中緯度・サブオーロラ帯における2次元電場観測の可能性

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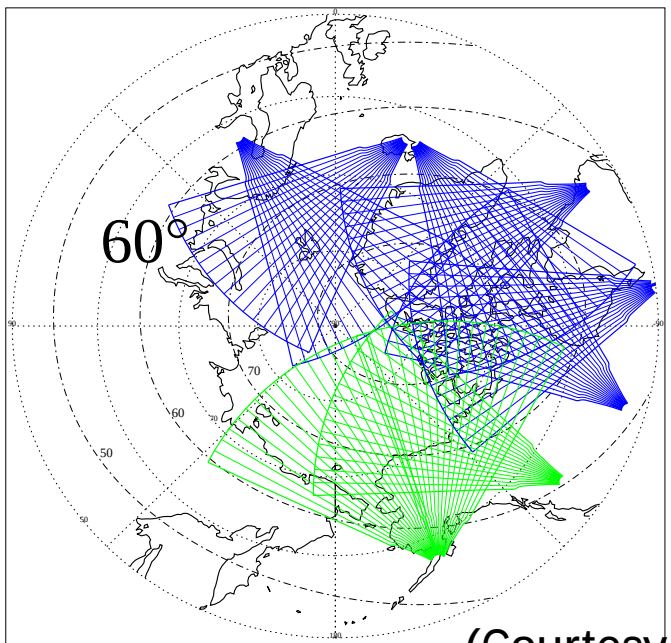
課題:
SuperDARNレーダーは現在全てが55° geomag. lat.より極側

有効視野は60°～

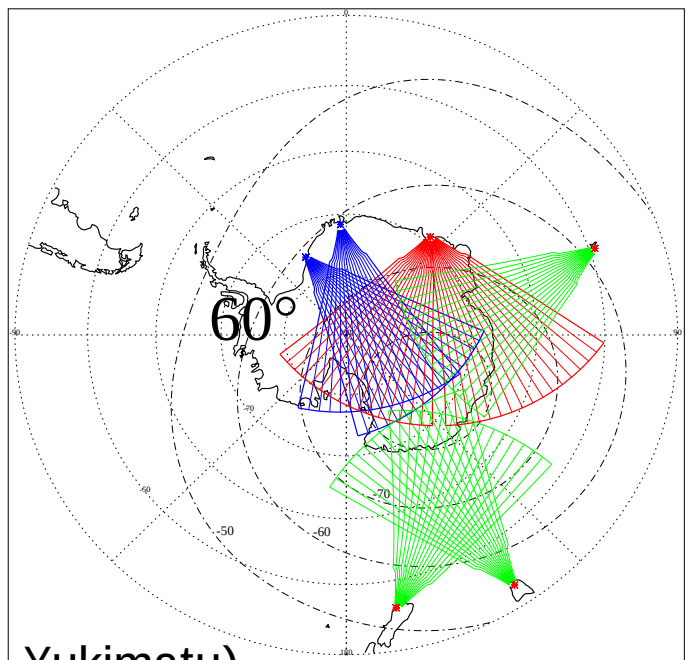
SuperDARN

Northern Hemisphere Map



SuperDARN

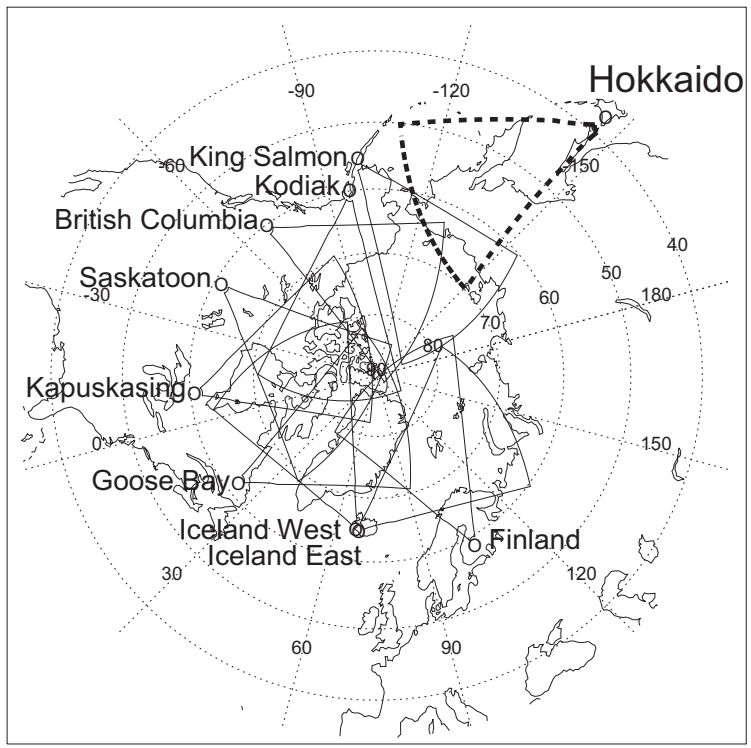
Southern Hemisphere Map



(Courtesy of A.S. Yukimatu)

北海道大型短波レーダー計画

1. 地磁気嵐時における磁気圏電場の中低緯度領域への侵入メカニズム
2. 高地磁気活動時のグローバル電離圏対流ダイナミクス
3. 中緯度領域でのMHD波動の特性
4. トラフ･オーロラ帯低緯度側境界領域の研究
5. 電離圏下部･熱圏における重力波およびプラズマ不安定現象の研究
6. 流星エコーによる下部熱圏中性風の研究
7. 夏期中間圏エコー観測による上部中間圏の研究



