中緯度レーダーデータの見方について

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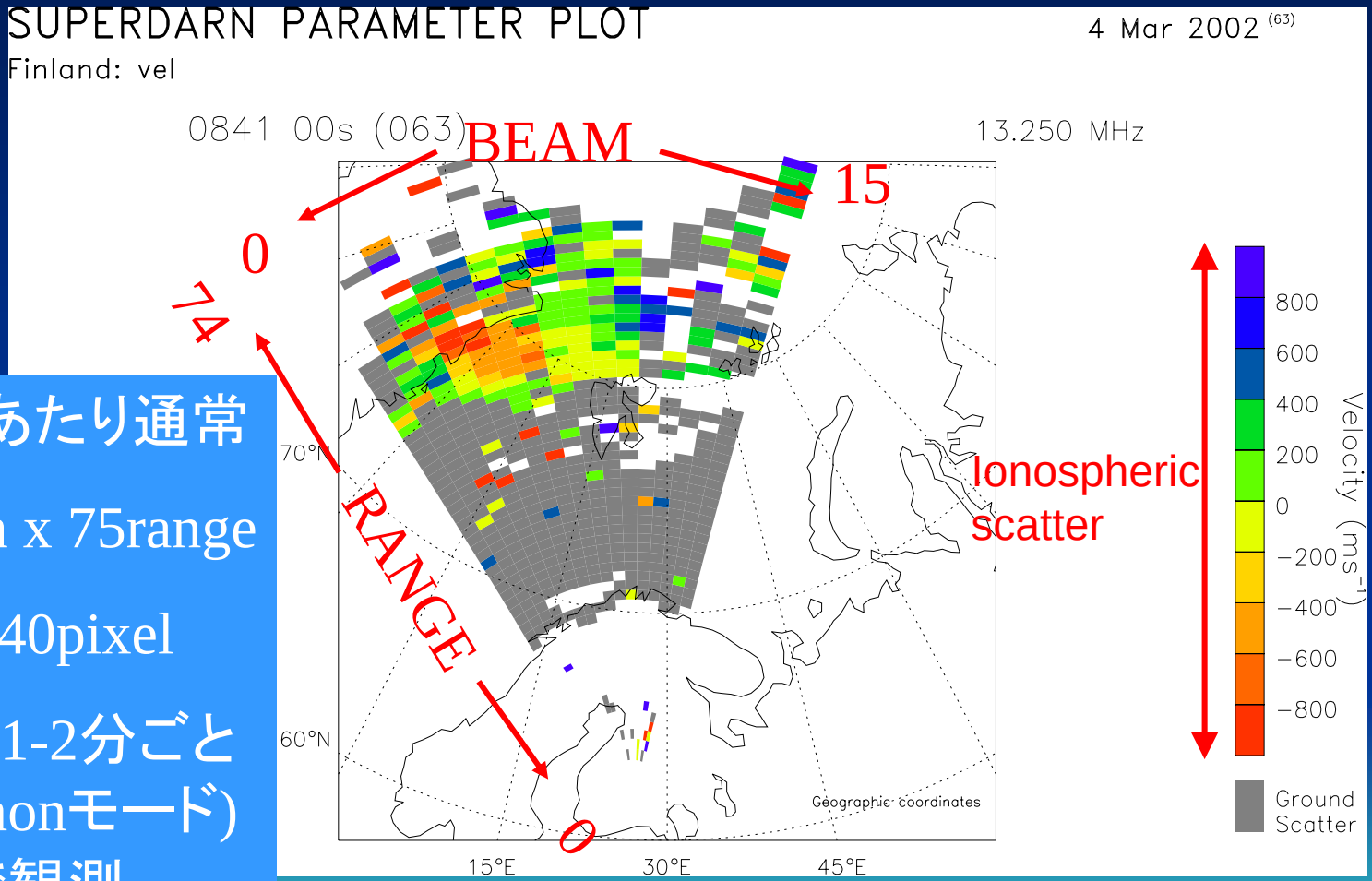
西谷　望

レーダー観測の基本用語集



1 scanあたり通常

16beam x 75range

=1440pixel

これを1-2分ごと(commonモード)で観測

Range: ground rangeとslant rangeの区別に注意

レーダーで観測されるパラメータ

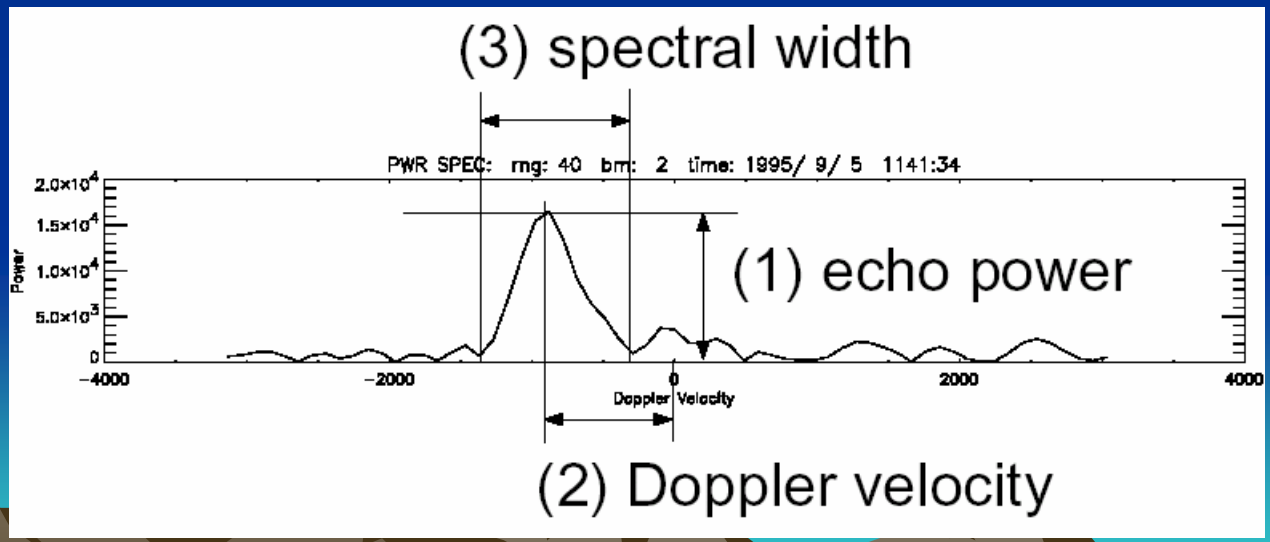
(1) Echo power

(2) Doppler velocity

(3) Doppler spectral width

spectral width : low

spectral width : high



Typical size of 1 pixel: 15~45 × ~100 km, Typical integration time: 1-7 seconds

Description of quicklook plots

This is a summary plot of the Hokkaido radar data for beam 5. There are total of 16 beam directions: beam 5 is directed along the line which is about 11 degrees shifted clockwise from the geographic north).

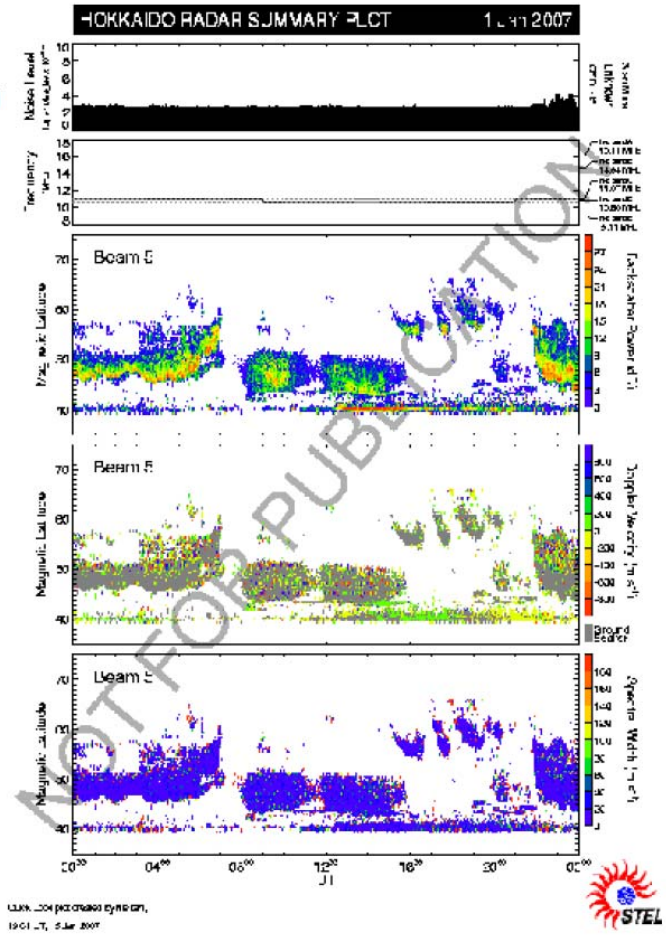
The plot consists of 5 panels.
The top panel shows the noise level versus Universal Time (UT, given at the bottom). If the level is above 4, the data might be contaminaed with other artificial radio waves.

The 2nd panel shows the radar frequency against UT. The Hokkaido radar is allowed to use only 5 frequency bands. These are indicated by the dotted lines.

The 3rd panel shows the amount of backscatter (color scale, in dB) that the radar has received at a certain magnetic latitude (AACGM) on the ordinate and UT on the abscissa.

The 4th panel shows the Doppler velocity. Only when and where the radar has received ionospheric backscatter, the velocity of ionospheric plasma and ionospheric electric field can be determined. The gray pixels are the so-called ground (sea) scatter echoes. They cannot be used for determining horizontal plasma velocity, but they can be used to estimate the vertical motion of the ionosphere. They can also be used to find Traveling Ionospheric Disturbances (TIDs).

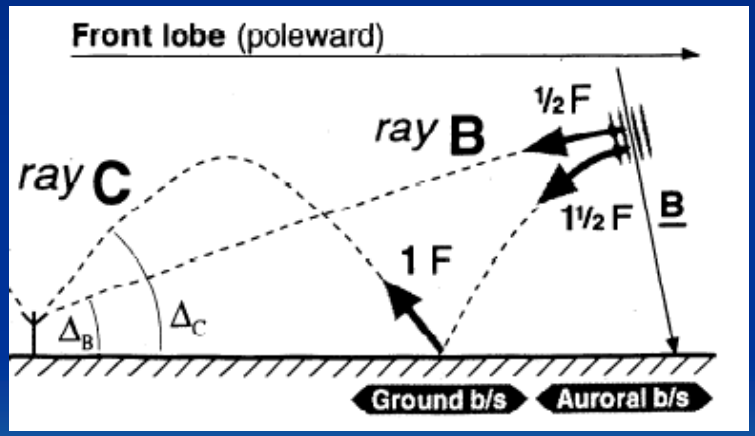
The bottom panel shows the Doppler spectral width, that is a measure of the degree of turbulence of the ionospheric plasma flow in one pixel. Ionospheric backscatter echoes have a larger Doppler spectral width than ground (sea) scatter echoes.



http://center.stelab.nagoya-u.ac.jp/web1/hokkaido/gif/quicklook_description/

SuperDARNで観測されるエコーの種類

- ionospheric scatter echoes(片岡)
- ground (sea) scatter echoes(細川)
- meteor echoes(近距離エコー)(行松、堤)
- PMSE(近距離エコー)　　--- 小川先生



