

Electric Field Oscillation behind Pulsating Aurora

Simultaneous observations
with all-sky TV camera and SuperDARN in Iceland

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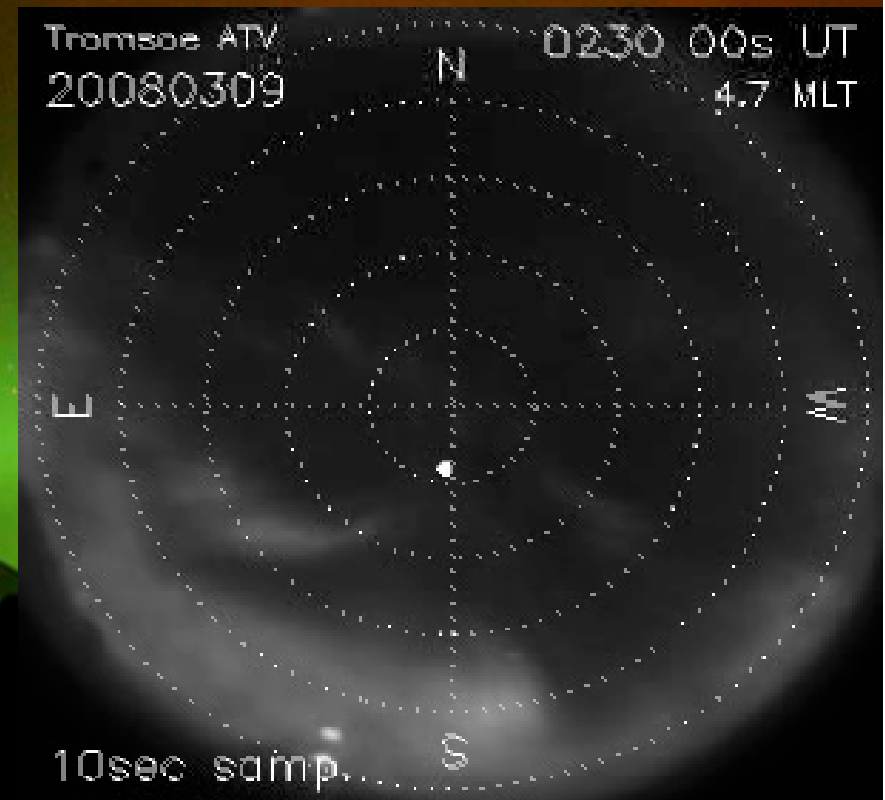
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pulsating aurora

- Observed universally during the **recovery phase of substorms** in the auroral and subauroral zones. Especially, their activities are more prominent **in the morning side**.
- Typical period ranges from **a few seconds to a few tens of second**.
patch of irregular shape or band-like structure.
- Modulated electron fluxes from as low as **a few keV to 100 keV** are responsible for the phenomena.
- Pitch angle diffusion due to periodic occurrence of **wave-particle interaction between energetic electrons and whistler-mode VLF waves** near the equatorial magnetosphere can cause pulsating aurora (**traditional model**).

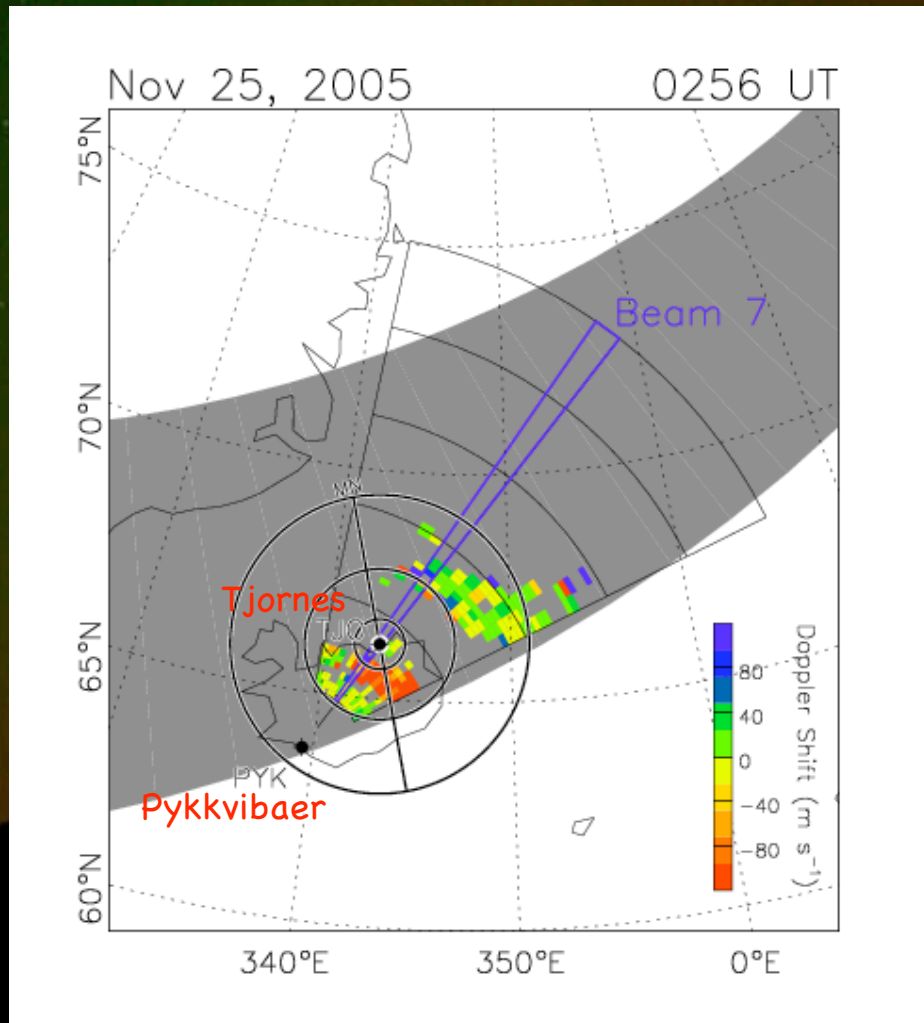


any role of ionosphere?