トラフ・オーロラ帯低緯度側境界領域における現象

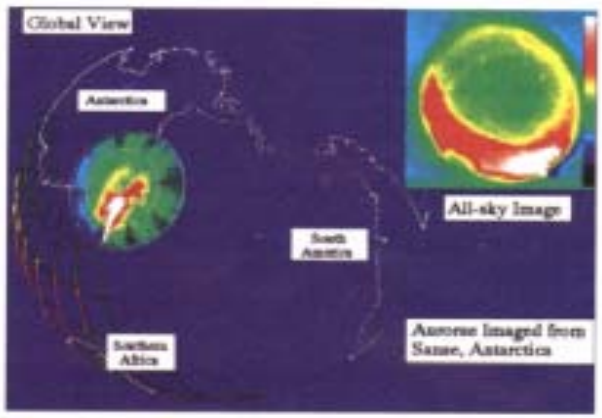


Figure 2. All-sky and projected images of giant undulation at 2358 UT.

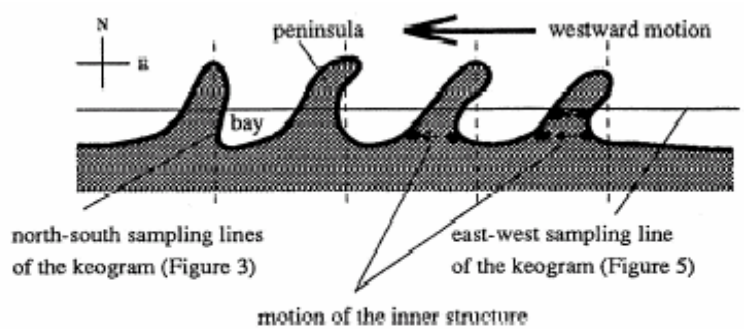


Figure 4. Schematic view of the observed giant undulation.

Nishitani et al., 1994, GRL