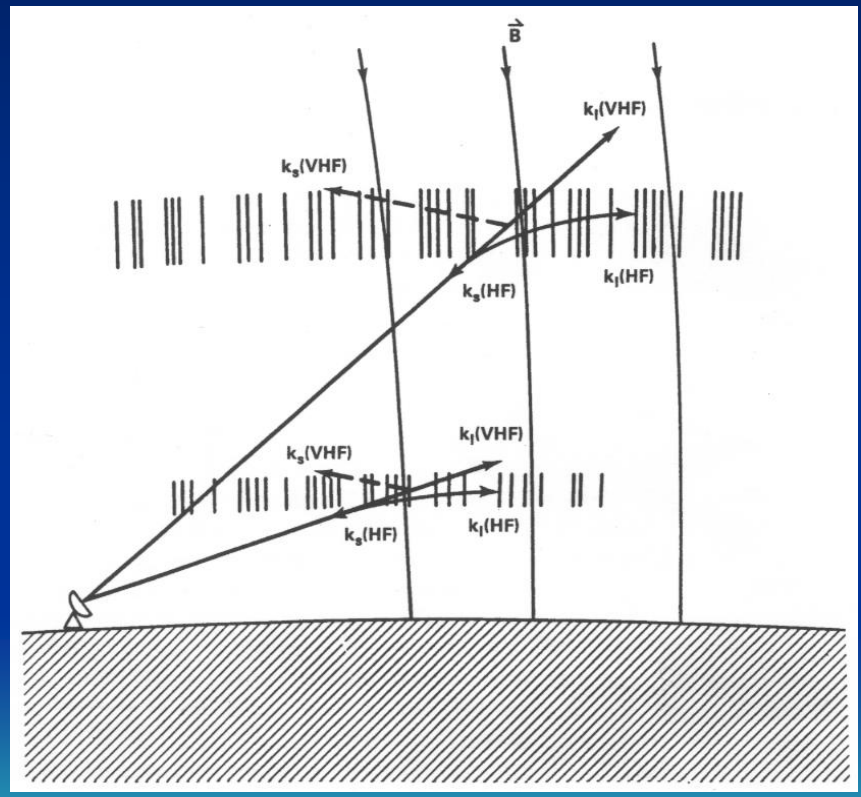
(Milan et al., GRL, 1998)

- Ground (sea) scatter エコーの判定条件:
  |(Doppler velocity)|≦30-1/3×(spectral width)

電離圏エコー
ionospheric scatter

HFレーダーによる電離圏エコーの受信条件(Bragg散乱を利用)

- 後方散乱域において、水平方向にλ/2の空間スケールを持つirregularity構造が存在する
- 散乱域において、電波の進行方向と磁力線方向とが直交する(irregularityは、磁力線に沿ってほぼ一様な構造を持つため)
- 電波の伝搬路において、D層による吸収等がほとんど存在しない



Irregularityの生成メカニズム: gradient drift instability

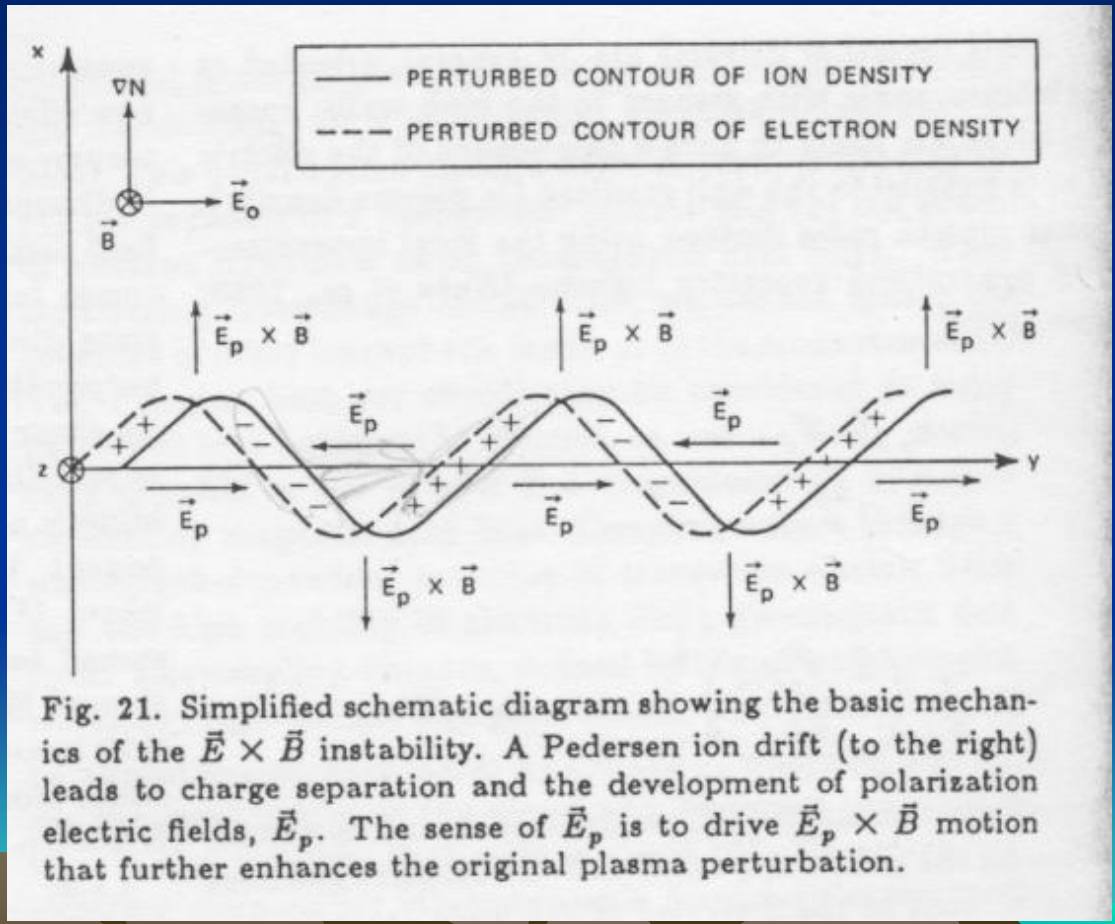
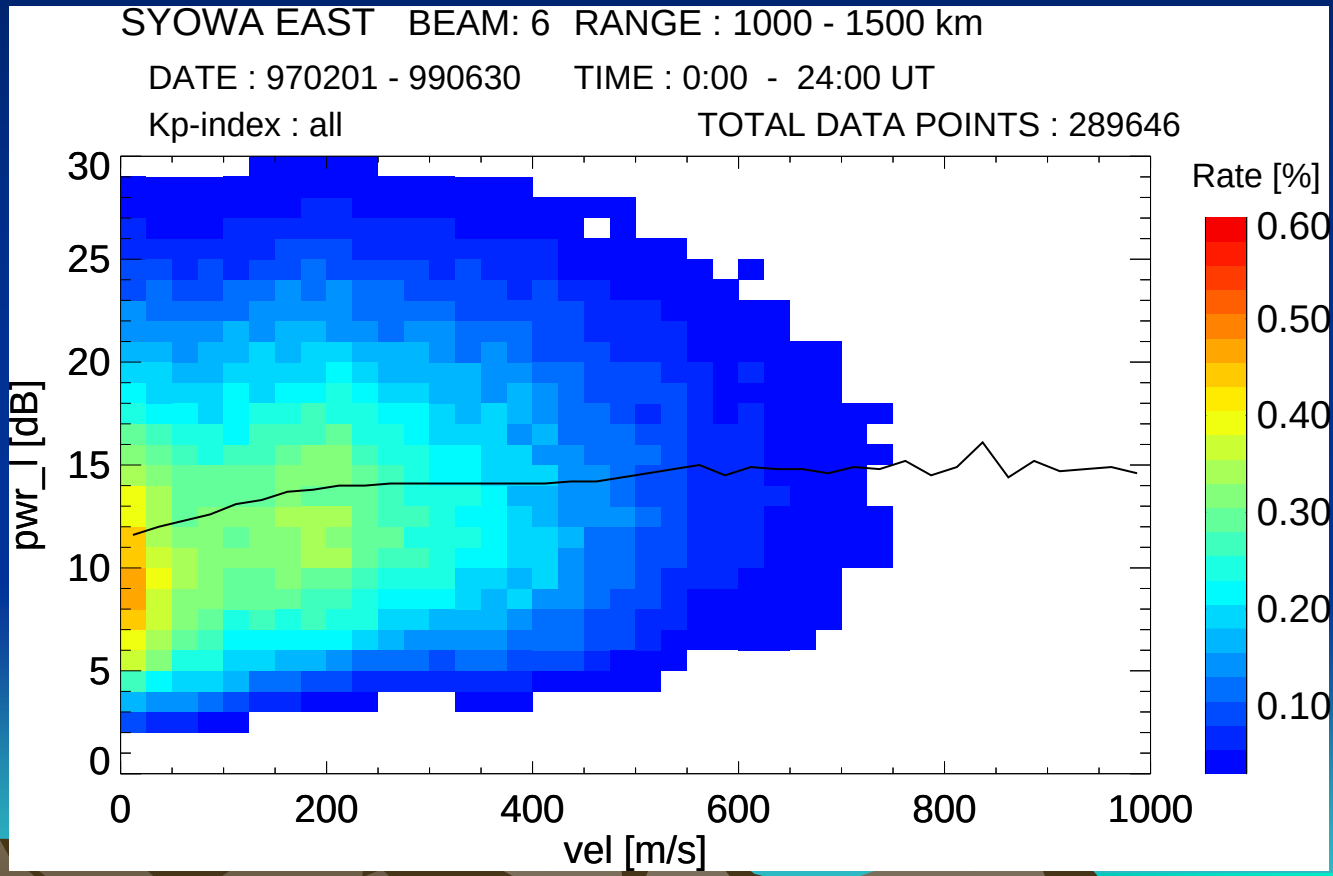


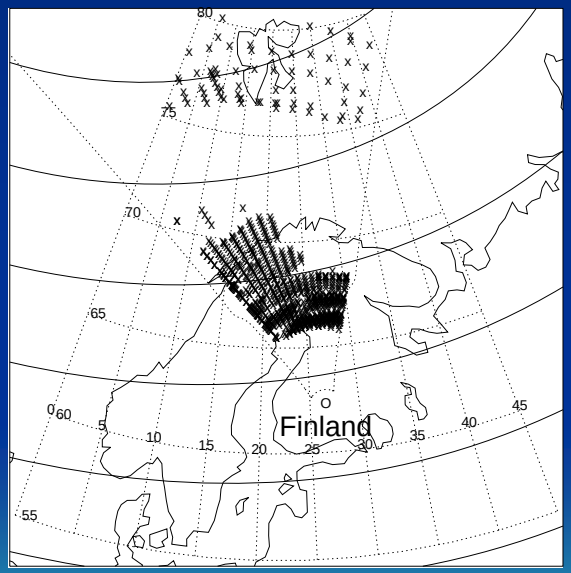
Fig. 21. Simplified schematic diagram showing the basic mechanics of the $\vec{E} \times \vec{B}$ instability. A Pedersen ion drift (to the right) leads to charge separation and the development of polarization electric fields, $\vec{E}_p$. The sense of $\vec{E}_p$ is to drive $\vec{E}_p \times \vec{B}$ motion that further enhances the original plasma perturbation.