- Most of the conjugate observations of pulsating aurora demonstrated that pulsating aurora appears in both hemispheres but **the shapes are not necessarily the same and the pulsation periods are in many instances different** between the two hemispheres (Stenbaek-Nielsen, 1973; Sato et al., 1998, 2004; Watanabe et al., 2007), which **cannot be explained by the traditional scenario only**.
- Stenbaek-Nelsen (1980), Sato et al (1998) and Tagirov (1999) have proposed **active ionospheric processes** which probably play an important (not crucial) role in causing pulsating auroras or characterizing their structures.
- **However, the exact role played by the ionosphere is still uncertain.**
- To date, **variation of ionospheric electric field**, which is one of the most important parameters to describe the conditions of the auroral ionosphere, **associated with pulsating aurora** has not been investigated.

experimental arrangement

SD E-region measurements + All-sky TV camera of NIPR



Radio measurement:

SuperDARN Pykkvibaer radar
(63.86 N, 19.20 W)

E-region mode (myopic mode)

- spatial resolution: 15 km
- integration time: 2 s
for one beam sequence

Optical measurement:

Tjornes (66.19 N, 17.93 W)

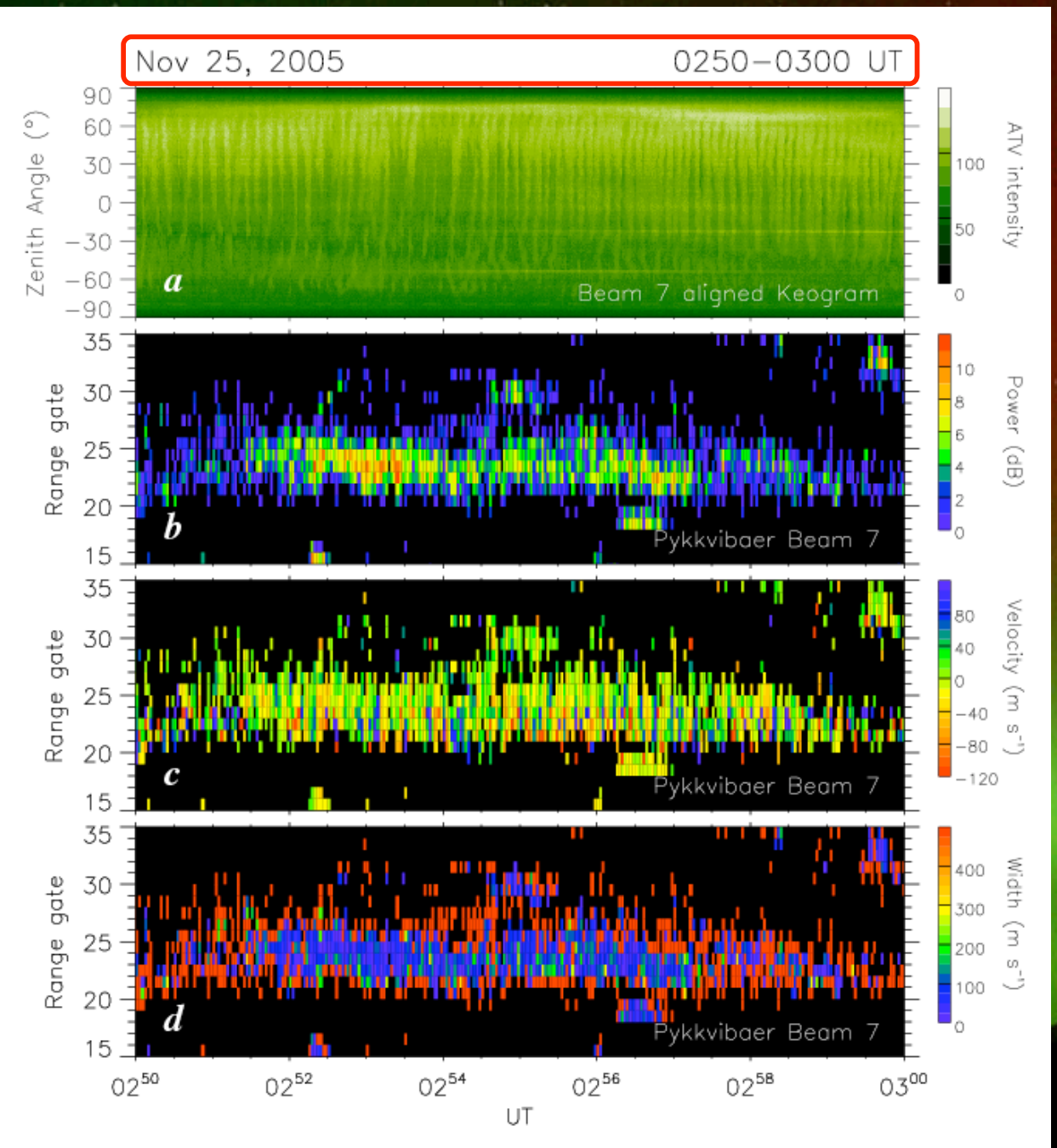
All-sky TV camera with I-I.