- SAID(sub-auroral ion drift) (Galperin et al, 1974)
- SAR ARC (Foster et al., 1994)
- Giant undulations (Lui et al., 1982; Nishitani et al., 1994)
- Ion upflow (Yeh and Foster, 1991)
- etc.

地磁気擾乱時のSub-auroral帯における電場･プラズマ密度分布

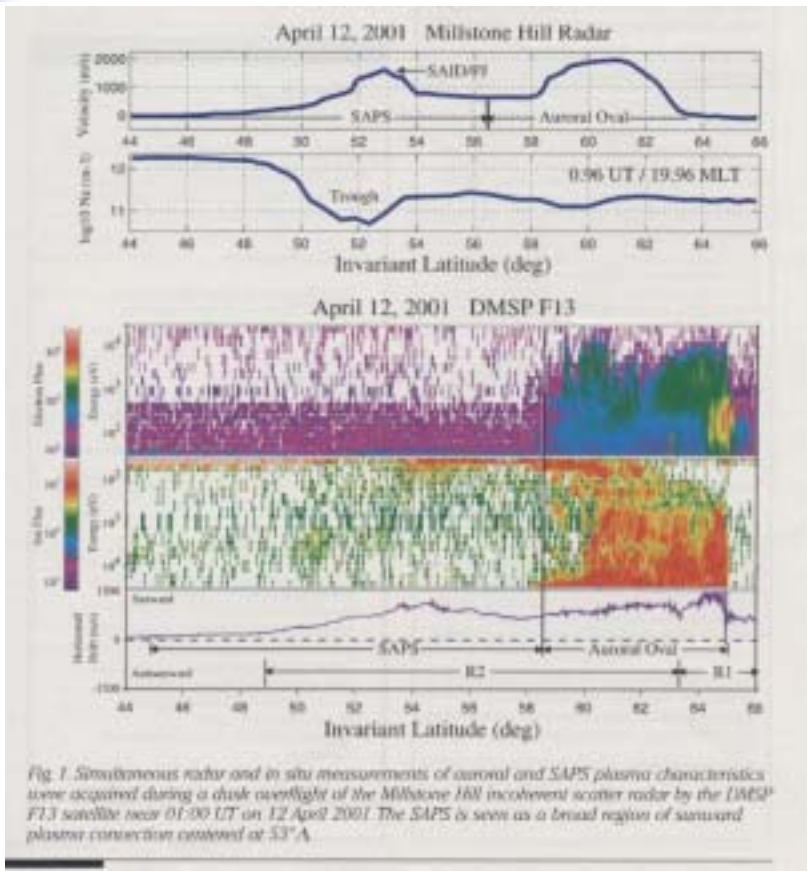
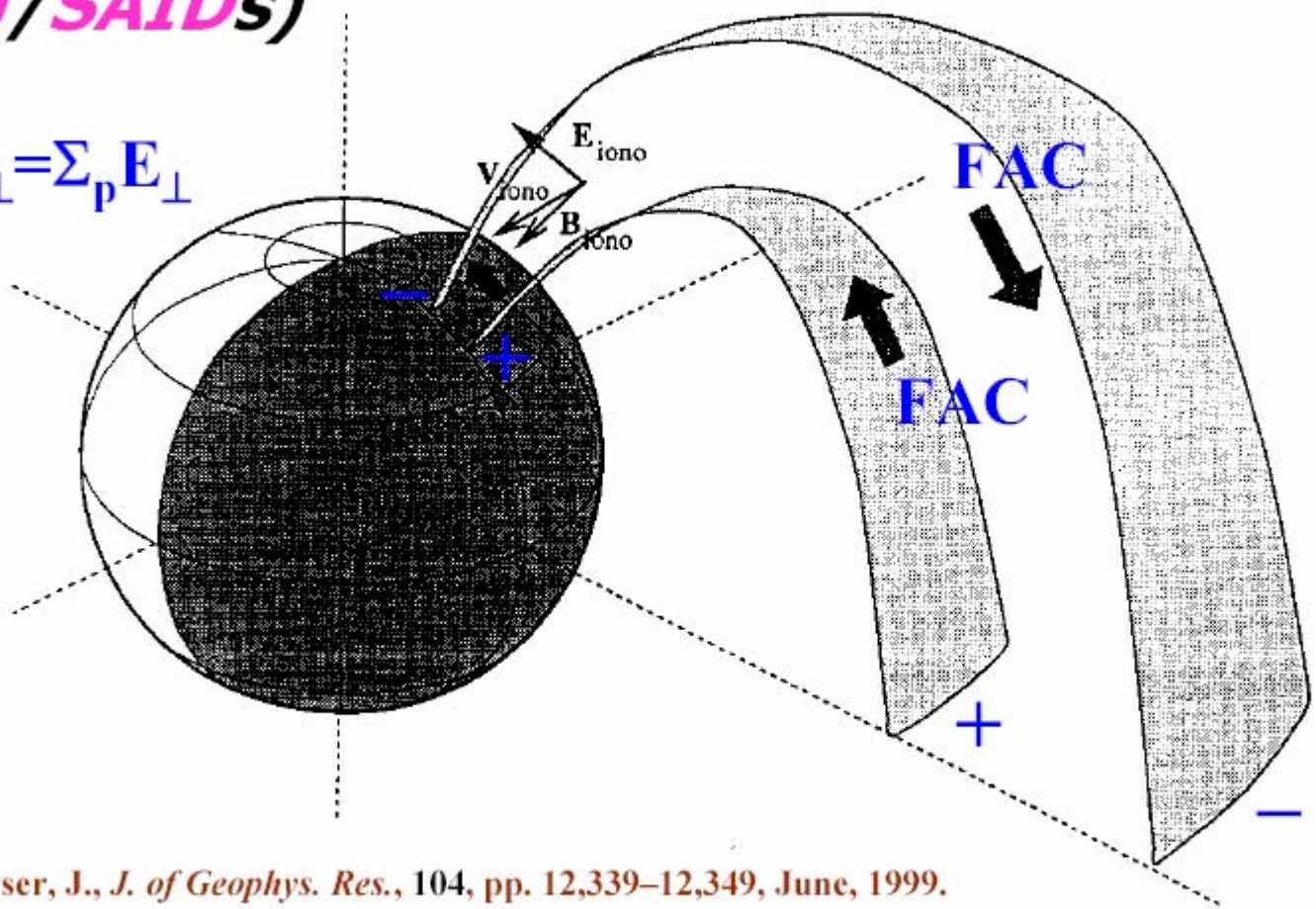