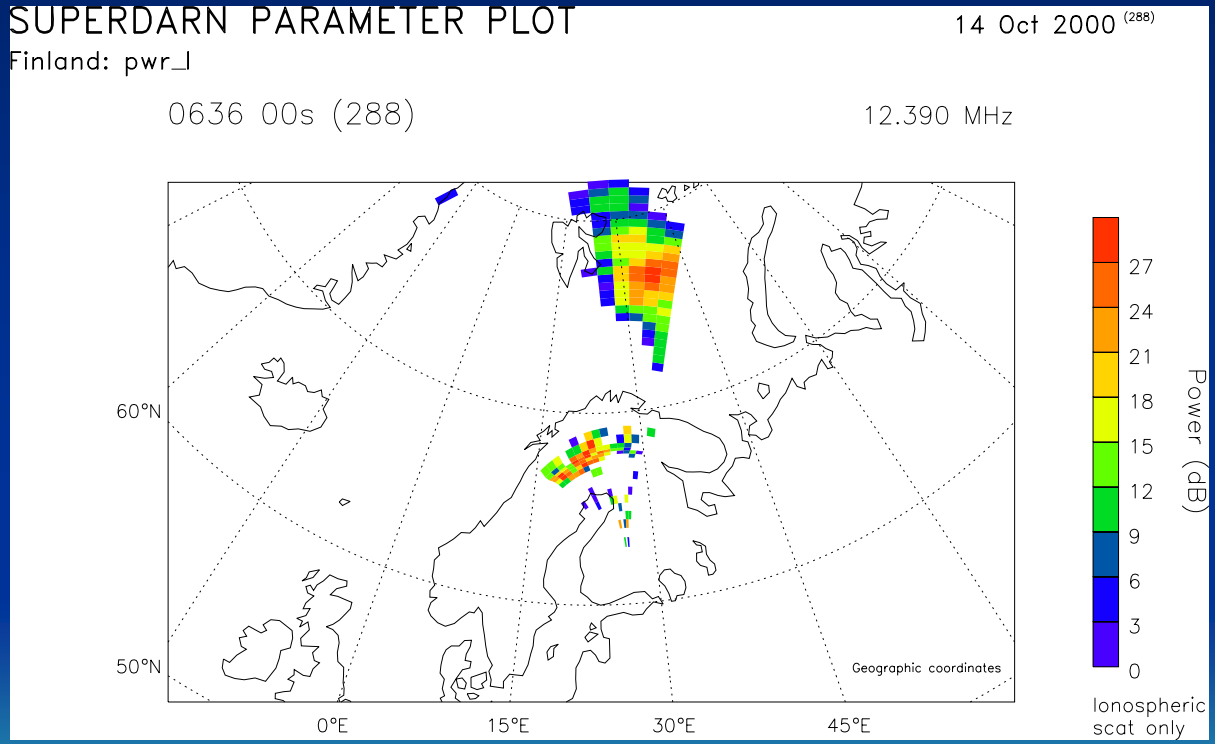
Tsunoda, 1988

Irregularity生成に電場が重要であることを示す例: Fukumoto, 2000.

