Relationship between auroral emission and GPS scintillation

Shumpei Mitsui[1], Keisuke Hosokawa[1], Yuichi Otsuka[2], Shinichiro Oyama[2], Kazuo Shiokawa[2], Yasunobu Ogawa[3], Michi Nishioka[4]

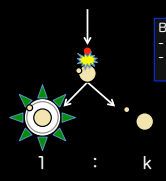
1 : UEC 2 : STEL, Nagoya 3 : NIPR 4 : NICT

Introduction

Aurora causes ionospheric electron density irregularity, and causes GPS Scintillation. When the strong scintillation occurred, receiver may not receive the signal stably.

This paper investigates the relationship between the intensity of auroral emission and the magnitude of the GPS scintillation indices, by comparing data from all-sky imagers, EISCAT radar and GPS scintillation monitoring system in Tromsø, Norway (69.60°N, 19.20°E).

Background



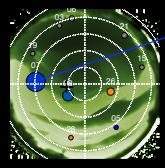
By the collosion...
- excited state → aurora
- ionization state → increase Ne
  ex : ion=1 : k (k: constant)

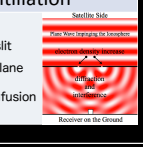
changing emission intensity & changing Ne are recognized relationship

changing emission intensity & Ionospheric Scintillation can be expected relationship

Ionospheric Scintillation

Refractive Scintillation	Diffractive Scintillation
time irregularity of Ne	spatial irregularity of Ne
$n_p = \frac{c}{v_p} = 1 - \frac{40.3 n_e}{f^2}$	irregularity of Ne plays role as slit
phase velocity changes sharply by changing Ne sharply → Only phase scintillation	✓ equiphase surface is NOT plane → phase scintillation ✓ signal interfere by phase confusion → amplitude scintillation





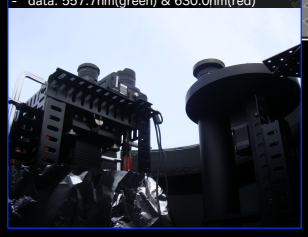
Instruments

GISTM (GPS ionospheric scintillation ant TEC monitor)
- L1 signal=50Hz sampling
- data: TEC, σ_ϕ & S_4 every 1min

EISCAT
- UHF (931MHz)
- data: Ne every 5sec

All-Sky digital camera
- expose time: 8 sec
- two frame per 1min
- data: RGB (0-255)

OMTI All-Sky Imager
- one frame per 1min
- data: 557.7nm(green) & 630.0nm(red)

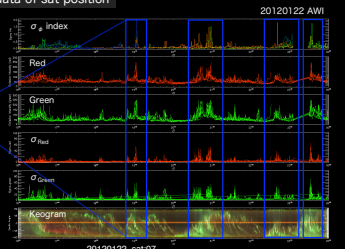


All-Sky Watec Imagers
- expose time: 1 sec
- one frame per 1sec
- data: RGB (0-255)

Relationship

Getting data...

about each sat...
- scintillation index : receiver data
- emission intensity : OMTI / ASC / AWI
  data of sat position



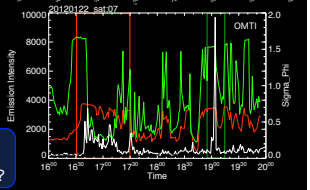
Relationship

As you can see, it can be recognized relationship between auroral emissions and phase scintillation

Time series plot

Reddish aurora vs σ_ϕ :
aurora emission: stable ⟷ σ_ϕ: stable

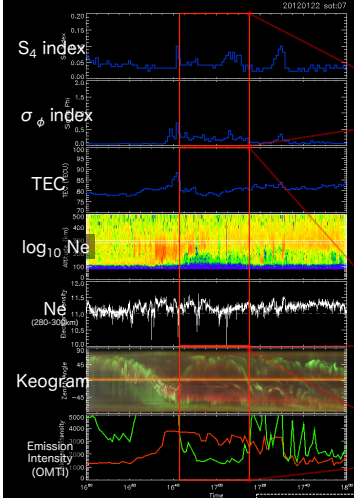
Green aurora vs σ_ϕ :
aurora emission : transient ⟷ σ_ϕ: transient



There is a difference in scintillation between the reddish and green aurora.
Different scintillation mechanism for different color of emission?