- temporal resolution: 30 Hz

optical and radar data along beam 7

optical
intensity

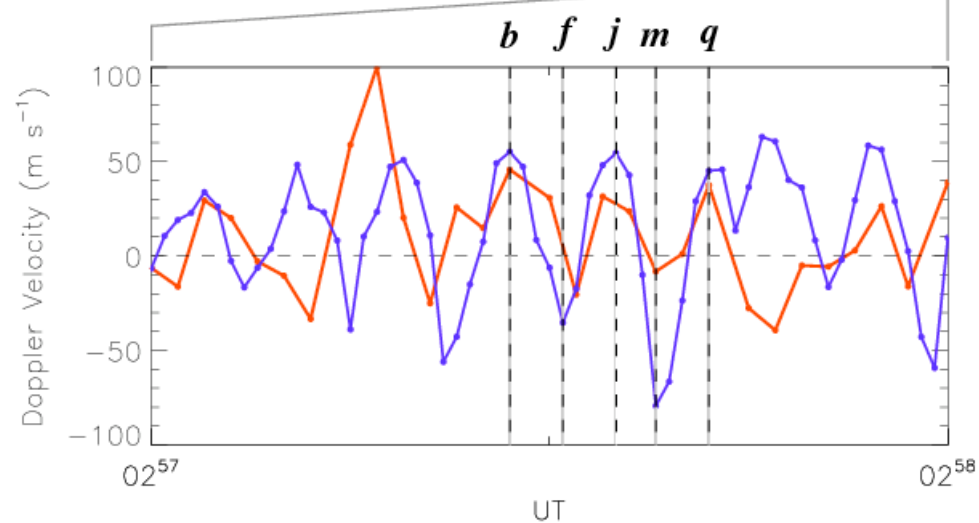
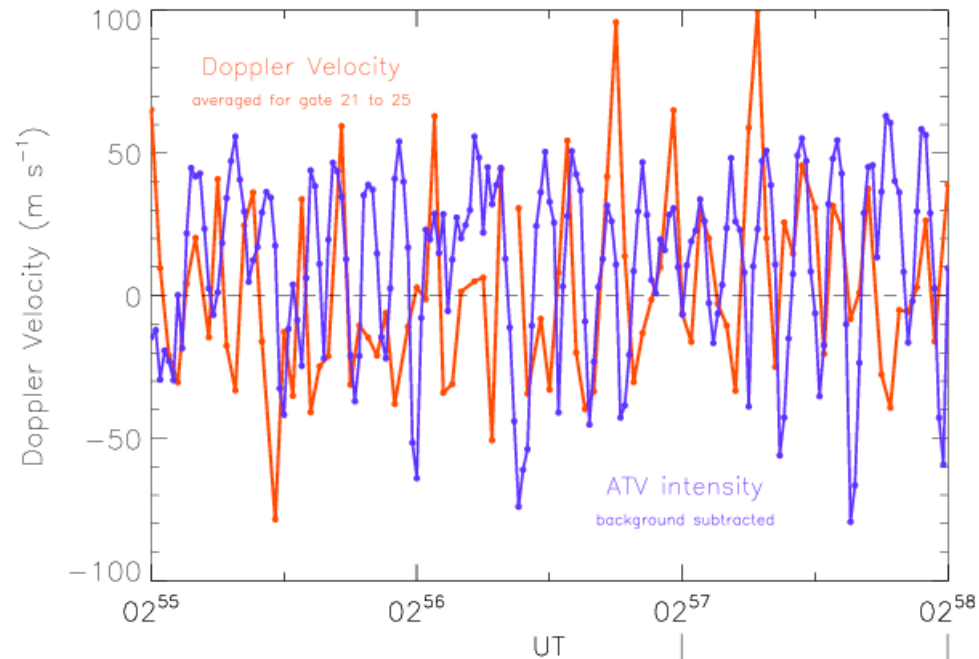
Doppler
velocity