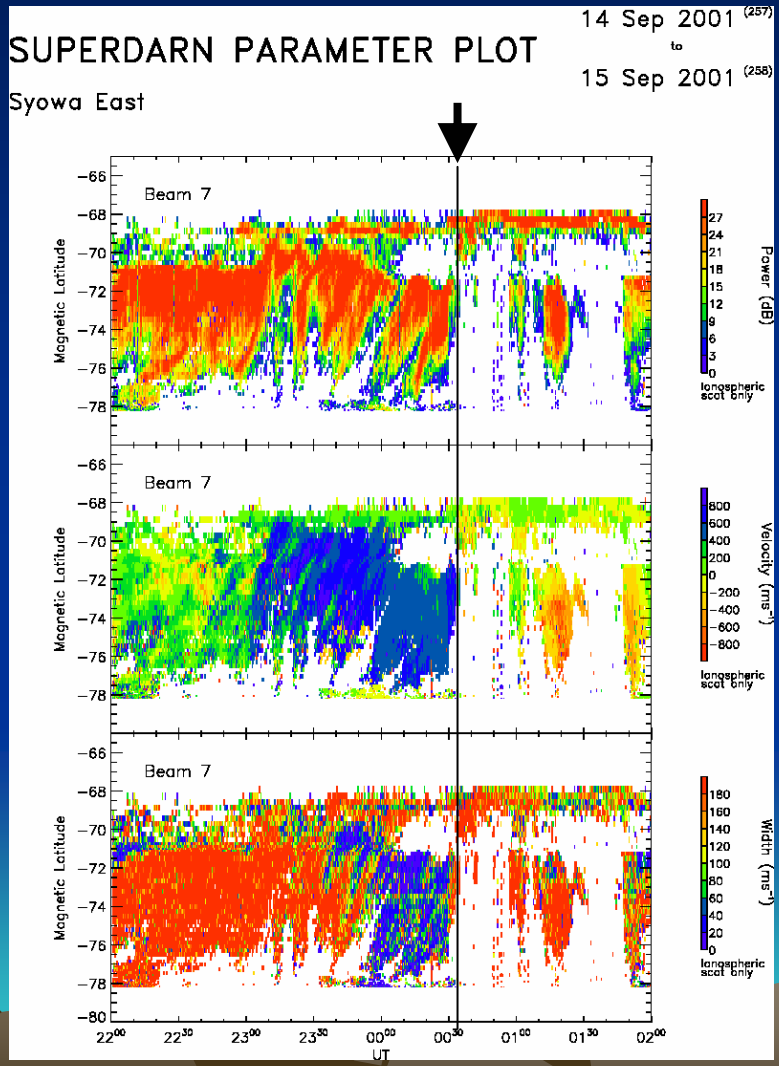


IRIのray path tracingによる、電波の直交条件の満たされる点の分布(左)および、実際のエコー分布

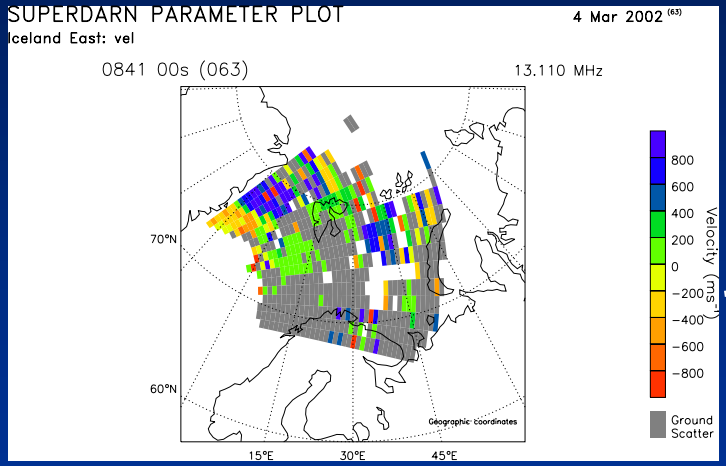


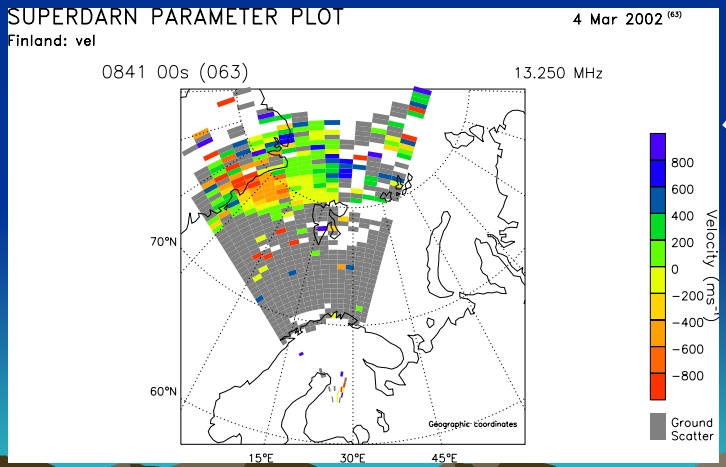


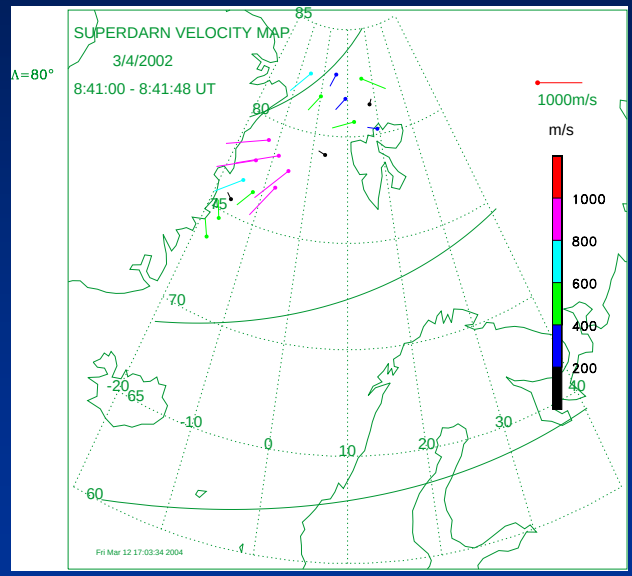
SubstormによるD層電離層吸収増加のため、エコーが消失する例



本来は水平対流の二次元ベクトルを求めるにはに方向からの観測が必要





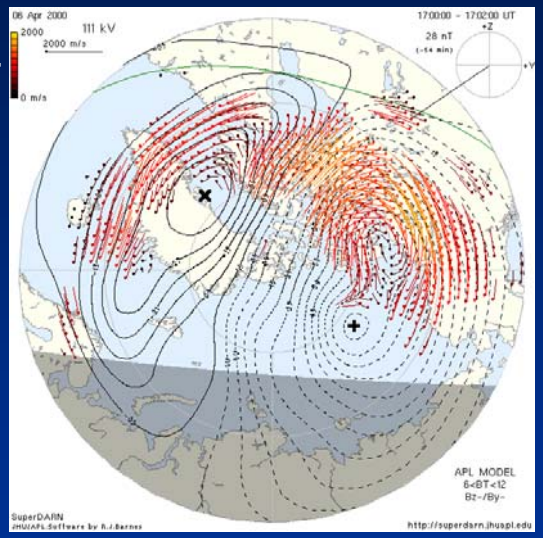


rad_mergeソフトウェア

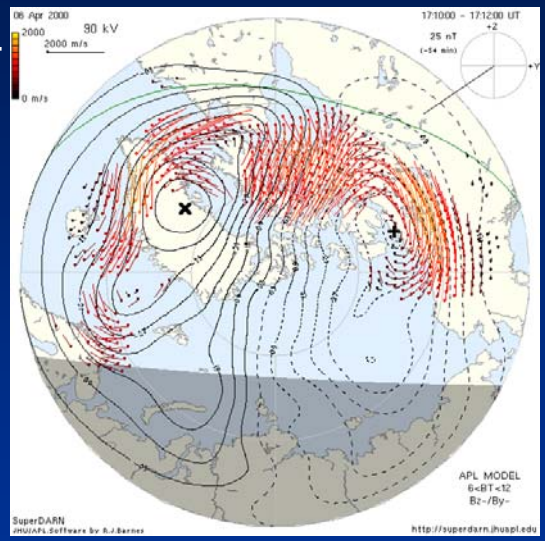
- かなり信頼性の高いデータを求めることができるが、データ範囲が非常に限られる

map_potentialソフトウェアでは、観測データ+IMFに依存した統計データを球面調和関数でfitting

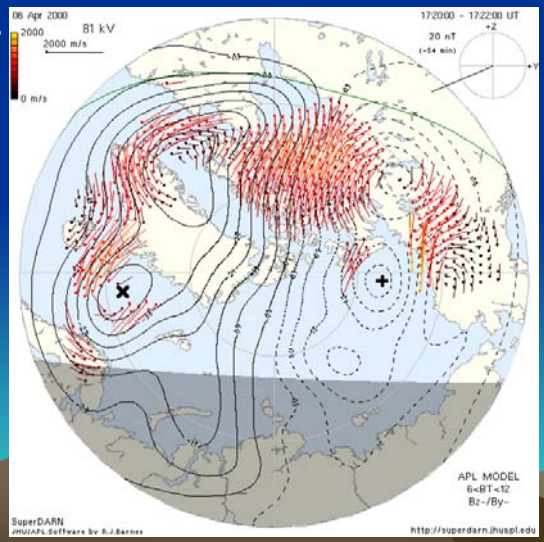
17:00 UT



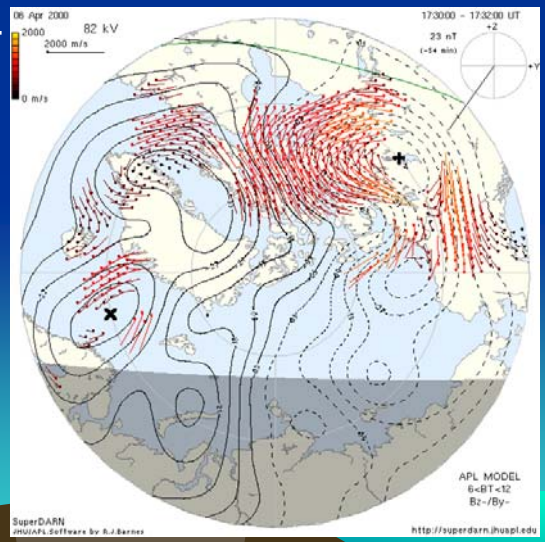
17:10 UT



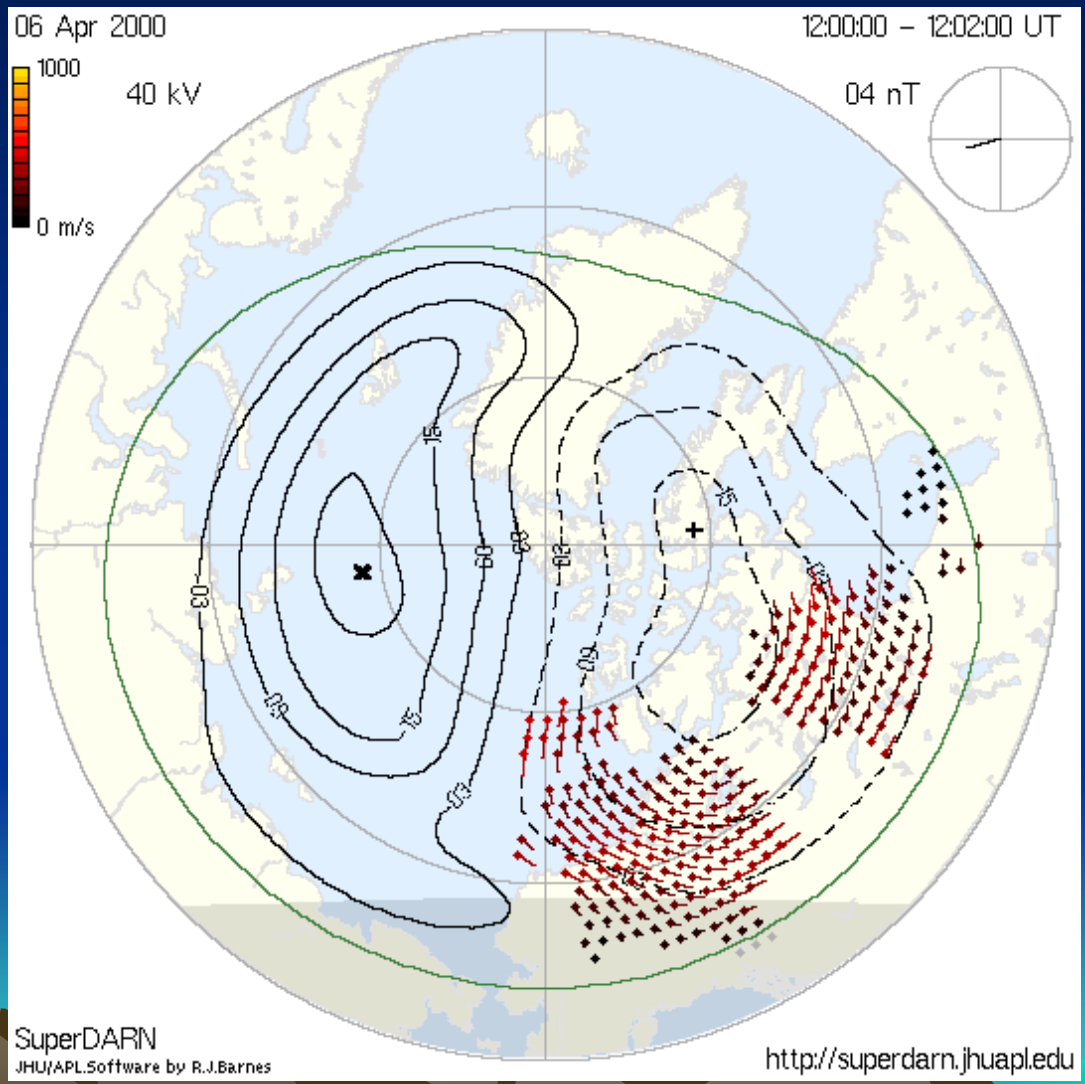
17:20 UT



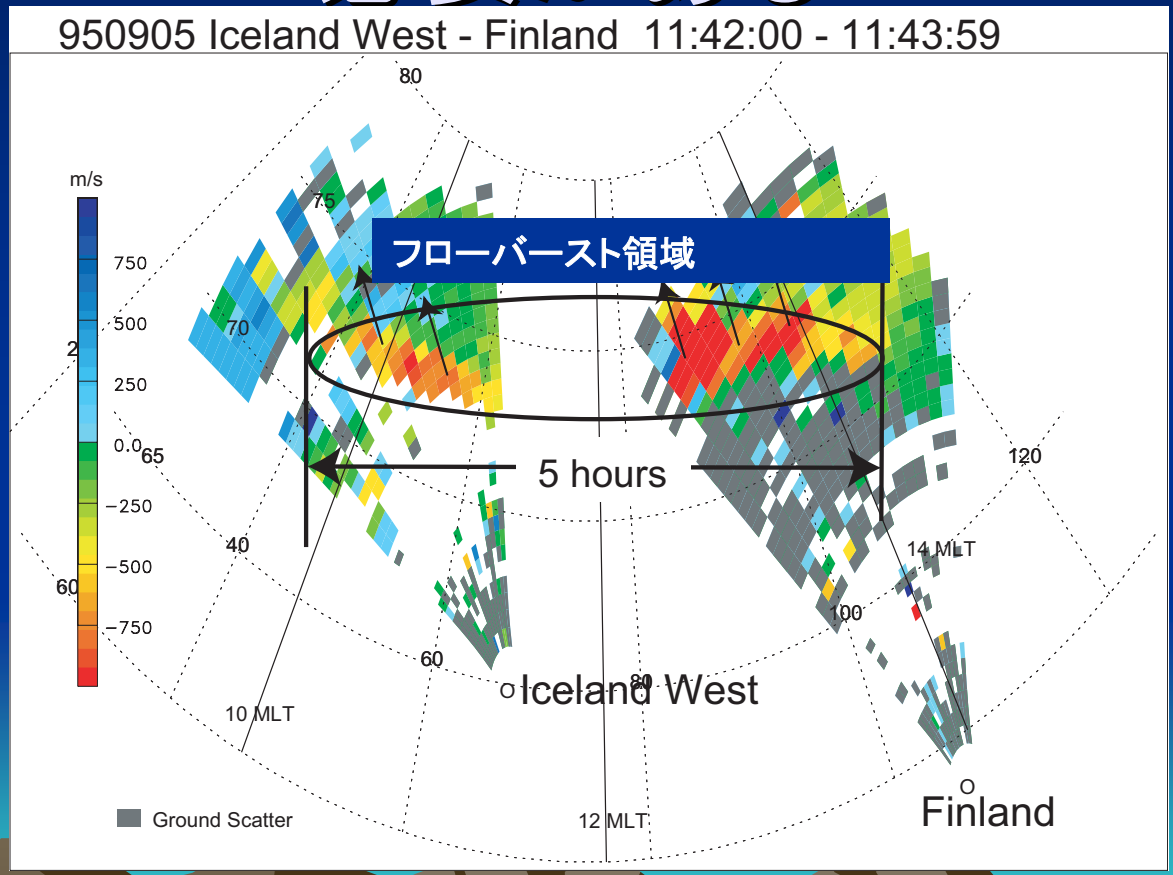
17:30 UT



電離圏プラズマ水平対流分布の時間変化



実際の解析においては、元のデータ(視線方向速度データ)を詳しく調べる必要がある

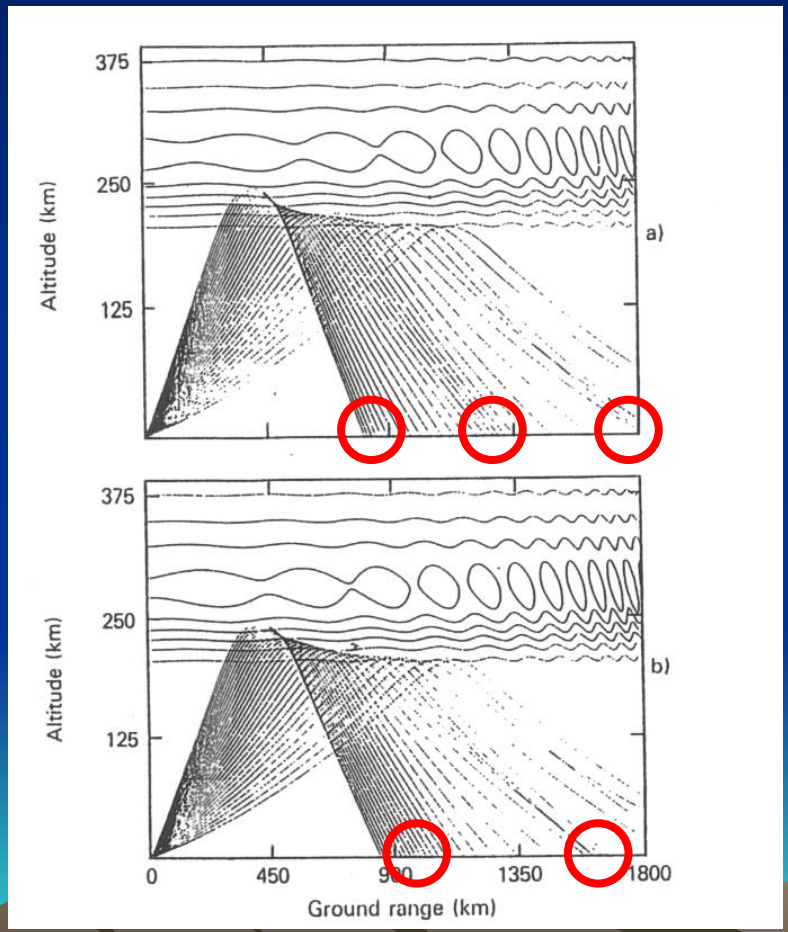


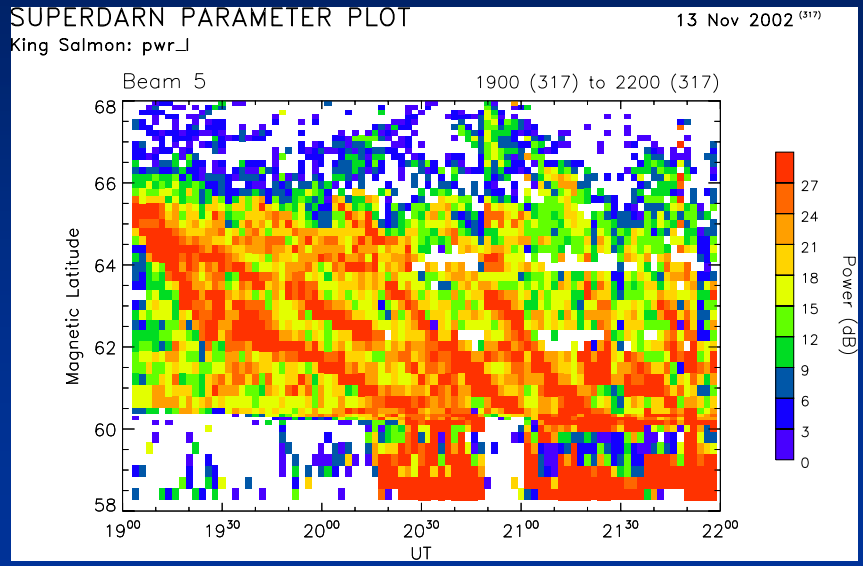
Nishitani et al., J. Geophys. Res., 1999