Reddish(630.0nm) aurora

– stable scintillation (not the case for the green aurora)
– strong spatial irregularity of Ne (SuperDARN)



MECHANISM

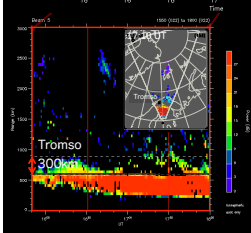
Diffractive Scintillation

Signal is more diffracted
- phase / amp scintillation: same response
- during strong irregularity, phase scintillation responds (1 hour)

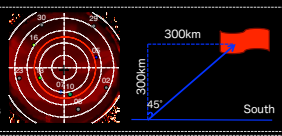
the magnitude of spatial irregularity in Ne is continuously strong
- SuperDARN
- magnitude of irregularity is strong ~30dB

Ne is continuously strong
- the height of 630.0 nm (red) aurora: 300km
- temporal irregularity in Ne
- No TEC irregularity in time

Reddish aurora emission is continuously strong
- Strong stable emission (3000 R~/1hour)



There are reddish aurora(630.0nm) and PRN 7 in the direction of 45° south from zenith. If we assume that the height of reddish aurora emission is 300km, we can estimate that the reddish aurora was located 300km south.



The spatial scale of Field-Aligned Irregularities (FAIs) which influence GPS scintillation is a few hundreds meter. On the other hand, SuperDARN can observe irregularities of tens meter in size. First, large scale FAIs is created and small scale FAIs is created from that large FAIs.(Tsunoda, 1988)
Threfore, it can be recognized that there is large scale FAIs (hundreds of meter) which influence GPS scintillation behind small scale FAIs (tens of meter) which is observed by SuperDARN.

Green(557.7nm) aurora

– only transient phase scintillation corresponding to transinet emission

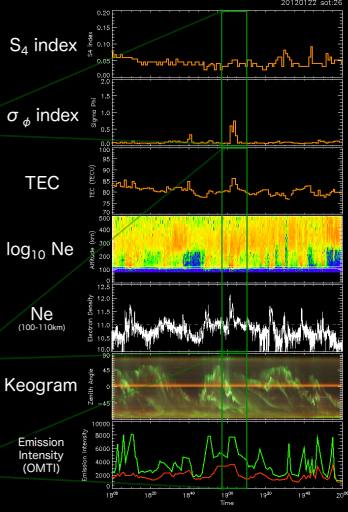
MECHANISM

Refractive Scintillation

Signal is more refracted
- only phase scintillation
- transient irregularity : spiky response (5mins)

Ne is transiently strong
- the height of 557.7 nm (green) aurora: 120km
- transient high Ne layer : $\log_{10}$12.0
- TEC: spiky response

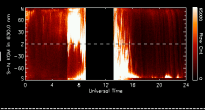
Green aurora emission is transiently strong
- Strong transient emission (8000 R~/5mins)

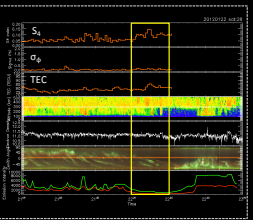


NO AURORAL EMISSION

- No aurora emission: Response = Only S_4
  → there is little possibility of increasing Ne by particles
  → Refractive Scintillation

Dense airglow (2012.01.22 at LYR) moved from North to South. Thus, polar cap patches behind this airglow are carried from the north of Tromso. Therefore, even if there is no optical emission (557.7 nm/630.0 nm), refractive scintillation can be observed because of spatial irregularity which is caused by airglow.





Summary

- We recognized a relationship between aurora emission and scintillation
- There are different mechanisms which depend on the colors of aurora.
- Reddish aurora (630.0 nm) emission causes refractive scintillation
- Green aurora (557.7 nm) emission causes diffractive scintillation

Conclusion

- This paper shows that the mechanism of scintillation depends on the auroral color
- In the future, we plan to elucidate the relationship between GPS scintillation and aurora emission intensity more quantitatively