backscatter
power

spectral
width

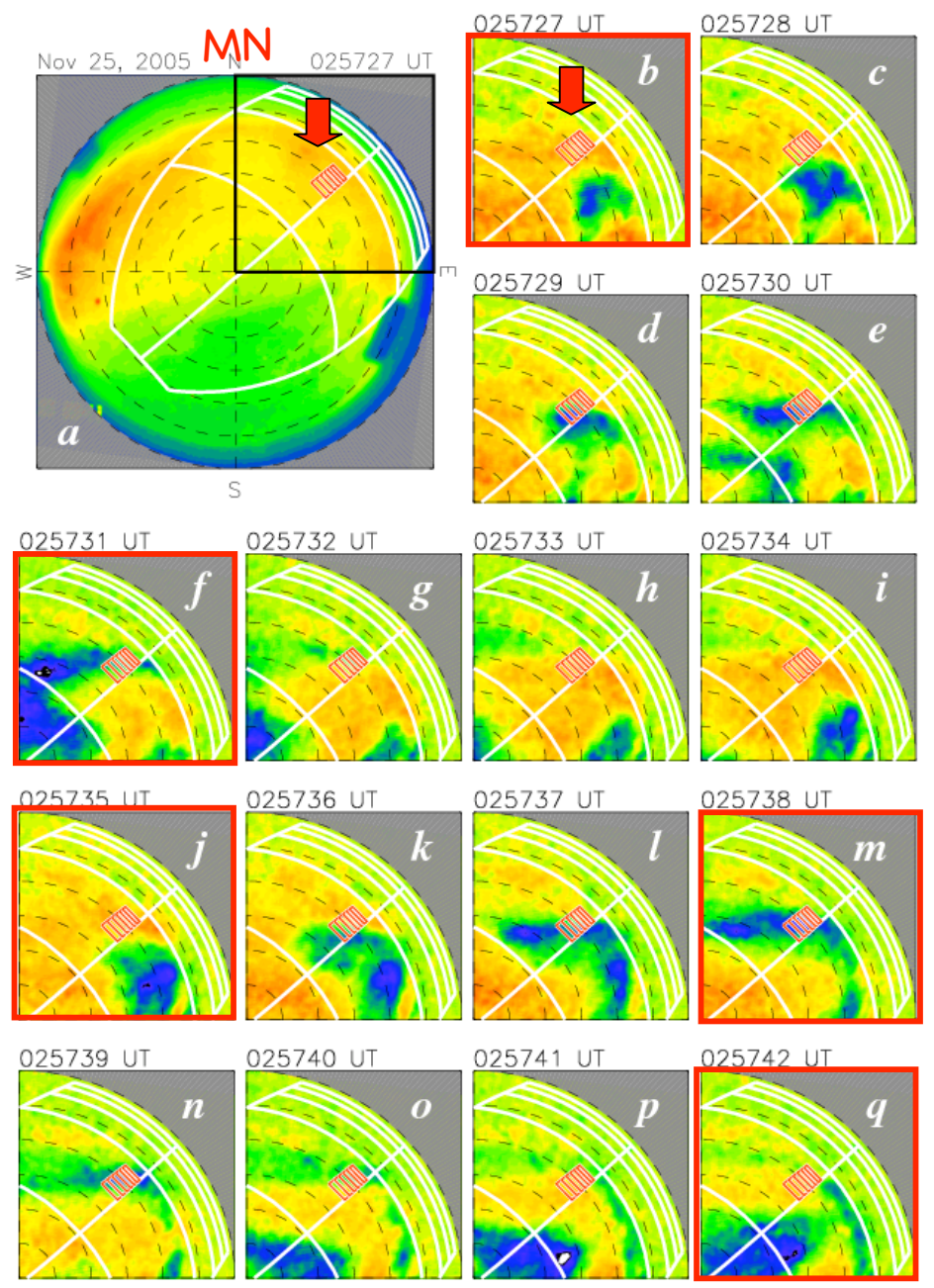
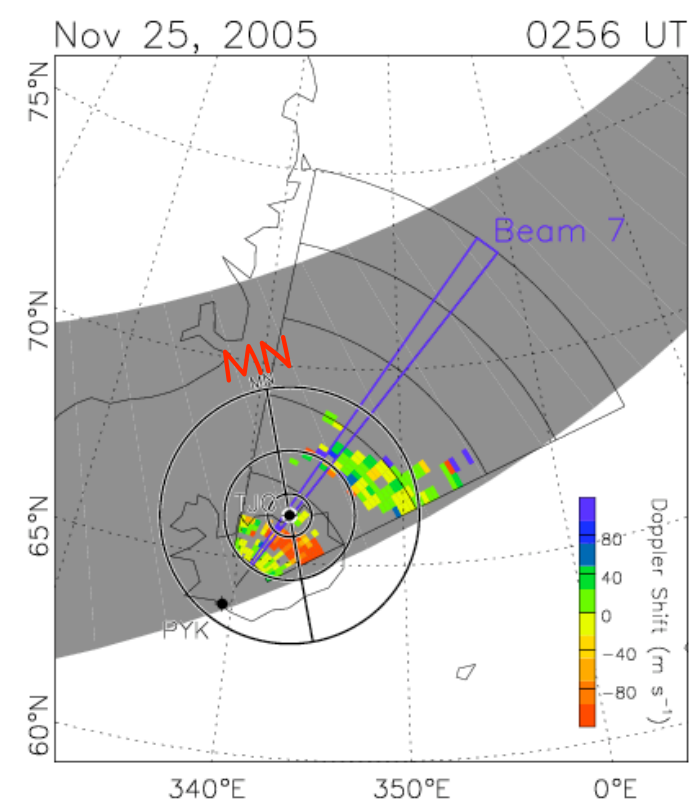
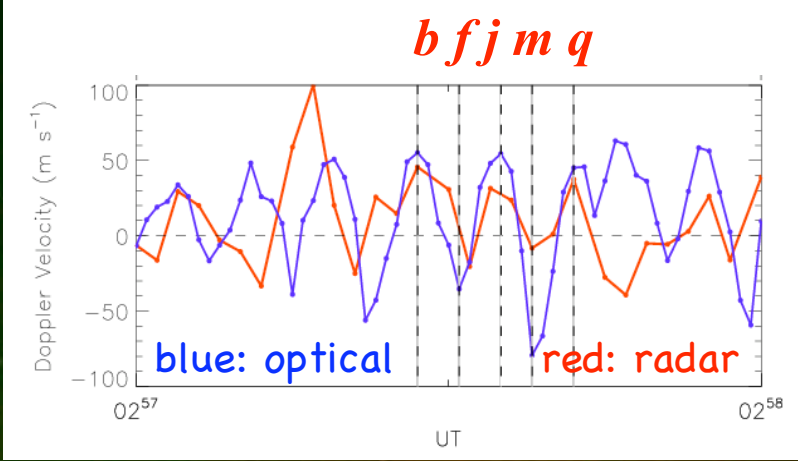
3 minutes



blue: optical pulsation
pulsating period: 8 s

red: radar pulsation
pulsating period: 8 s
(amplitude 100 m s⁻¹)

The line of sight
Doppler velocity turns
to positive (toward the
radar) when the
pulsating aurora is
"ON" and vice versa.



where is the origin?

- Is this electric field oscillation **a magnetospheric signal** vital to the mechanism that precipitates the electrons or just **a consequence of local current system** produced by the precipitation?
- If its origin is in the magnetosphere, its **phase should be delayed** by as much as a few tens of seconds, depending on where along the field line source of the wave is.
- During the interval under study, however, we cannot identify considerable time delay between optical and radar pulsations.
- This **rules out a magnetospheric source for the electric field oscillation.**

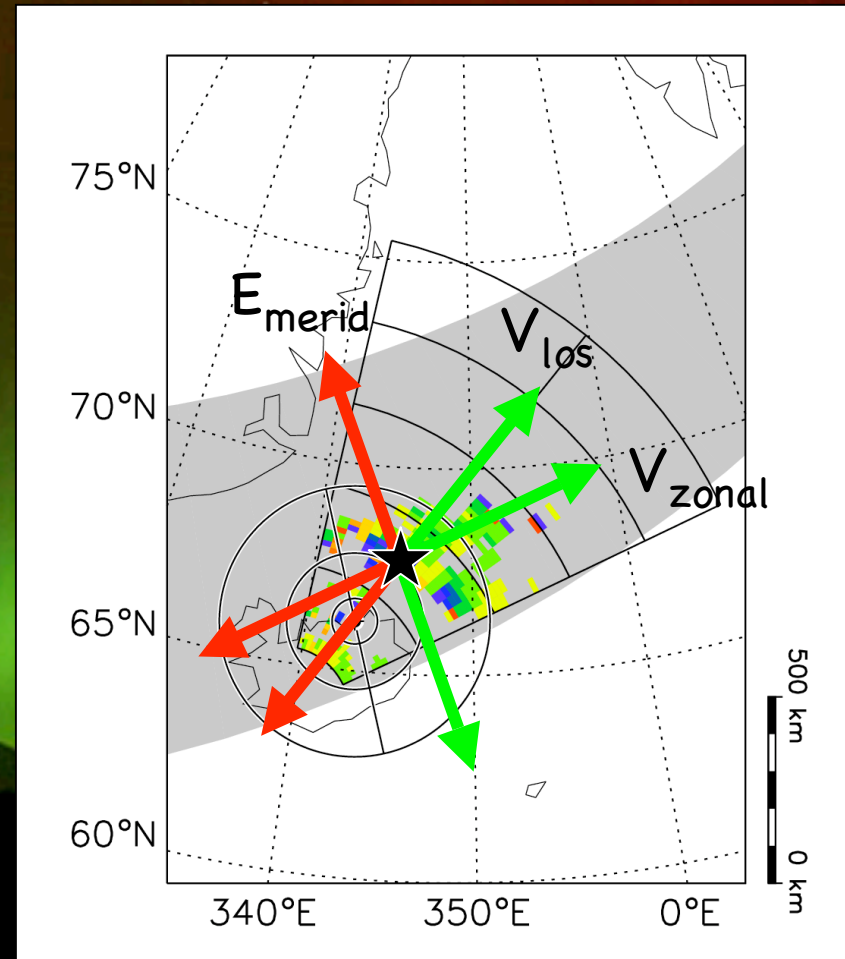
- Thus, we propose that the electric field oscillation associated with the pulsating aurora studied here is **the result of a local current system generated by enhanced conductivity in the lower ionosphere.**

