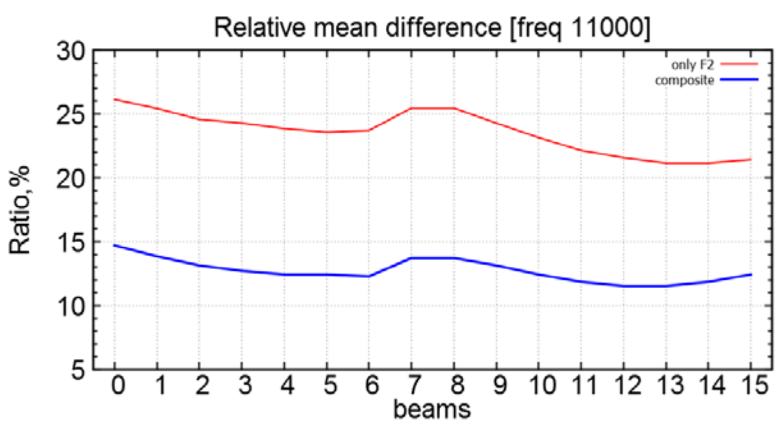
Initial

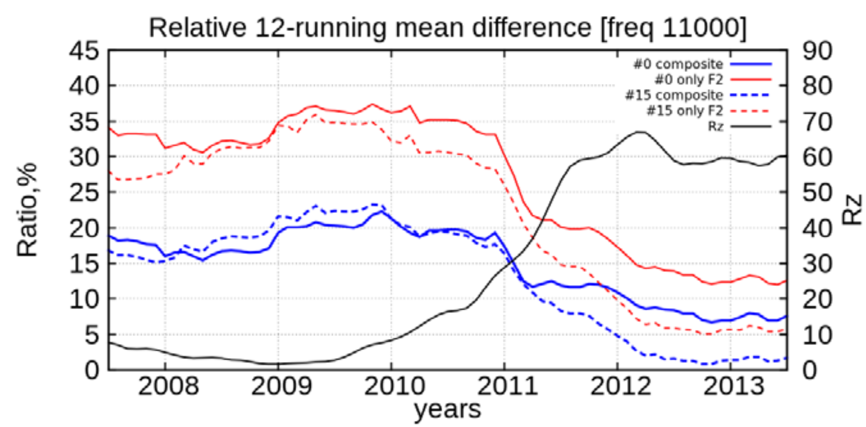


Composite



Dependence of mean difference on azimuth and level of solar activity
(red – initial, blue –composite)





CONCLUSION

Ground backscatter model for SuperDARN Hokkaido radar is developed based on simulations performed in the framework of waveguide approach and IRI-2007 model as a background media. The model can be used for improvement of the radar data interpretation and testing IRI model in a wide mid-latitude region.

The comparison with an extensive dataset of the Hokkaido radar shows that there is a significant "mixing" of GB echoes reflected from F2- and E- layers especially during daily hours in summer months. This mixing can be partially corrected by composite model where E-layer range values are used instead of F2-layer values when the last ones are greater then the E-layer range values.

The difference between the model and observational data in general doesn't exceed ~40% and 20% for "only F2" and composite versions accordingly. Corresponding RMS values don't exceed 30% (and 25% for composite model).

It is found that the difference dependents on beam number (azimuth) and solar activity level. It increases for years with low level of solar activity and for beams with smaller azimuth. Explanation of these effects required further investigation.

Thank you for attention!

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