# The analysis of an ionospheric heating experiment in polar region

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## Abstract

Based on the incoherent scatter radar data of the ionosphere heating experiment carried out in polar region on November 23th, 2011. The disturbance characteristic of electron density was analyzed, and a large density enhancement was found. The enhancement percent can be up to 500% near the reflection height, and away from the resonance region, the density enhancement can also be more than 70% in the height of 300km-580km. According to the analysis of incoherent scatter spectra, it is found that the huge enhancement in the reflection region was caused by coherent scatter, but the other enhancement should be true and the mechanism of electron density enhancement is presented.

## 1. Instruction

Ionosphere is an important part of the earth, and many new methods were developed to study it. Since the Luxemburg effect was found [1], a new technique was originated to understand the complex physical process in ionosphere, say ionosphere heating. They use the high power radio wave to modify the ionosphere, and observe the respond with the outside force. The respond of the disturbed ionosphere includes: (1) Stimulated Electromagnetic Emission [2-3], (2) VLF/ELF/ULF wave radiation [4-5], (3) Langmuir turbulence [6-7], (4) enhancement of electron temperature and density. Large scale electron temperature enhancements have been measured by incoherent scatter radars many times since the first observations by Gordon et al. [8-9]. And the first observations in high latitudes were performed at Tromsø, Norway during the daytime [10-11]. Temperature increases up to about 55% (about 700 K) and electron density increases of up to about 15% near the HF wave interaction height in their experiment. Much greater electron temperature enhancements up to 300% (3000 K above background) caused by powerful HF-radio wave injection along the magnetic field aligned direction have been observed during night time [12]. However, due to the fact that more energy is needed for the density change, the density enhancement is not obvious in usual. The value of 30% in Blagoveshchenskaya experiment is rare [13], and maybe the enhancement come from the wrong explain of traditional incoherent scatter theory to the abnormity spectra.

Using the EISCAT HF pump facility and its ionosphere plasma diagnostics facilities, we carried the heating experiment on November 23, 2011. The obvious enhancement of electron density was observed, and the reason of the phenomena was discussed.

## 2. Experiment description

The heating experiment was carried out in Norway on November 23th, 2011, and the position is located in Tromsø (69.59°N, 19.23°E). The site includes three heating arrays, and the Array 1 was used in order to match with the local ionospheric critical frequency. The pump beam point to filed-aligned direction, the same with the UHF incoherent scatter radar pointing, which is the main diagnosed instrument. The heating circle is 18 min on – 12 min off, and the frequency is stepping, with the time interval of 10s.

## 3. Analysis of observation results

Figure 1 displays the variation of electron density and temperature of the experiment. During the heating period, the density and temperature was enhanced obviously, and the range the temperature enhancement was located near the reflection height, which was observed analogously in past experiments [14]. But the large density enhancement is infrequent. The electron density can be changed by three reasons. One reason is that the less recombination induced by the increase of the electron temperature [15], and it can cause a density enhancement of about 5%. The other reason is that the density diffusion induced by heating at reflection height,

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this generally can bring a 10% decrease. Both of the two mechanisms are so weak that the density enhancement is close to ionosphere parameters error, and we cannot found the density variation in most of heating cases. The third is the increase of growth rate induced by instabilities, and it can cause a larger density enhancement. In order to achieving the detail of heating, the period of obvious enhancement (12:08:00-12:08:30) is chosen to compare with the unheated time (12:18:00-12:20:00). The enhancement can be found from 186km to 600km, and the value is up to 578.3% at 200km. However, the enhancement of electron density is not rational. The density is inversed from enhanced ion line spectra, but the Maxwellian incoherent scatter theory at reflection is not authentic. The echo is from the joint scatter of artificial field-aligned irregularities and free electrons, and the coherent scatter dominate in the region. So the mis-analysis is the real reason of density enhancement.

However, the enhancement is between 70%-100% in the region far from resonance area of 300-580km. The instabilities cannot happen in so large range, thus the phenomenon should be true. In order to validate the conclusion, the heated and unheated ion lines in different height are analyzed. In order to reduction of the noise, the unheated spectra are averaged between 12:20:00-12:21:30, and the heating data is averaged between 12:08:00-12:08:30. The frequency range of the unheated spectra in F region is between -10KHz and 10KHz, and the shape is double-humped. But there is a zero-frequency peak in the two range gate near the reflection height during heating, and the bandwidth is between -15KHz and 15KHz. The amplitude of spectra increases from 0.09 to 0.85, which is another evidence of coherent scatter. There is no essential difference between unheated spectra and the ion line away from reflection height of 10km. A minor enhancement of the entire spectra and the increase of peak-to-valley ratio are caused by the change of ionosphere parameters, so the Maxwellian incoherent scatter theory can still be use to inversion in these region. The similar spectra characteristics can be found in higher altitude, thus the density enhancement in these heights should be true. And the increase of density decrease with height.

