

「IQ 時系列データ解析と中性大気・電離圏研究への応用 + 」

行松彰（国立極地研究所）

「現在極域レーダー観測で行っていること」

不等間隔マルチパルス法による電離層プラズマ対流ドップラーACF 観測

不等間隔マルチパルス法による IQ 時系列データ解析手法

流星風観測への応用

広域流星レーダーネットワークの構築

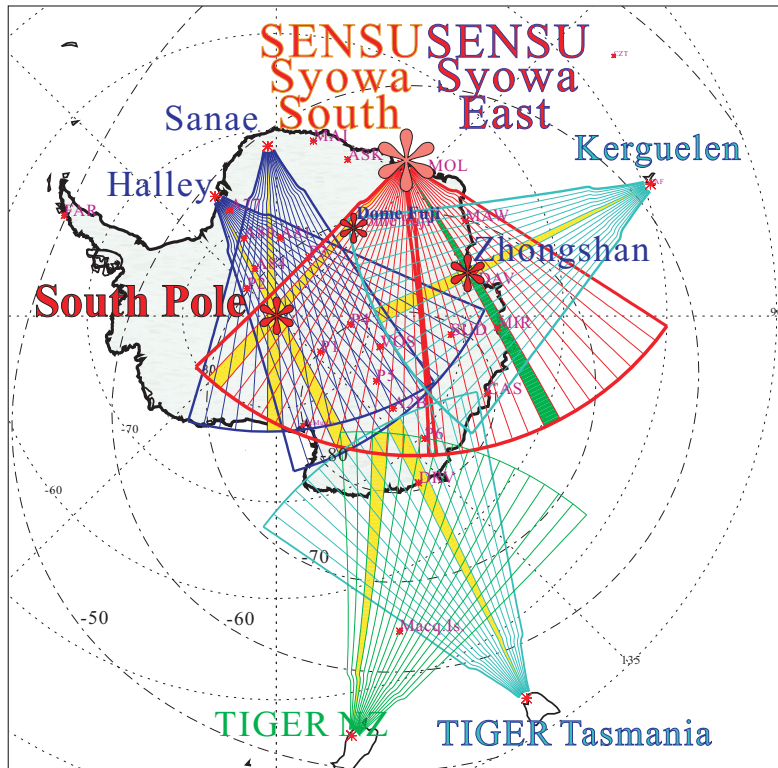
電離層研究への応用

FAI 研究、M・I マッピング / カップリング研究

SuperDARN



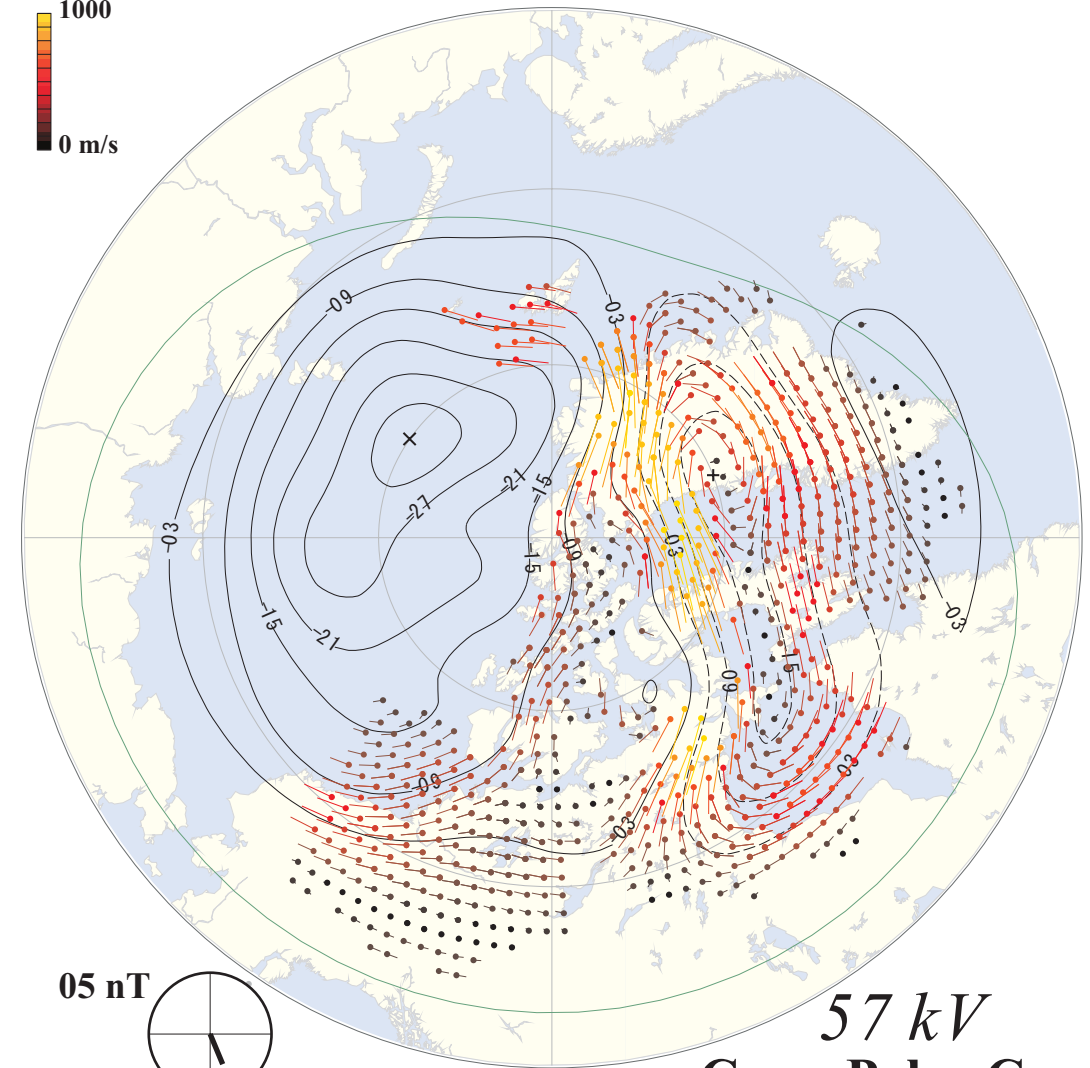
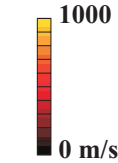
Southern Hemisphere Map