Ground (sea) scatter echoes

SuperDARNのground scatterによるTIDの観測

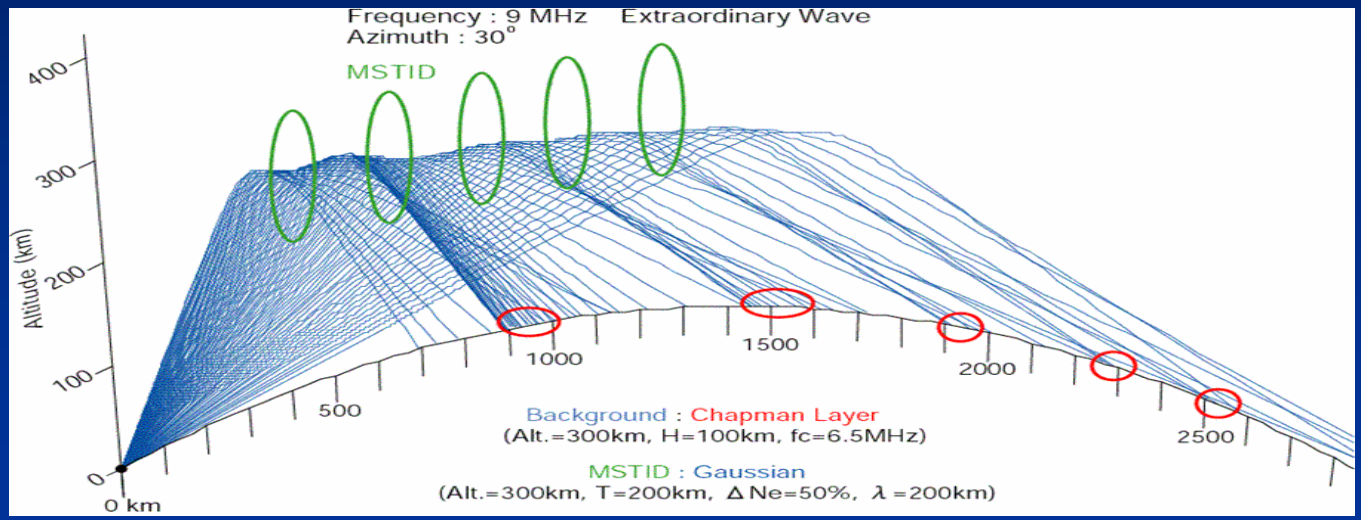
(coutesy of T. Kikuchi, CRL)





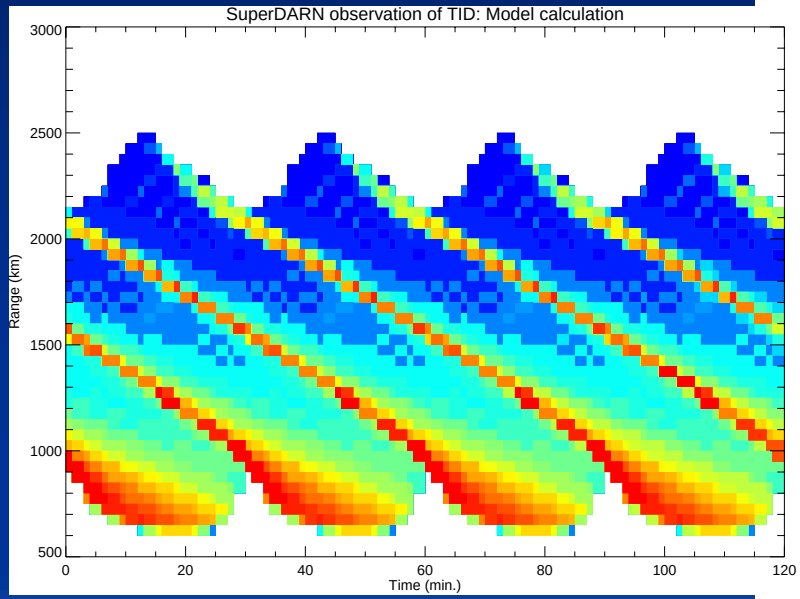
- 電離層中の密度波状構造により波がfocusing-defocusingを受ける
- 観測されたground scatter中の波状構造を観測すれば波の波数ベクトル・伝搬方向がわかる
- さらにmulti-frequencyで観測すれば鉛直方向に関する情報が得られる

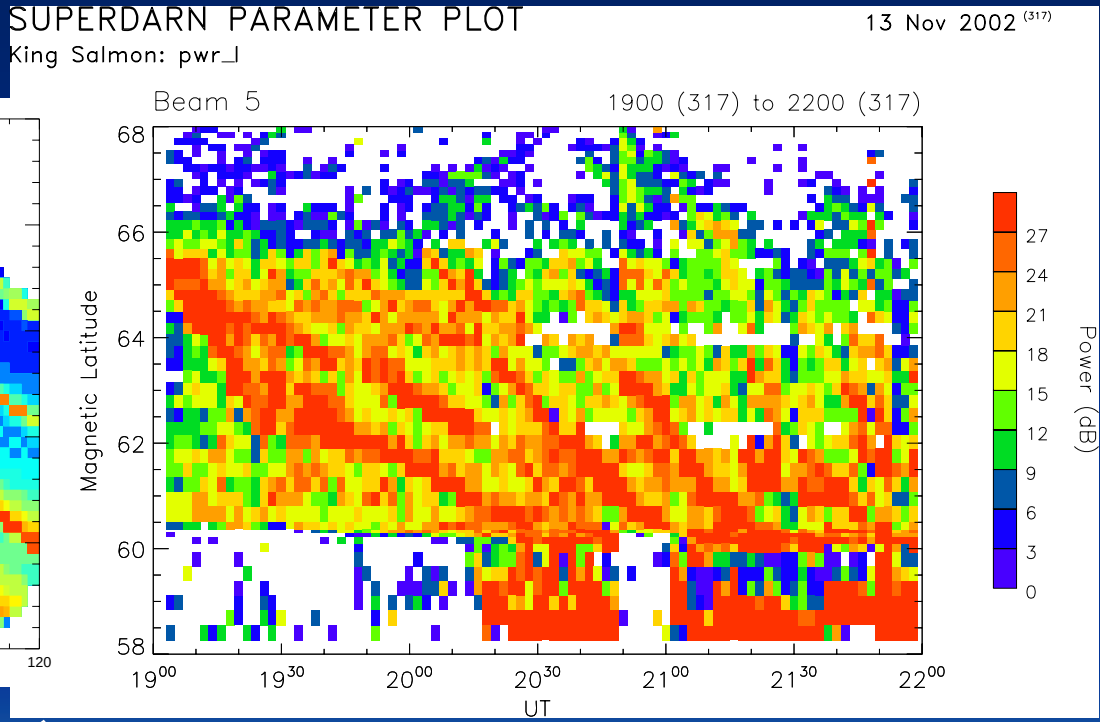
TIDによるfocusing-defocusingのモデル計算



- 多数のtracingを行えば各rangeにおけるエコー強度を求めることができる

TIDによるfocusing-defocusingのモデル計算

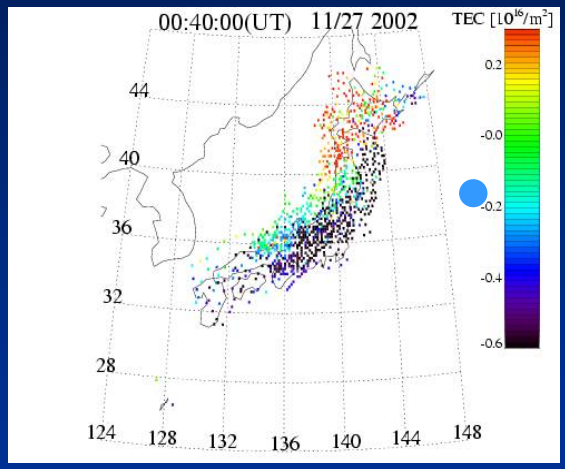


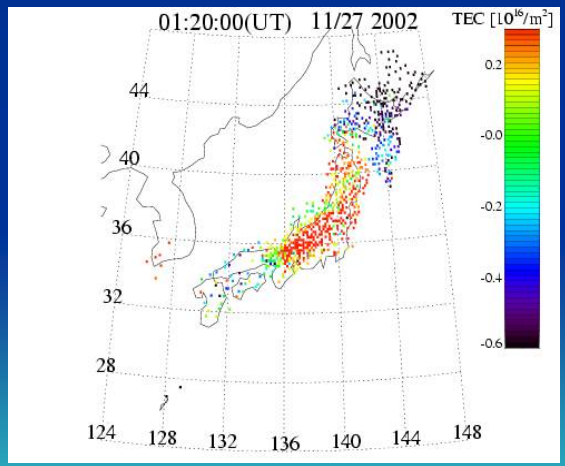


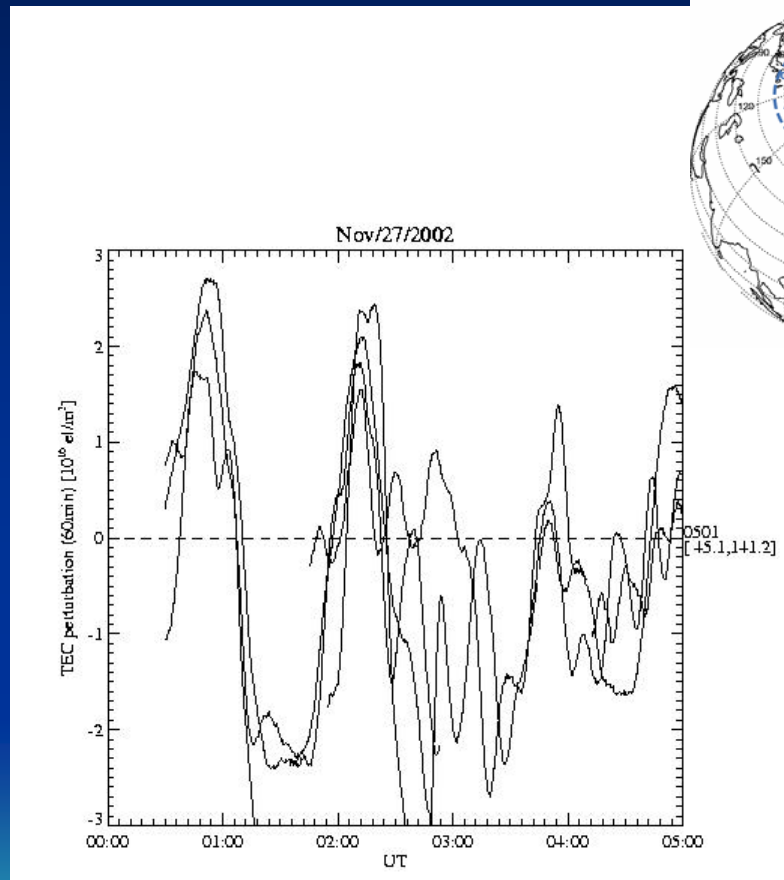
- 左:モデル計算、右:観測データ(King Salmon SuperDARN)
- FittingによりTIDのパラメータを求めることができる
- 複数周波数の観測データがあれば高度情報がわかる