Fig. 1. Simultaneous radar and in situ measurements of auroral and SAPS plasma characteristics were acquired during a dusk overflight of the Millstone Hill incoherent scatter radar by the DMSP F13 satellite near 01:00 UT on 12 April 2001. The SAPS is seen as a broad region of sunward plasma convection centered at 53°A.

(Foster and Burke, EOS, 2002)

- SAID:**局所的に極向き電場が強まった領域**
- Trough: **プラズマ密度減少領域**
- **両者の位置はほぼ一致**

Polarisation Jets or Sub-Auroral Ion Drifts (PJ/SAIDs)



De Keyser, J., *J. of Geophys. Res.*, 104, pp. 12,339–12,349, June, 1999.

Figure 1. Schematic view of the current sheet connecting the nightside ionosphere where a PJ/SAID is observed to the magnetosphere. The ionospheric magnetic field $\mathbf{B}_{iono}$ points down, the ionospheric drift $\mathbf{V}_{iono}$ is westward, and the electric field $\mathbf{E}_{iono}$ is directed poleward. The arrows indicate the direction of the field-aligned and ionospheric currents.

(adapted from Parkinson et al., Proc. 2003 SD meeting)

SAID and SAR arc (Foster et al., JGR, 1994)

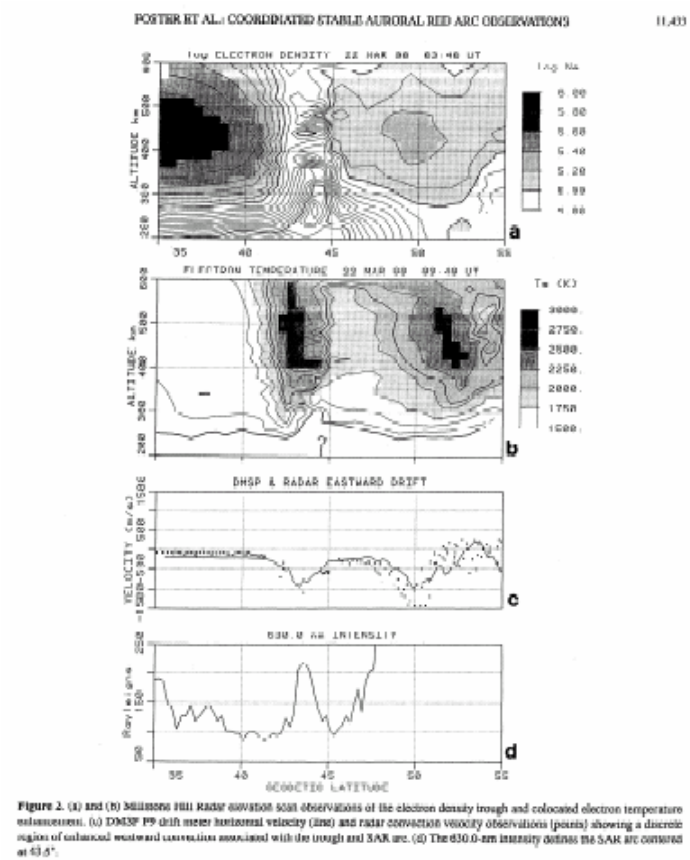
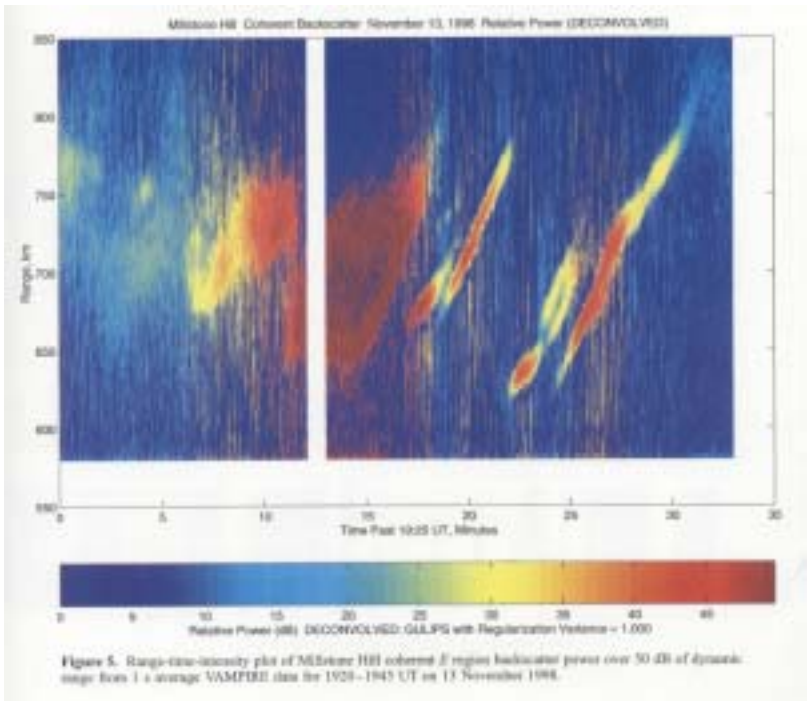


Figure 2. (a) and (b) Millstone Hill Radar elevation scan observations of the electron density trough and colocated electron temperature enhancement. (c) DMSP F9 drift meter horizontal velocity (line) and radar convection velocity observations (points) showing a discrete region of enhanced eastward convection associated with the trough and SAR arc. (d) The 630.0-nm intensity defines the SAR arc centered at 43.6°.

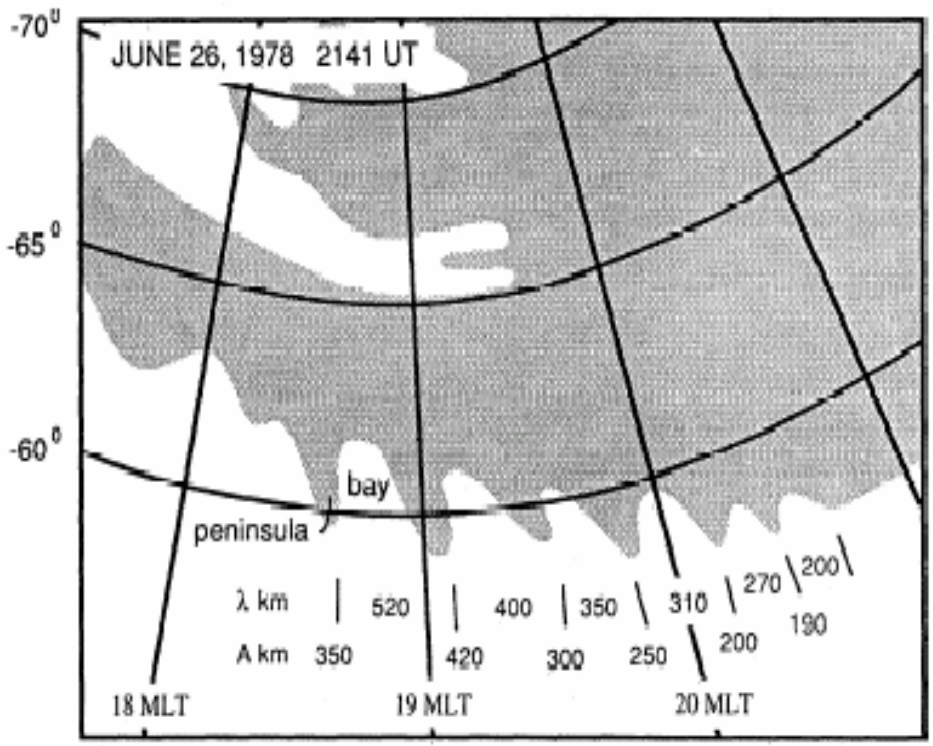
- Trough, SAID**領域と**630nm emission**領域が一致**
- Model**計算による**emission rate**とほぼ**consistent

空間･時間的に急激に変動するsub-auroral電場構造:SAIDの観測 (Erickson et al., Radio Sci., 2001)