relationship between the observed parameters

Poleward electric field appears when the pulsating is "ON"

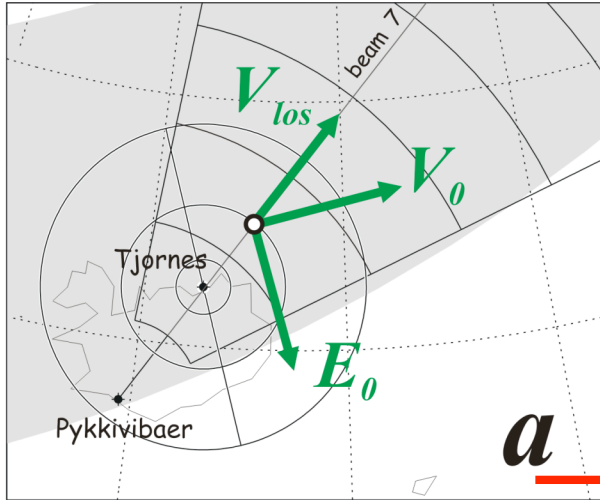
electric field is directed equatorward when the pulsating aurora is "OFF"

		pulsating aurora	
		ON	OFF
SuperDARN	V_{los}	toward	away
	V_{zonal}	west ward	east ward
	E_{merid}	north ward	south ward



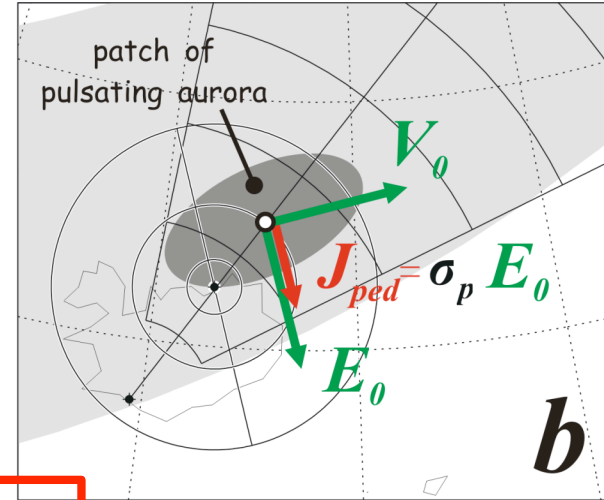
scenario A

pulsating aurora is off



a

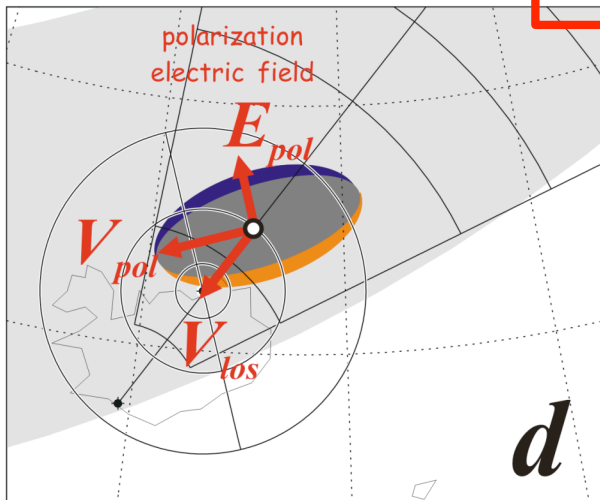
pulsating aurora is on



b

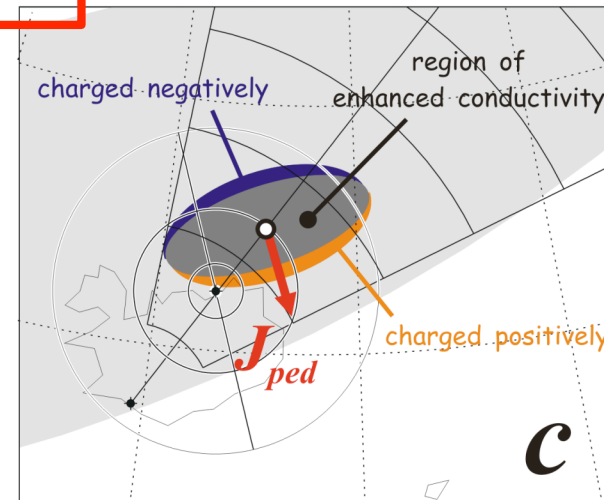
one cycle of pulsation

charge accumulation occurs on the edges of PA



d

polarization E-field is formed and is detected with SD



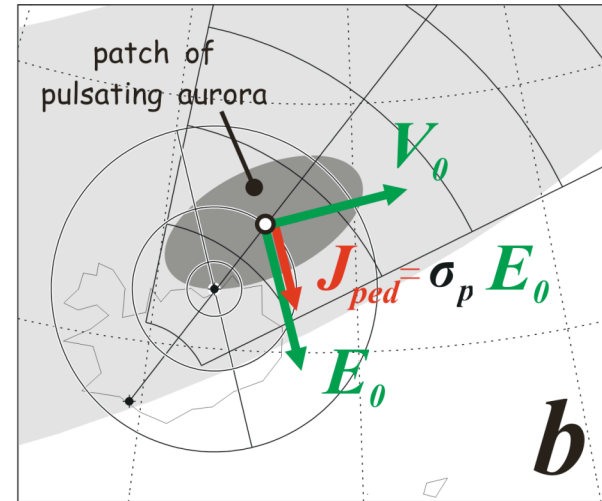
c

scenario A

E_{pol} is actually anti-parallel to E_0 (i.e. poleward!).