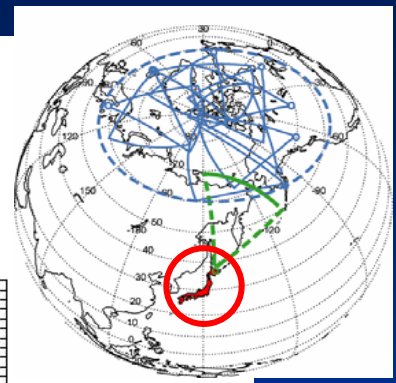
Ground scatterによるLSTIDの観測

高緯度-中緯度電離圏・熱圏結合
~昼間側LSTIDの場合~

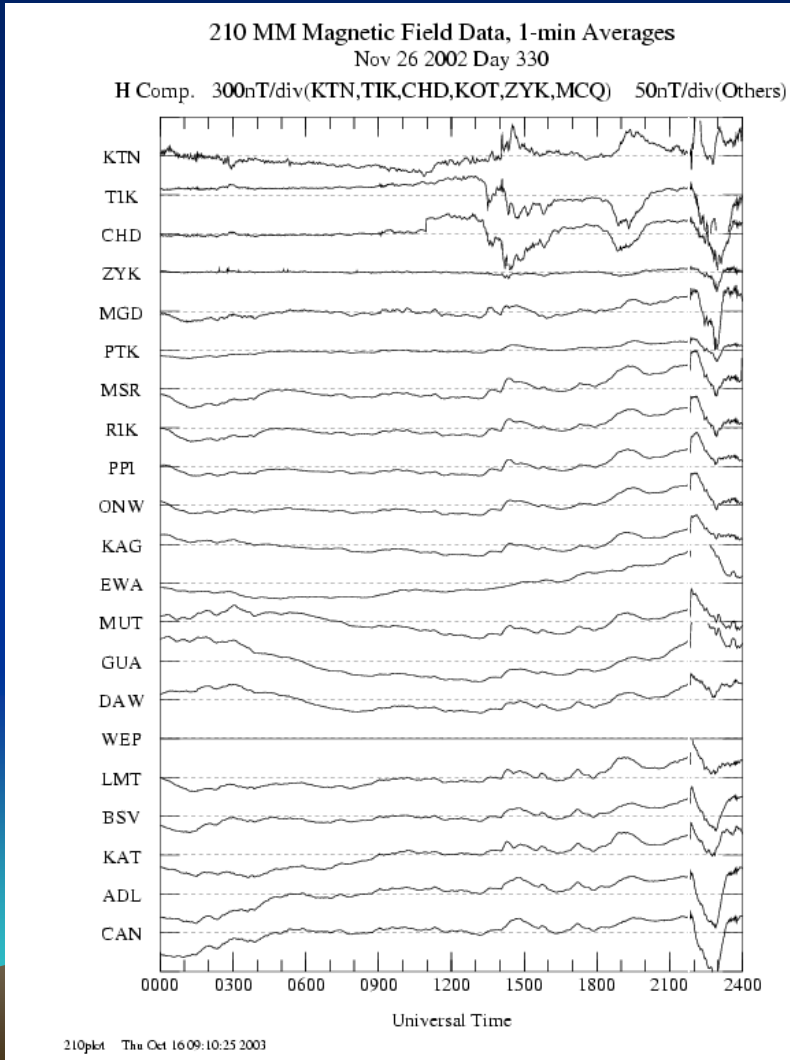


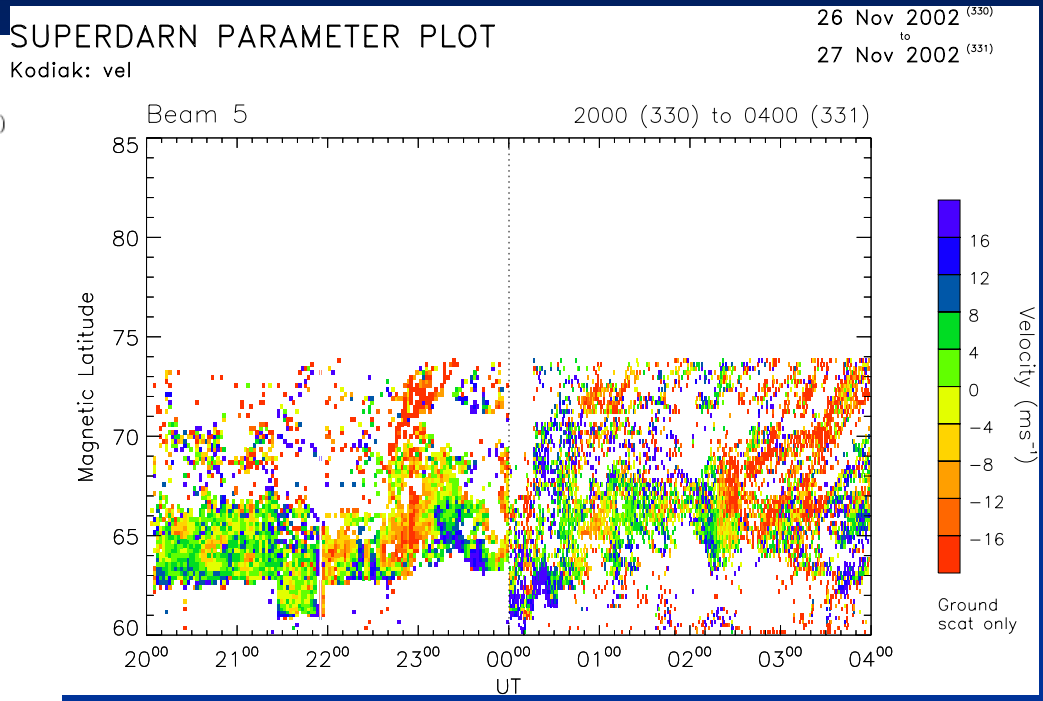


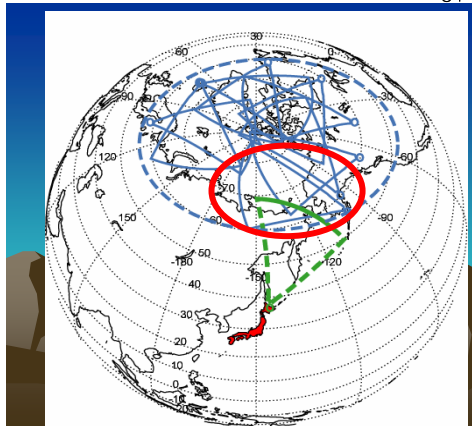


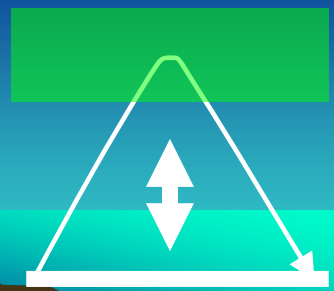


高緯度領域で観測された擾乱: 中緯度LSTIDの有力なsource



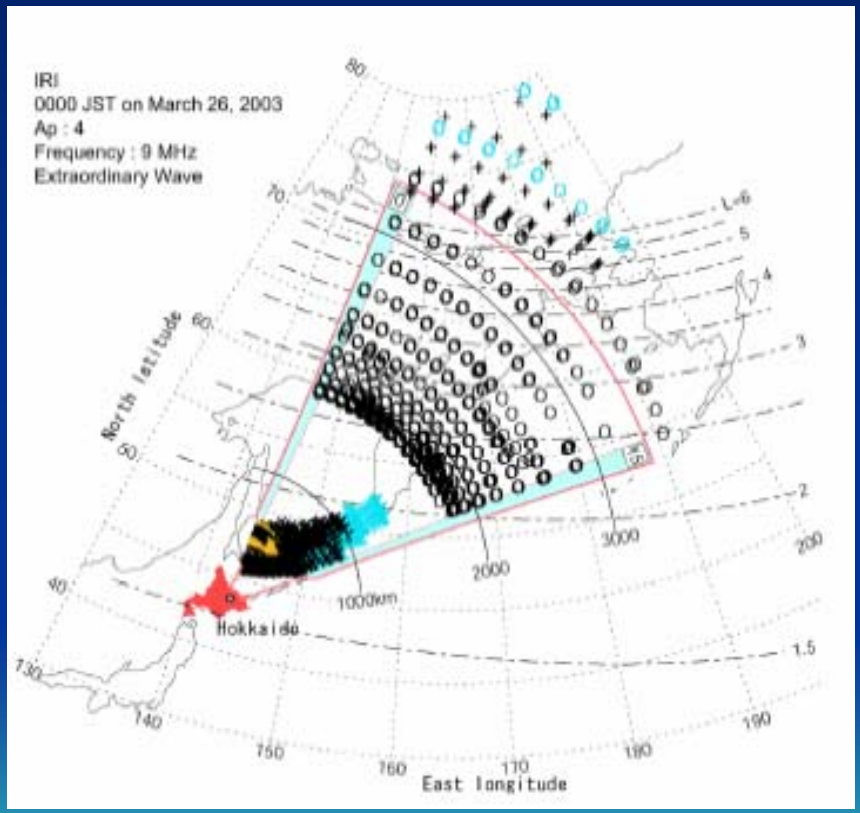


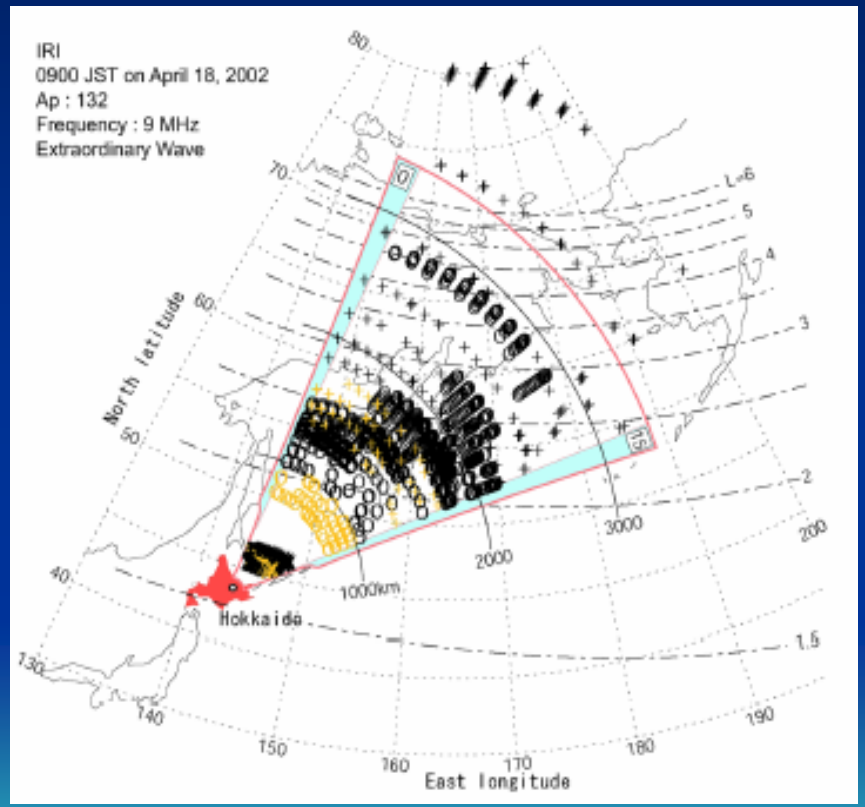




北海道ー陸別HFレーダーにおけるエコーの見え方について

電波の直交条件を満たす領域 (左側: 夜、右側: 昼)