- Millstone Hill radar observation
- Echo**強度から電場強度の時間･空間構造を推定**
- **空間分布については、**DMSP**衛星との同時観測により値の正当性を確認**

Giant undulation (Lui et al., JGR, 1982)



Yamamoto et al., JGR, 1994

DMSP image

- **低緯度側**diffuse auroral boundary**付近に発生**
- **地磁気擾乱時に発生**
- **比較的まれ**

  ->Viking,Freja**等ではもっと頻繁に観測されている**?
- **場合により**

  A(amplitude) > λ

Temporal and Spatial characteristics of giant undulation (Nishitani et al., 1994, GRL)

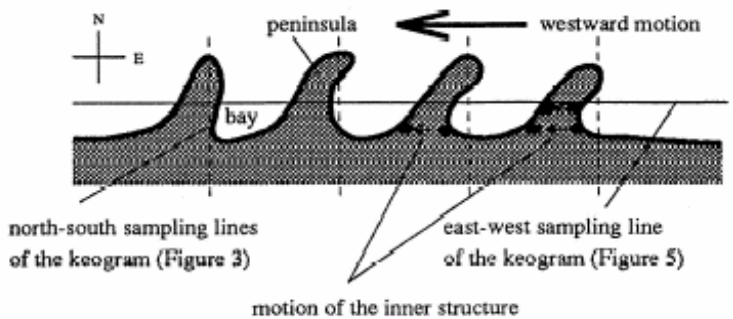


Figure 4. Schematic view of the observed giant undulation.

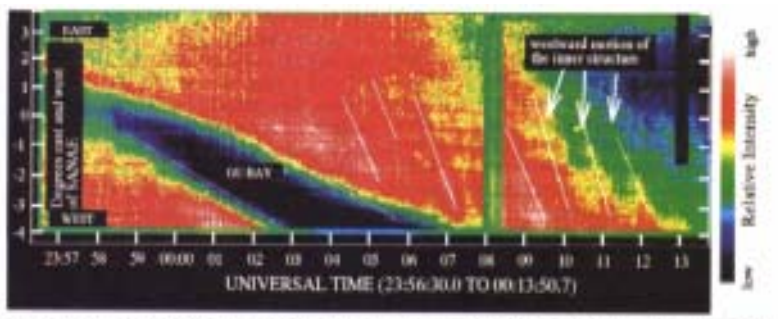
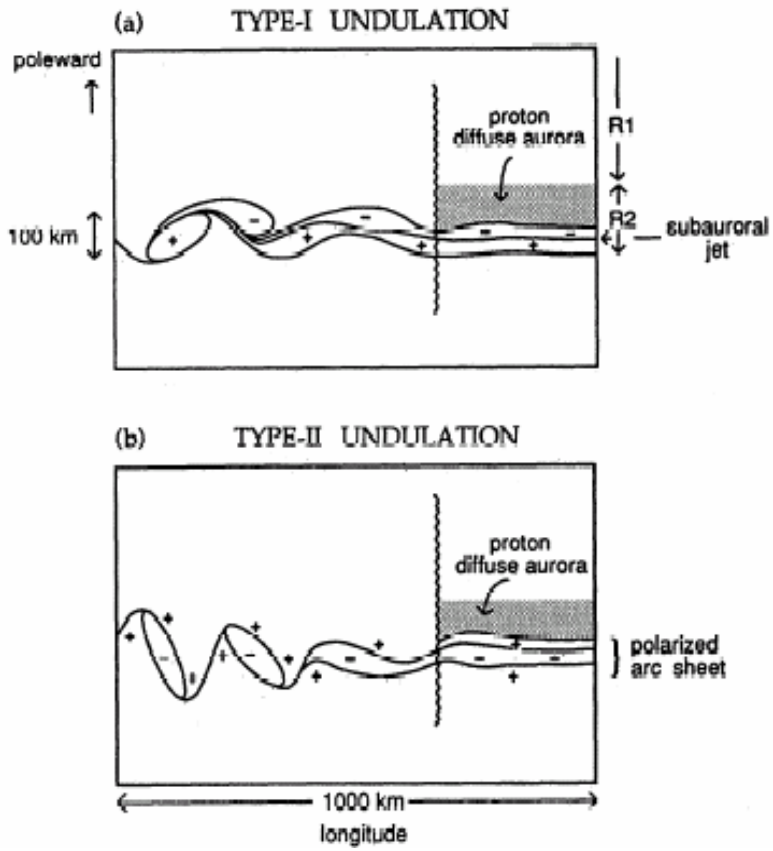


Figure 5. Auroral keogram sampled along two lines along the wave forms, as illustrated in Figure 4. The westward motion of inter structure is clearly seen as indicated by white lines and white arrows, together with that of bay structure. The speed of these inner structure is measured to be 2.5 to 4.0 km/s.