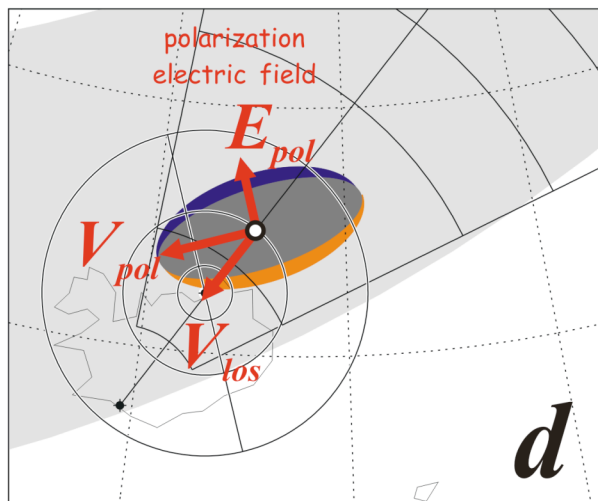
However, its magnitude is less equal to $|E_0|$ even if we assume no charge escape at the edges via FAC.

This scenario cannot explain the current observation.



pulsating aurora is on

charge accumulation occurs on the edges of PA



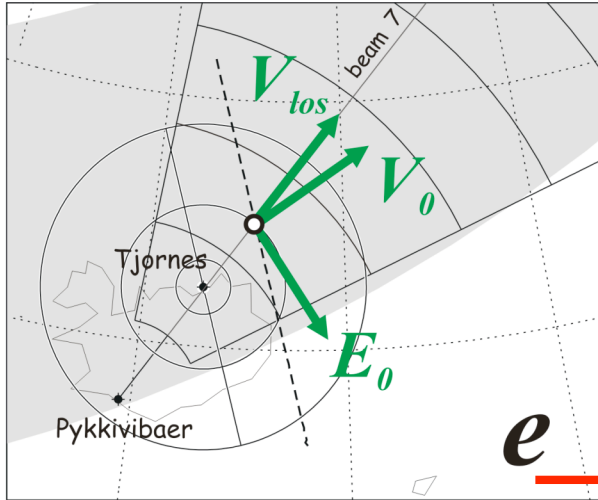
$$\sigma_P E_{pol} = J_{ped}$$

$$= \sigma_P E_0$$

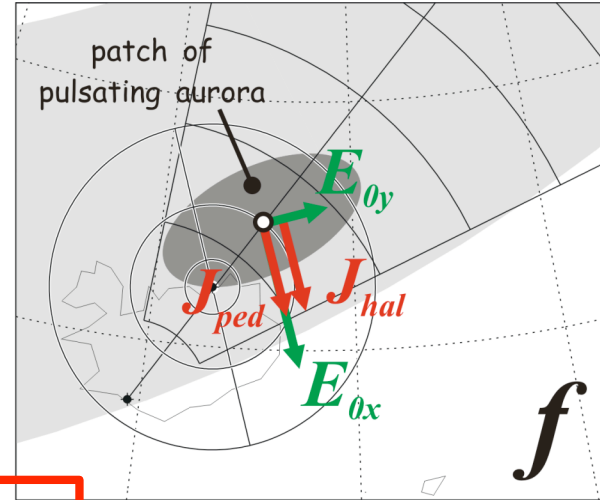
$$E_{pol} = E_0$$

scenario B

pulsating aurora is off



e

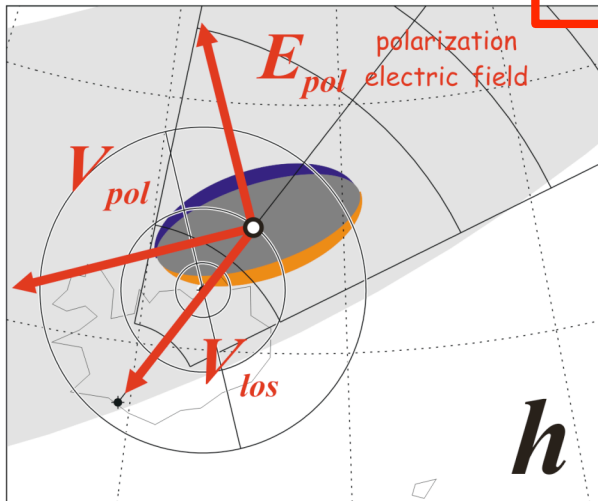


f

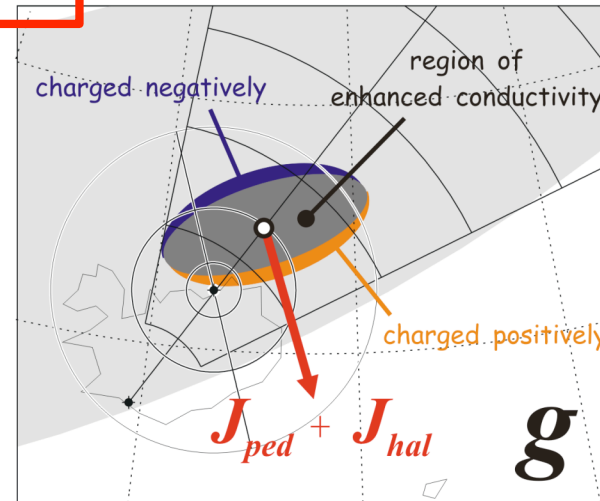
pulsating aurora is on

one cycle of pulsation

charge accumulation occurs on the edges of PA



h



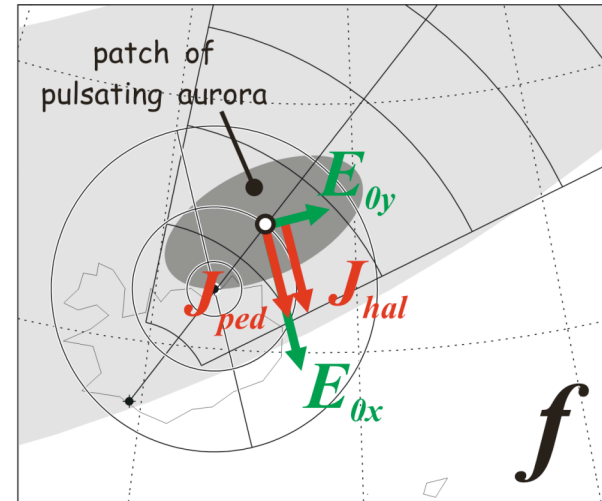
g

polarization E-field is formed and is detected with SD

scenario B

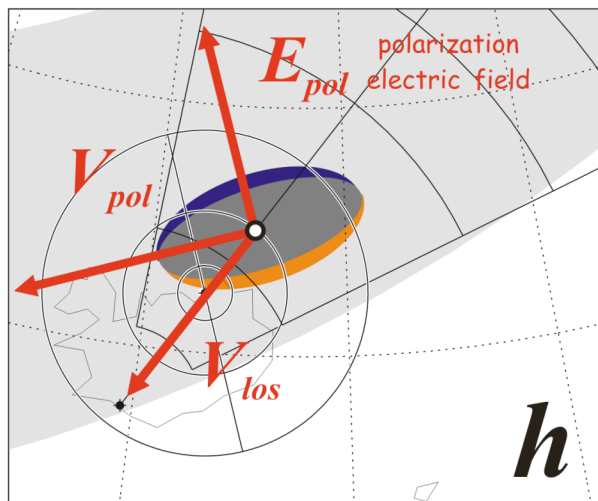
Contribution of Hall current from E_{0y} can produce poleward electric field whose amplitude is greater than $|E_0|$.

Assuming a Maxwellian distribution having characteristic energy of 10 keV, Hall/Pedersen ratio is about 4.



pulsating aurora is on

charge accumulation occurs on the edges of PA