Jones and Stephenson (1975) algorithm + IRI-2001

Nishitani and Ogawa, APUAR, 2005

伝搬経路は地磁気活動度、地方時、使用周波数に高い依存性を持つ→その時々の状況に応じて最適周波数を選ぶ

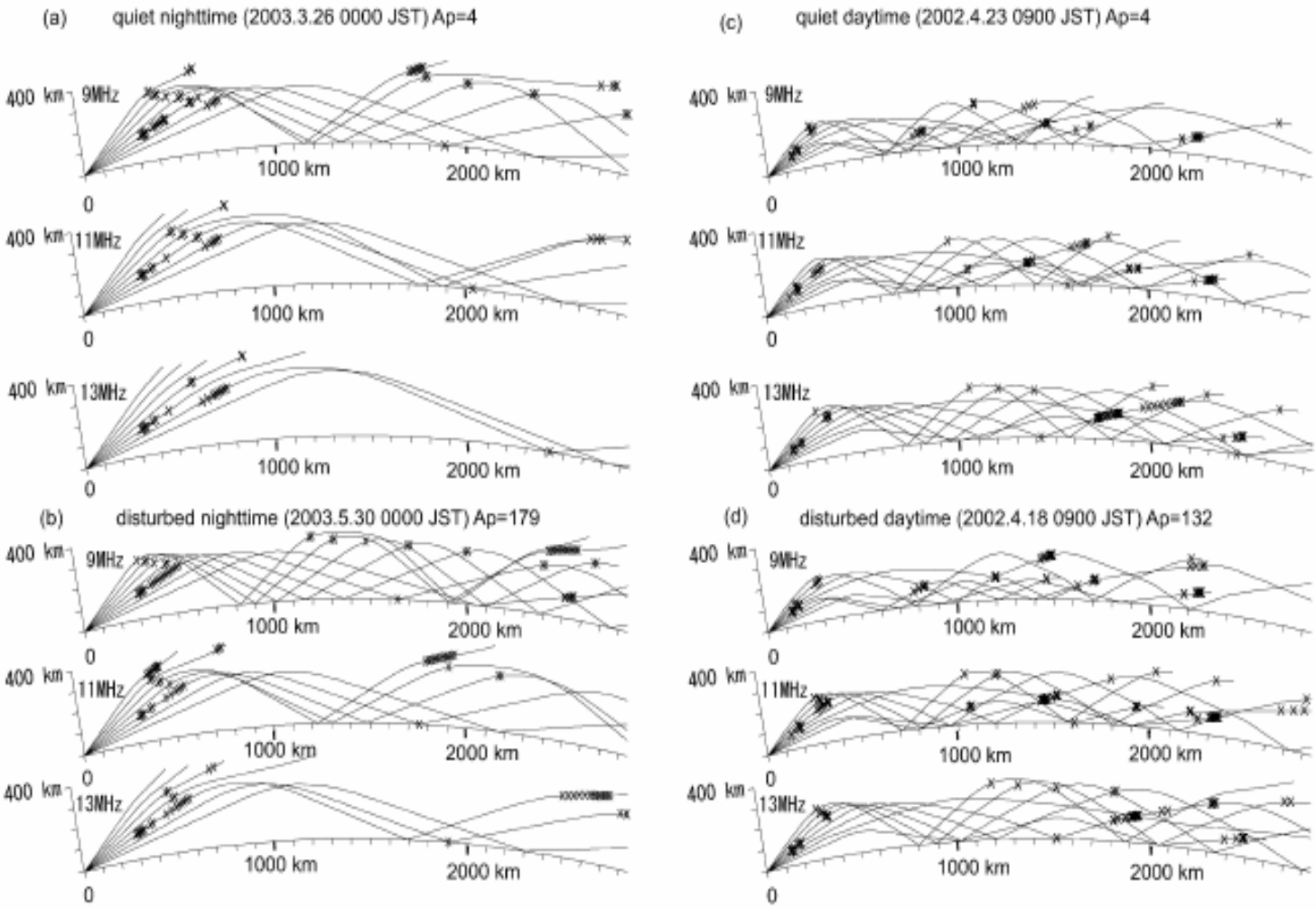


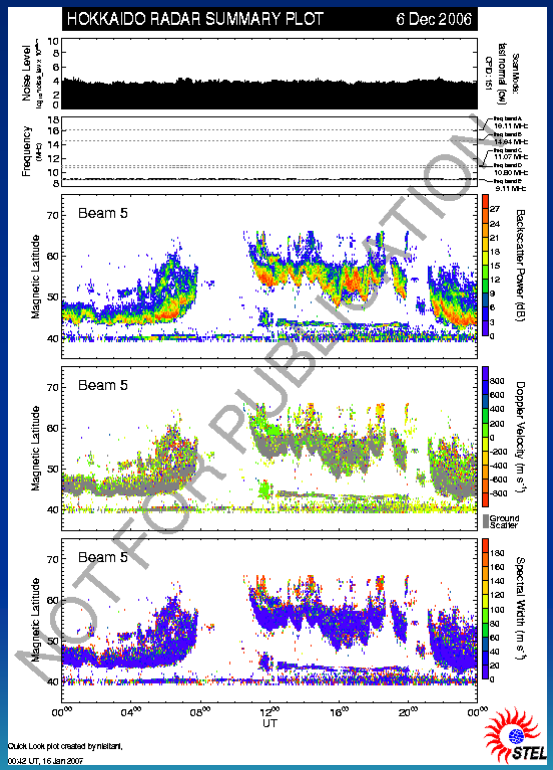
Fig. 3. Vertical profile of HF ray paths (solid curves) in the model ionosphere. The horizontal axis is the distance from the radar antenna, and the vertical axis is the height. The radar wave is emitted at a horizontal angle of 30° clockwise from the geographic north. At × points, where the angle between radar HF ray vector and the ambient magnetic field vector is within the range of 90°±1°, HF waves are expected to be backscattered by ionospheric field-aligned irregularities (if they exist). Four sets of 3 panels show the results for (a) quiet nighttime (2003/03/26, 00 JST), (b) disturbed nighttime (2003/05/30, 00 JST), (c) quiet daytime (2002/04/23, 09 JST) and (d) disturbed daytime (2002/04/18, 09 JST) conditions respectively, with 3 different frequencies.

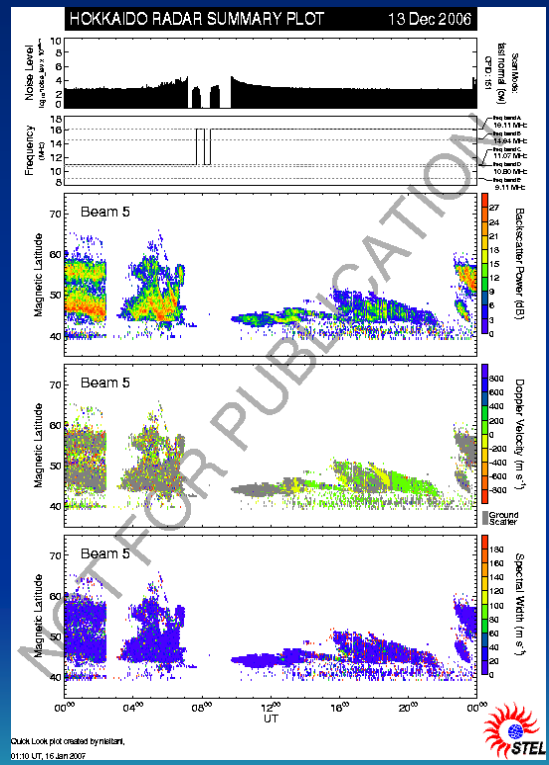
北海道レーダーに許可された周波数

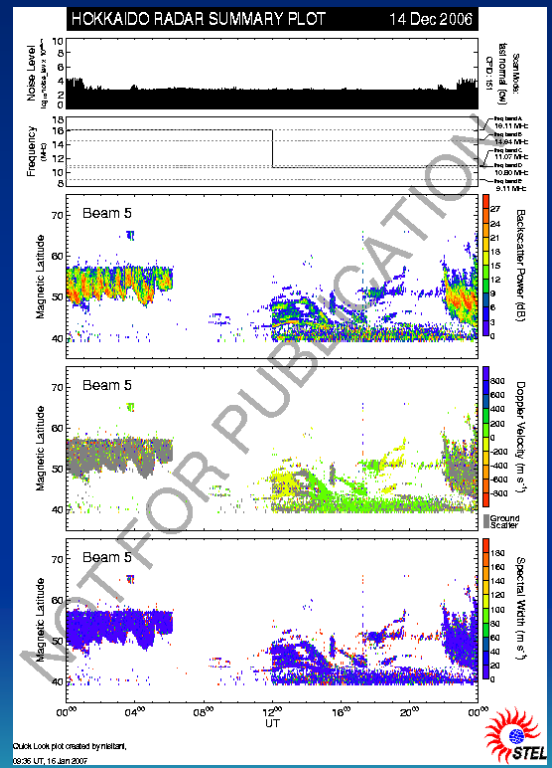
- 9120±20kHz
- 10810±20kHz
- 11070±20kHz
- 14650±20kHz
- 16120±20kHz