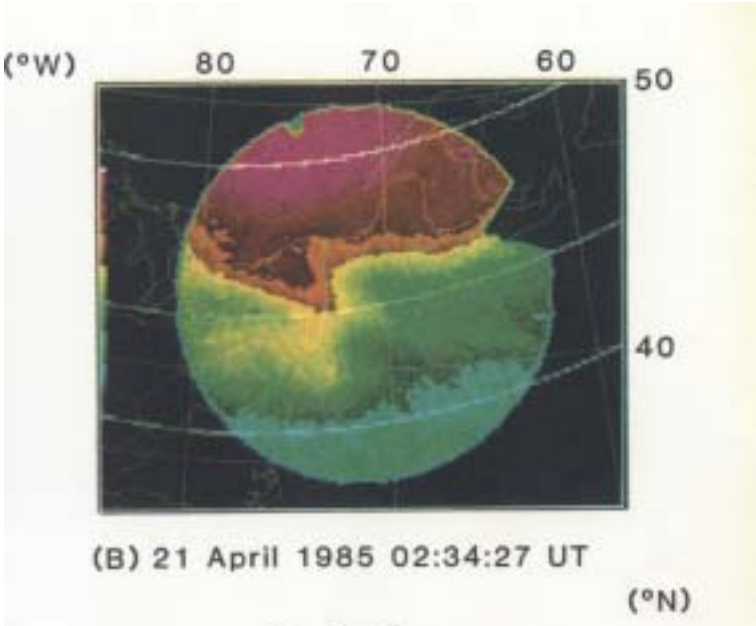
- Wave: westward motion
- Wave amplitude grows with time (70 -> 140 km)
- Small-scale inner structure moving westward (2.5 to 4 km/s) much faster than the wave motion (~500 m/s)
- Observed growth rate is slightly slower than the linear theory of shear instability

2-D electrostatic particle simulation by Yamamoto et al. (JGR, 1993, 1994)

- TYPE-I: 2 charged sheet**を仮定->**
  波状構造が発達するがA>λまで至らず
- TYPE-II: 3 charged sheet**を仮定->**
  A>λまで発達する
  が、このようなsheet**構造に関連した電場分布の観測例なし**



Auroral undulationと電場分布の対応例 (Providakes et al., JGR, 1989; Mendillo et al., JGR, 1989)



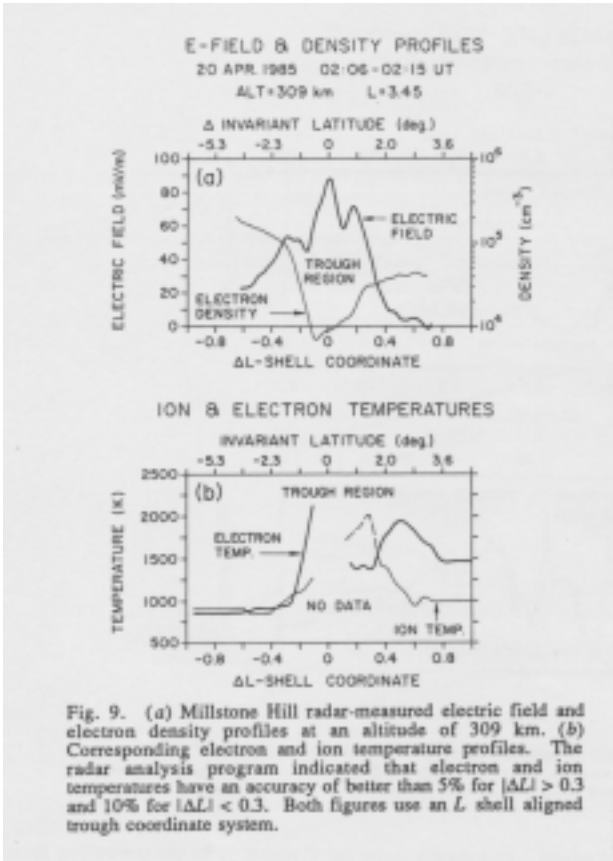


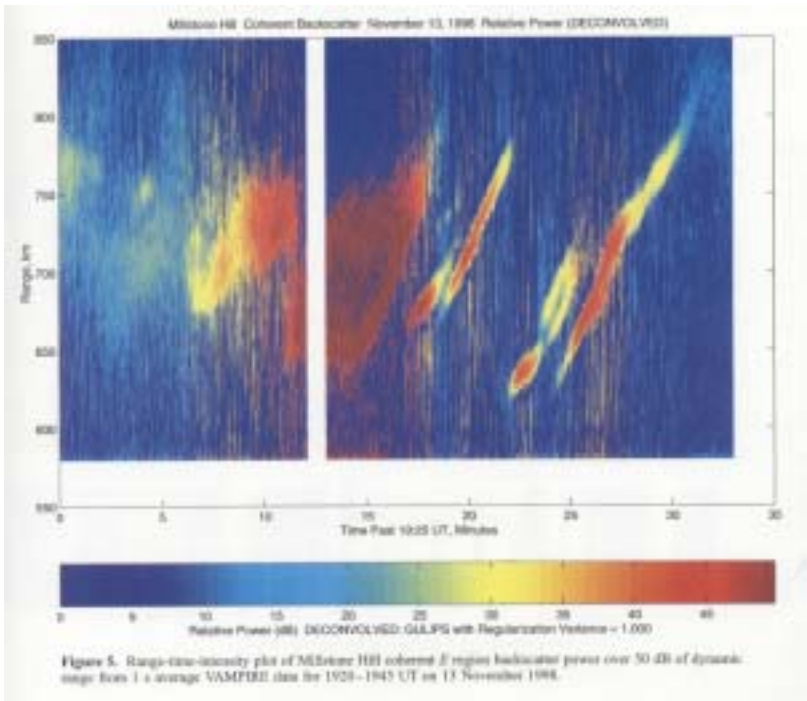
Fig. 9. (a) Millstone Hill radar-measured electric field and electron density profiles at an altitude of 309 km. (b) Corresponding electron and ion temperature profiles. The radar analysis program indicated that electron and ion temperatures have an accuracy of better than 5% for $|\Delta L| > 0.3$ and 10% for $|\Delta L| < 0.3$. Both figures use an L shell aligned trough coordinate system.