$$\begin{aligned} \sigma_P E_{pol} &= J_{ped} + J_{hal} \\ &= \sigma_P E_{0x} + \sigma_H E_{0y} \\ E_{pol} &= E_{0x} + \frac{\sigma_H}{\sigma_P} E_{0y} \end{aligned}$$

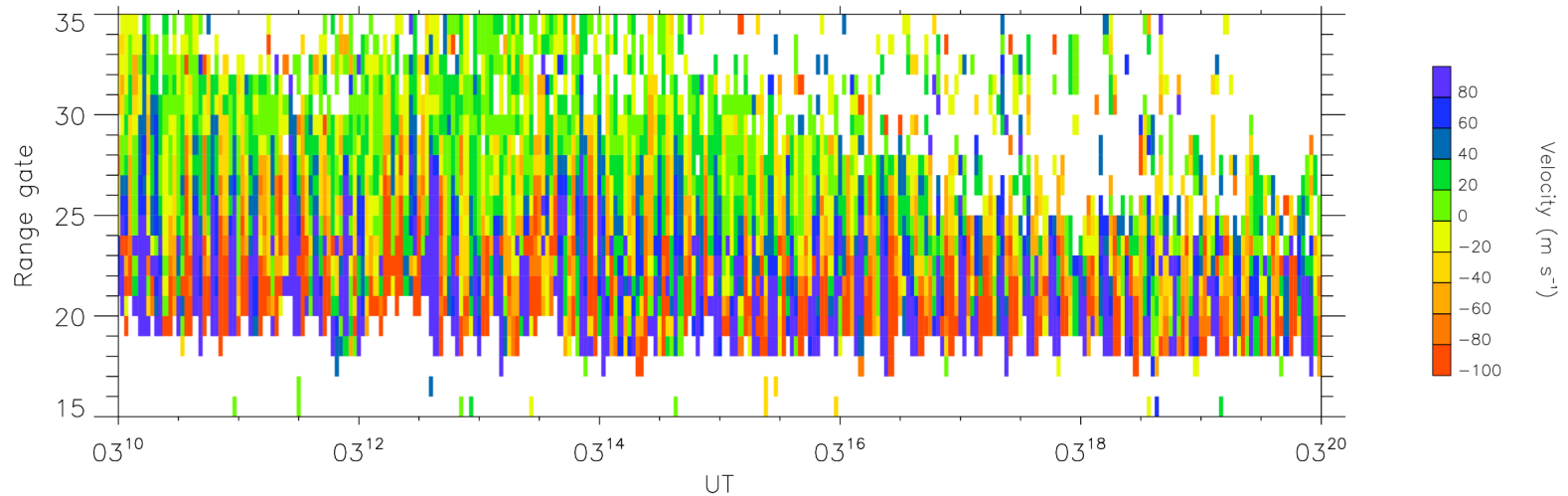
summary

- We have conducted campaign observations of pulsating aurora over Iceland with radio (SuperDARN Pykkvibaer) and optical (all-sky TV camera at Tjornes) equipments in the recent 3 years.
- We have found an event of pulsating aurora that were observed simultaneously by the radio and optical instruments. The event occurred on Nov 25th, 2005.
- During the interval of interest, the SuperDARN radar identified **electric field oscillating in phase with pulsating aurora**. These are the first direct measurement of electric field associated with pulsating aurora.
- This oscillating electric field can be interpreted as a **polarization electric field generated as a consequence of an enhanced conductance within the patch of pulsating aurora**.
- As a next step, we have to discuss how characteristics of pulsating aurora can be modified or controlled by the local ionospheric conditions such as the polarization electric field reported here.