この中で最適な周波数を選択する必要あり

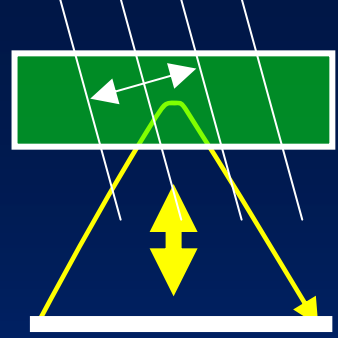
異なる周波数での
エコーの見え方の違い

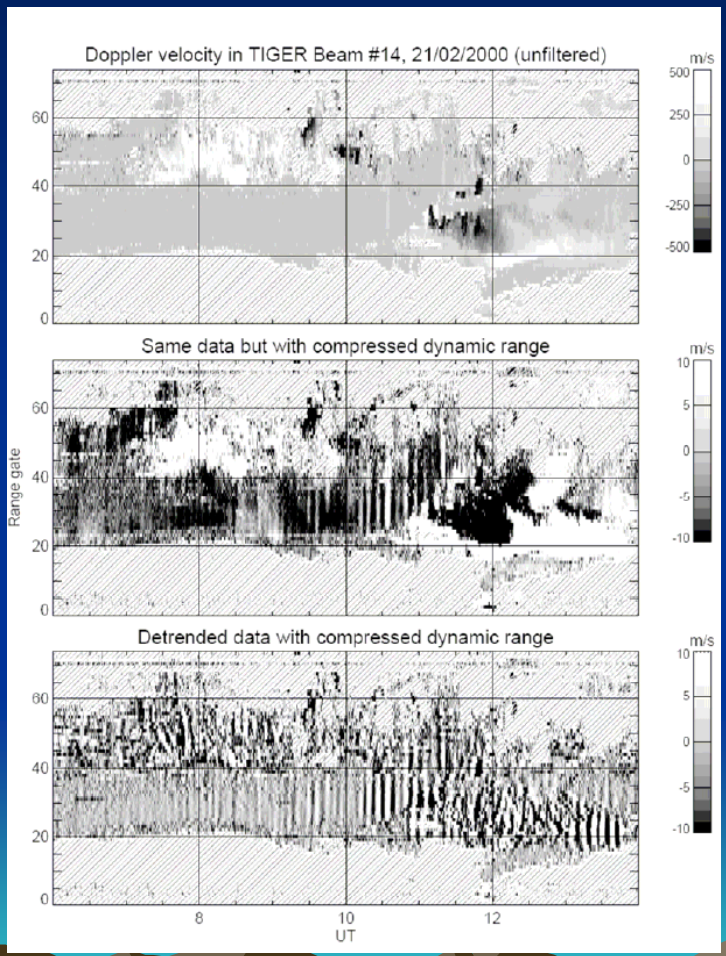






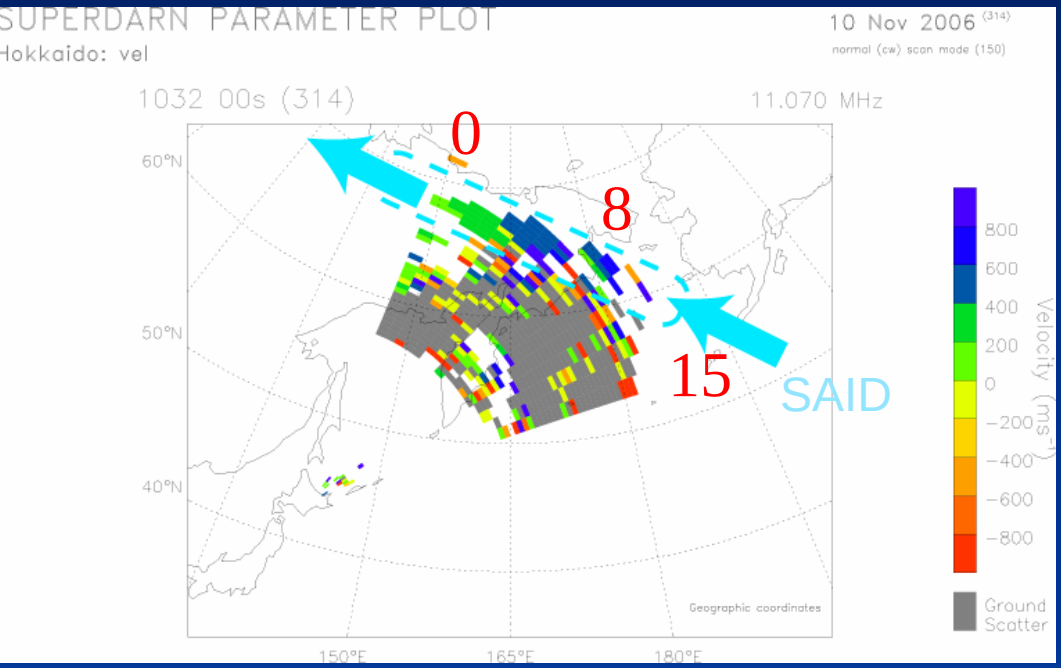
Ponomarenko et al. (2002)





- Sea scatterエコーによるPC pulsationの観測
- 通常 pulsationは電離圏エコーにより観測されるが、磁力線が地面に垂直でない場合、プラズマが磁力線に垂直に動くことにより、電離圏の上下方向の振動を生じる

Beam swinging

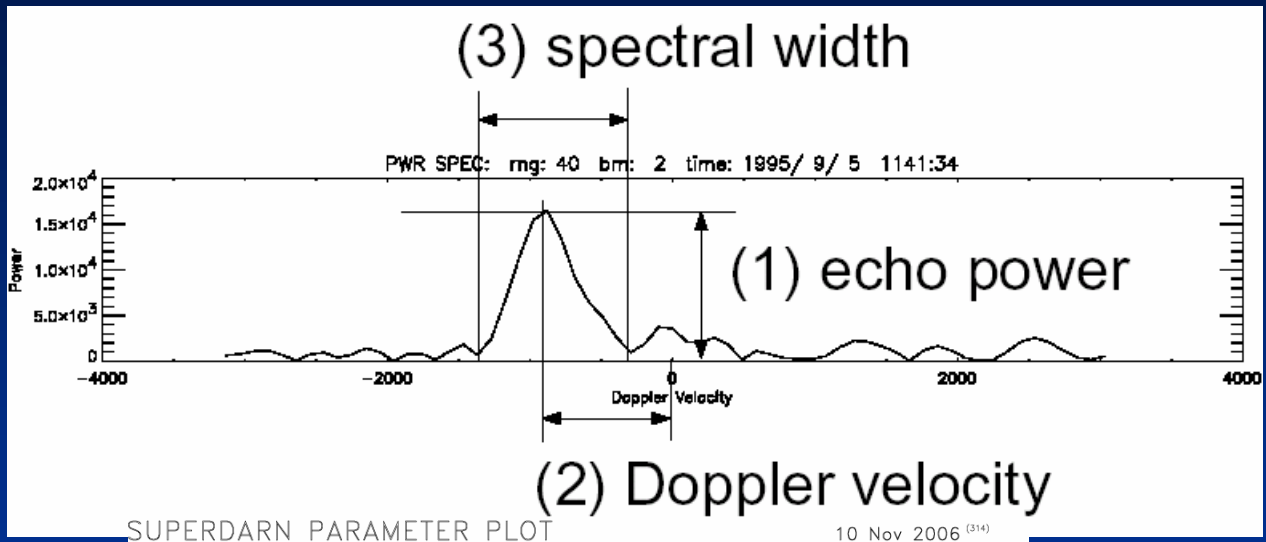


- ノーマルモードではbeam 0,1,2,..,15のようにscanしていくが、これだと各ビームはfast modeでも一分おきしか観測できない
- たとえば0,8,1,8,2,8,.., 14,8,15,8のようにscanすれば少なくともbeam 8は6秒の周期でscanすることができる
- 現在ソフトウェアの準備中

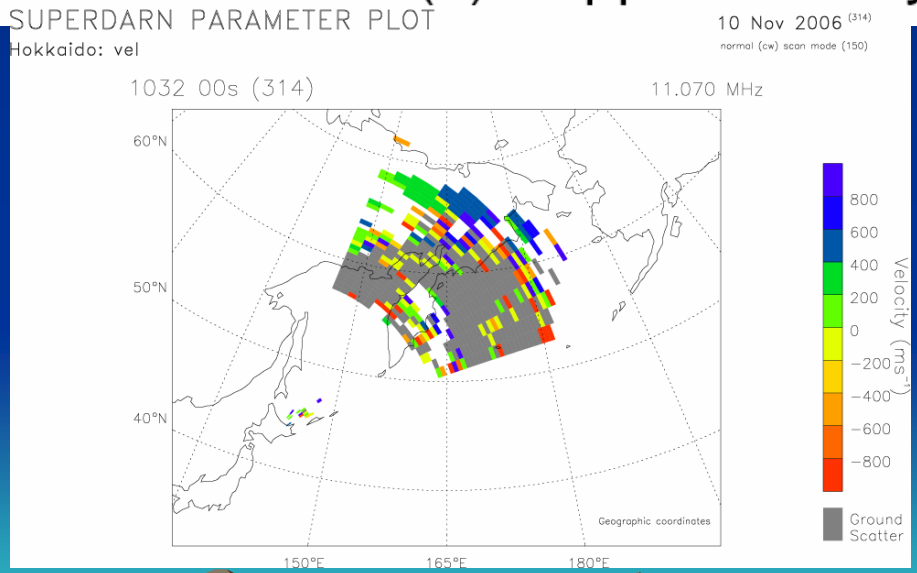
SuperDARNデータの種類ならびに使用方針について

SuperDARNデータの種類

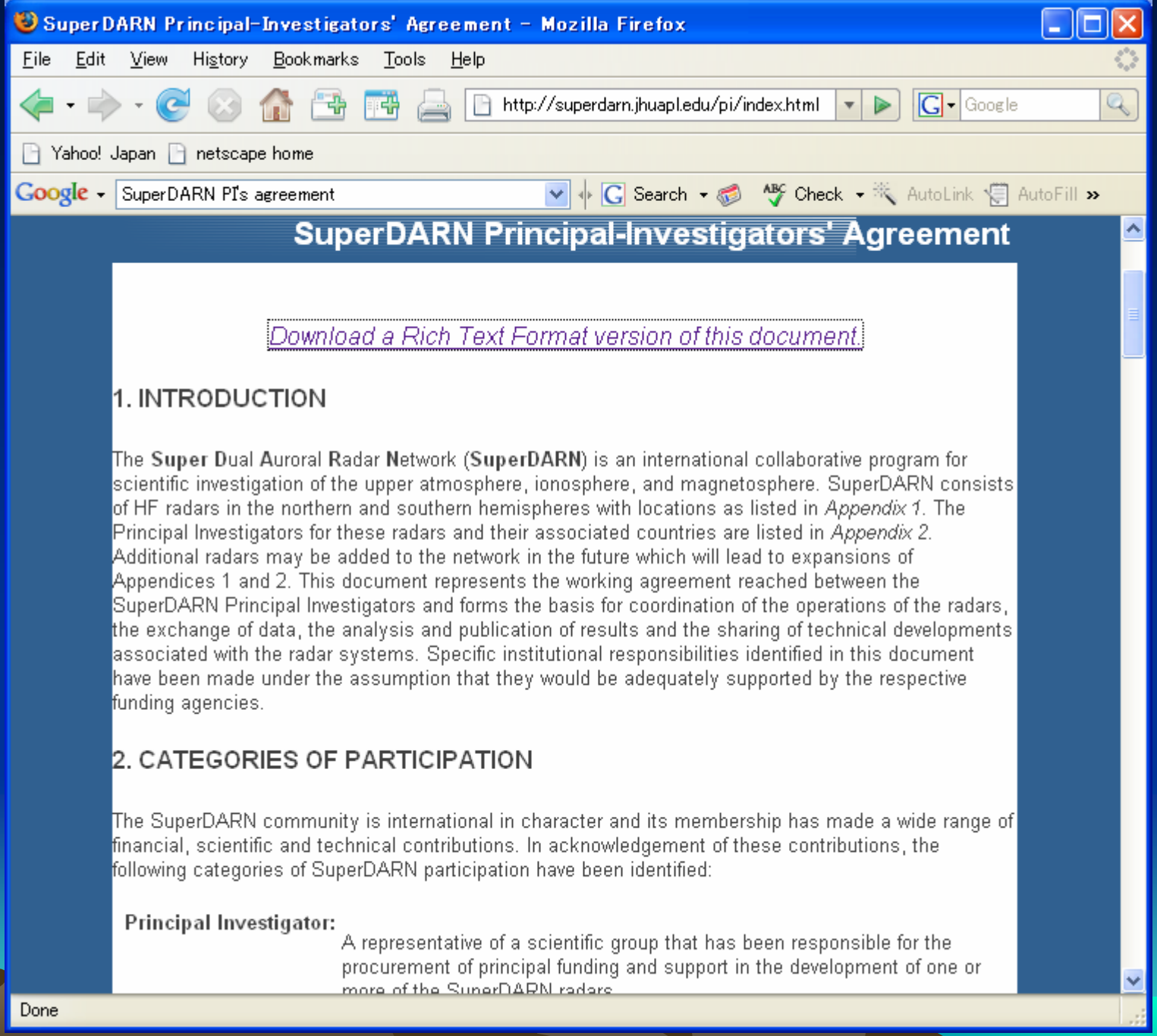
- datデータ



- fitデータ



- 他にsmr, grd,tms等のフォーマットあり



http://superdarn.jhuapl.edu/pi/index.html

データ使用法

- Quicklook data: 公開中

  http://center.stelab.nagoya-u.ac.jp/web1/hokkaido/gif

- より詳細なデータを使用したい場合は
  - SuperDARN distribution data DVDが国内の主要研究機関(NIPR, NICT, STE, UEC, Kyoto Univ. etc.)に配布されるのを待つ
  - 日本国内ではもっと速やかなデータ公開の方法を検討中
  - とりあえず名大STE研の西谷　望宛にコンタクトして下さい。

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    FAX: 052-789-5891, Tel: 052-747-6345