詳細な対応例はまだ存在しない

Unsolved problems of giant undulations

- Occurrence conditions
- Mechanism of wave generation / growth to $A>\lambda$
- Relationship to SAID
- Relationship to current / electric field distribution
- Connection to the magnetosphere

空間･時間的に急激に変動するsub-auroral電場構造:SAIDの観測 (Erickson et al., Radio Sci., 2001)

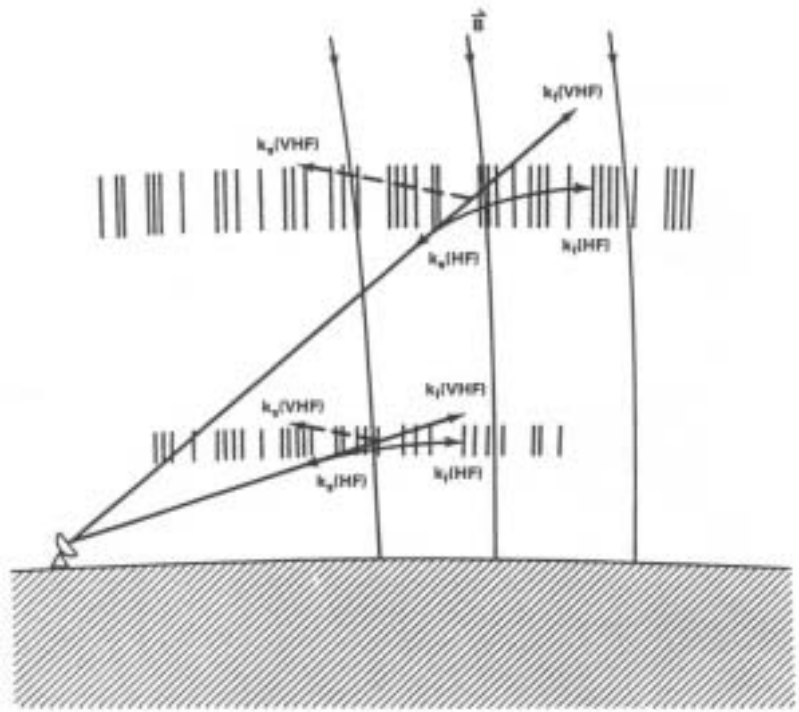


- 5分周期で周期的に変化する電場構造
- 緯度幅: 100-200 km

↓

- これらはundulationに対応する電場構造??
- 2次元観測ではないので詳細は不明
- SuperDARNのような2次元snapshotの観測が不可欠

レーダーエコー観測条件 (ionospheric scatter)

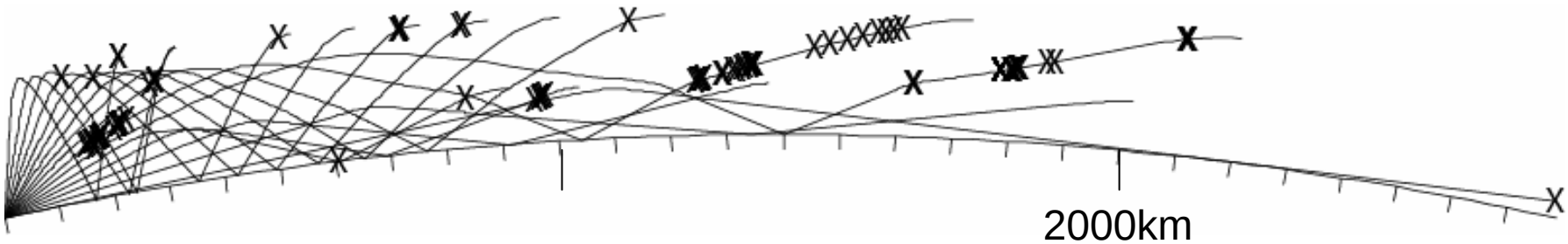


Greenwald et al., Space Sci. Rev., 1995

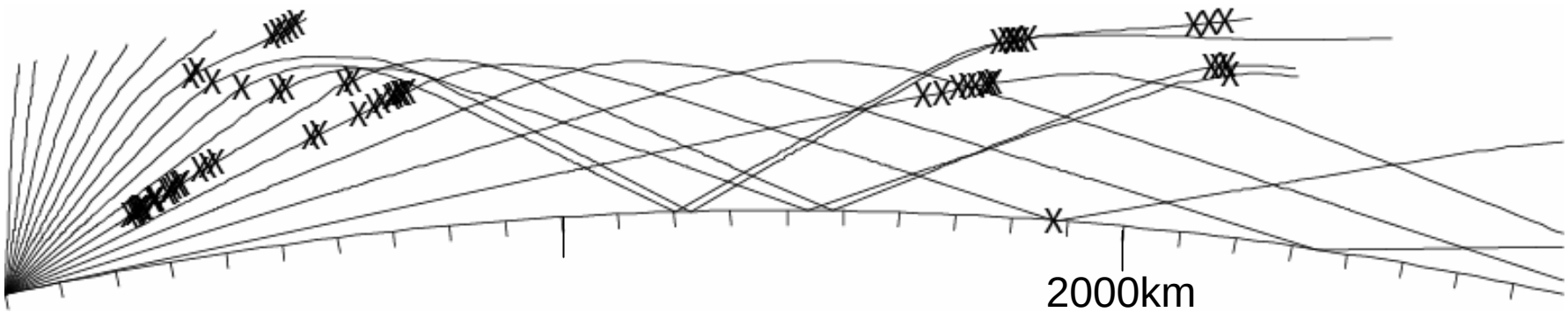
- **電離層中の** decameter scale irregularities**が存在する**(Bragg**散乱を受けるため**)
- **後方散乱を受ける場所において電波の進行方向が磁力線に対して直交する**
- **電波の進行経路で大きな吸収が起こらない**