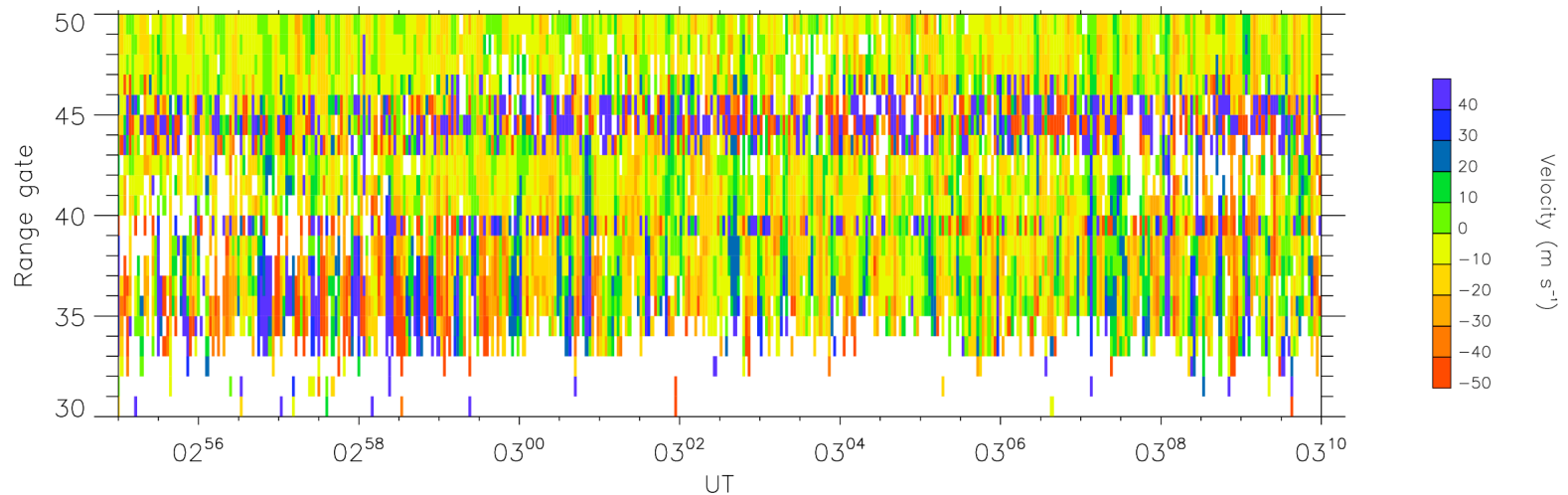
it appears quite often ...

Similar oscillating electric field appears quite often during the recovery phase of substorm. Unfortunately, optical data were not available during the two event shown below.

20051125
0310-0320 UT



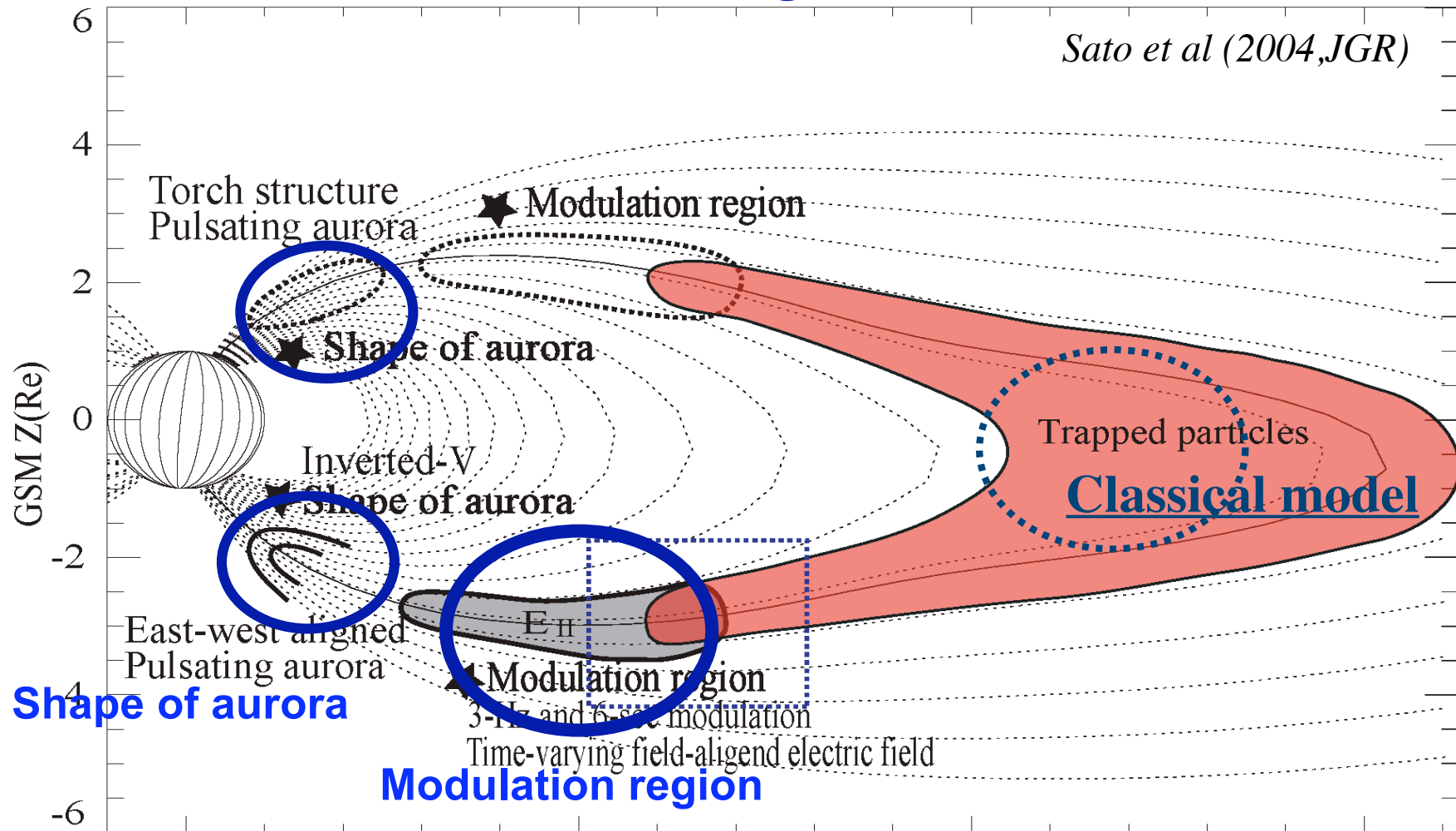
20060925
0255-0310 UT





Model: Generation region and shape of pulsating aurora

New evidences against Classical model



Modulation region is expected to be located near the Earth , so it is not necessary to perform “Conjugacy”