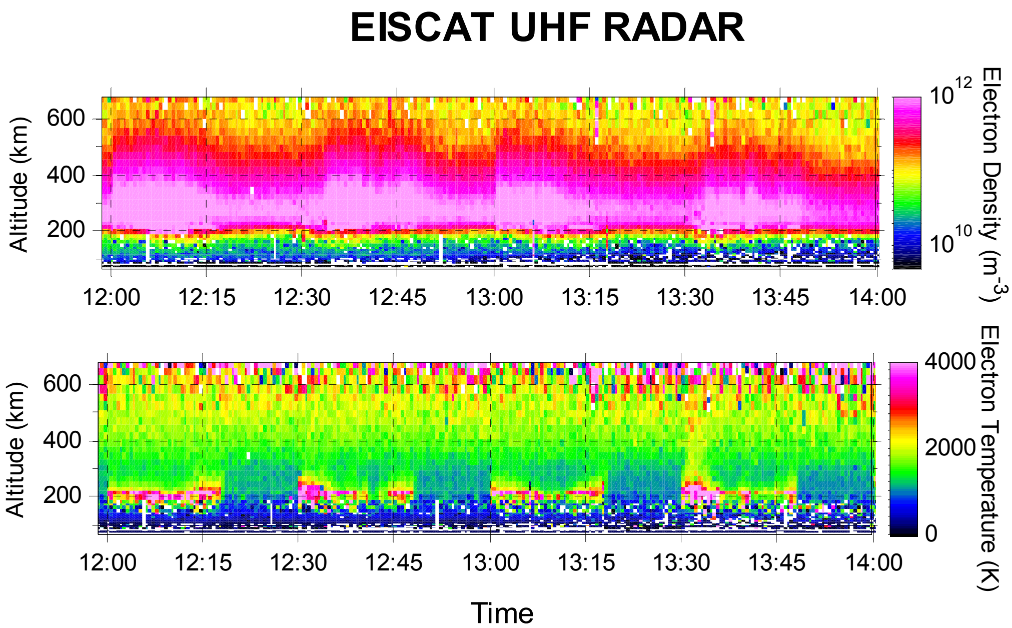


Fig 1　Variation of electron density and temperature during the experiment from UHF radar

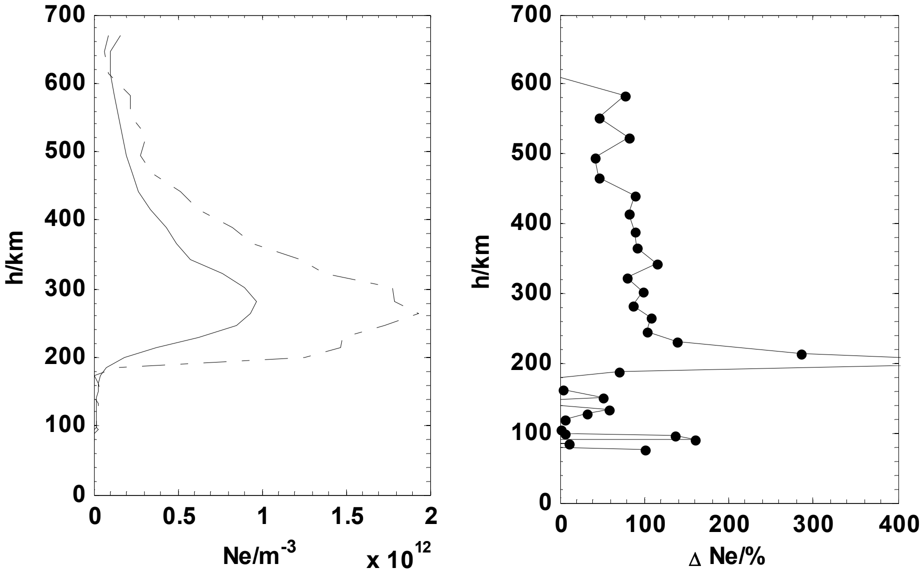


Fig 2 Variation of electron density induced by ionospheric heating during 12:08:00-12:08:30

## 4. Conclusion

The large disturbed heating case of the electron density is found in the experiment carried out in polar region on November 23th, 2011. The enhancement range is up to 300km, and the amplitude is more than 100%. The huge enhancement is an interesting phenomenon, among the three mechanism of the density disturbance, only the instabilities induced by pump wave can realize it. However, the single instability cannot produce so large a density enhancement, with the no significant difference of the pump wave power and background ionosphere condition. The density change of 100% means the a huge increase of pump wave absorption flux, so one of possible reason is that multiple absorption mechanisms work together in some special time. The burst condition of the absorption mechanisms is analyzed, and we found that 5$^{th}$ gyro-frequency height was the same with the reflection height at 12:08:00, say cyclotron and eigen oscillation happens in the same place at the same time. The two mechanisms couple with each other, which makes the efficiency of energy absorption increase non-linearly. Besides the amplitude, the large enhancement range is a new scientific problem. The reason of this phenomenon may be that the ionosphere electron absorb the HF pump wave energy, and part of them change into internal energy, which represents the temperature increase. Part of them accelerates the electrons, which produces the super thermal electrons. With the action of the two absorption mechanisms, super thermal electrons have a very high velocity at a short time, and the free path of these electrons can be up to several hundred kilometers, which means the super thermal electrons can collide with the neutral atmosphere away from generation region of several hundred kilometers, and ionize them. So we can observe the density enhancement in a large range. Simulation of these physical processes and validation with the new experiment is our further work.

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