IRI (International Reference Ionosphere)を使用したtracing

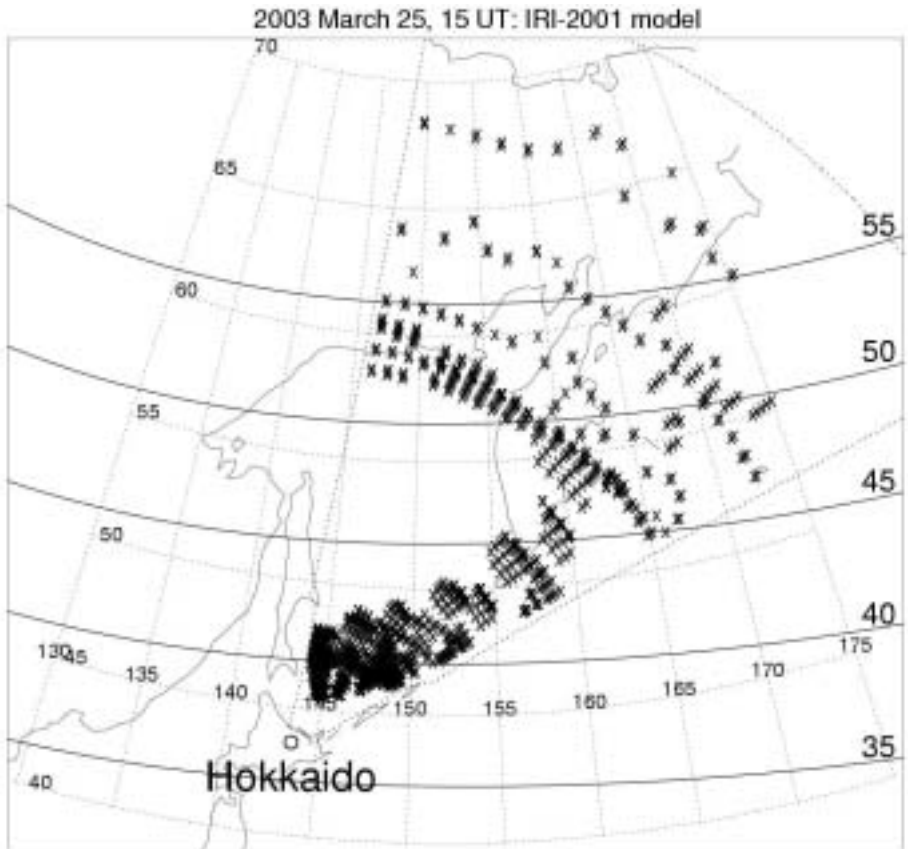
2002.4.18 00 UT (09 LT) – daytime, Ap=132 (active)



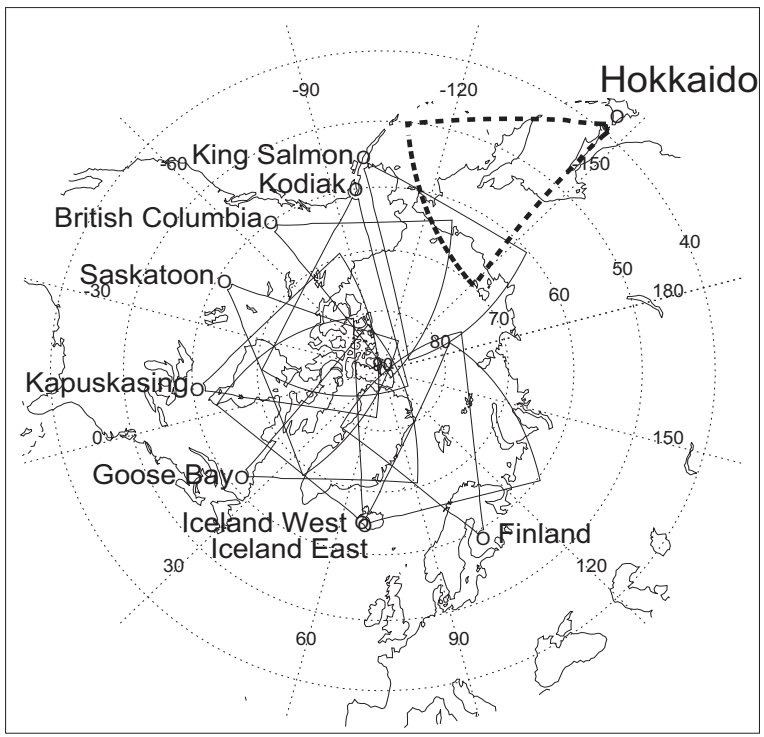
2003.03.25 15 UT (00 LT) – nighttime, Ap=4 (quiet)



電波の直交条件を満たす領域 (2003.3.25 00 LT, Ap=4)



まとめ



- 中緯度短波レーダーにより中緯度からsubauroral帯にわたる広域の2次元電場観測が期待できる
- 特にsubauroral帯では、様々な時間・空間的に変動する現象の観測が有望である