APL real time convection map

16 Oct 2001

08:40:00 ~ 08:42:00 UT



05 nT



IMF

57 kV

Cross Polar Cap
potential drop



F - region ionospheric global plasma convection, or polar cap electric field potential,

SuperDARN was originally designed for the ionospheric researches, but studies on MLT region dynamics was also triggered by Canadian SD group



SuperDARN near range ACF data analysis

Grainy near range echoes are mainly from underdense meteor trails and their Doppler LOS velocity data reflect neutral wind velocities in the mesopause region (~95km)

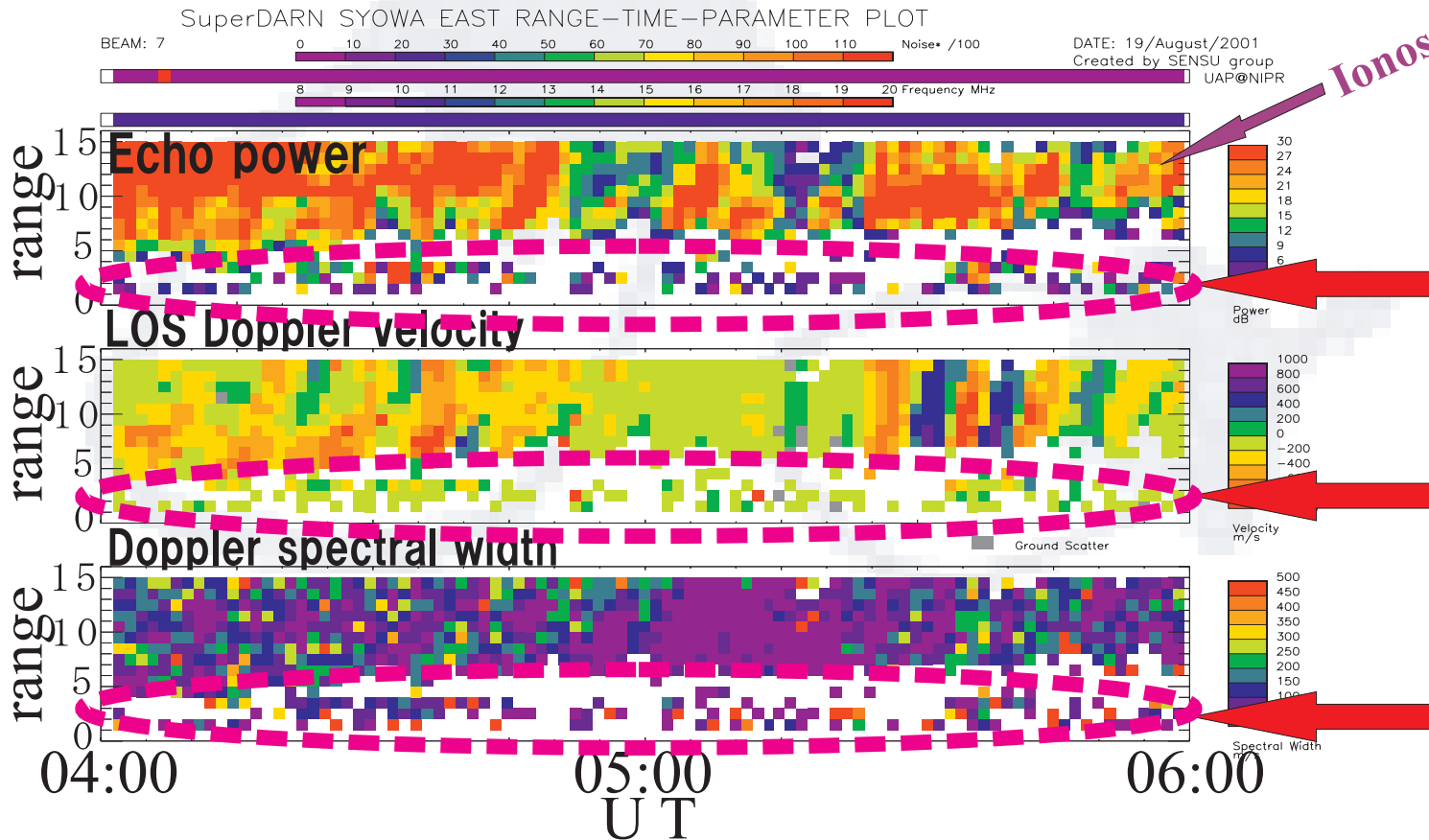
[G. Hall et al., JGR, 1997]

Ionospheric echoes

Power

Vlos

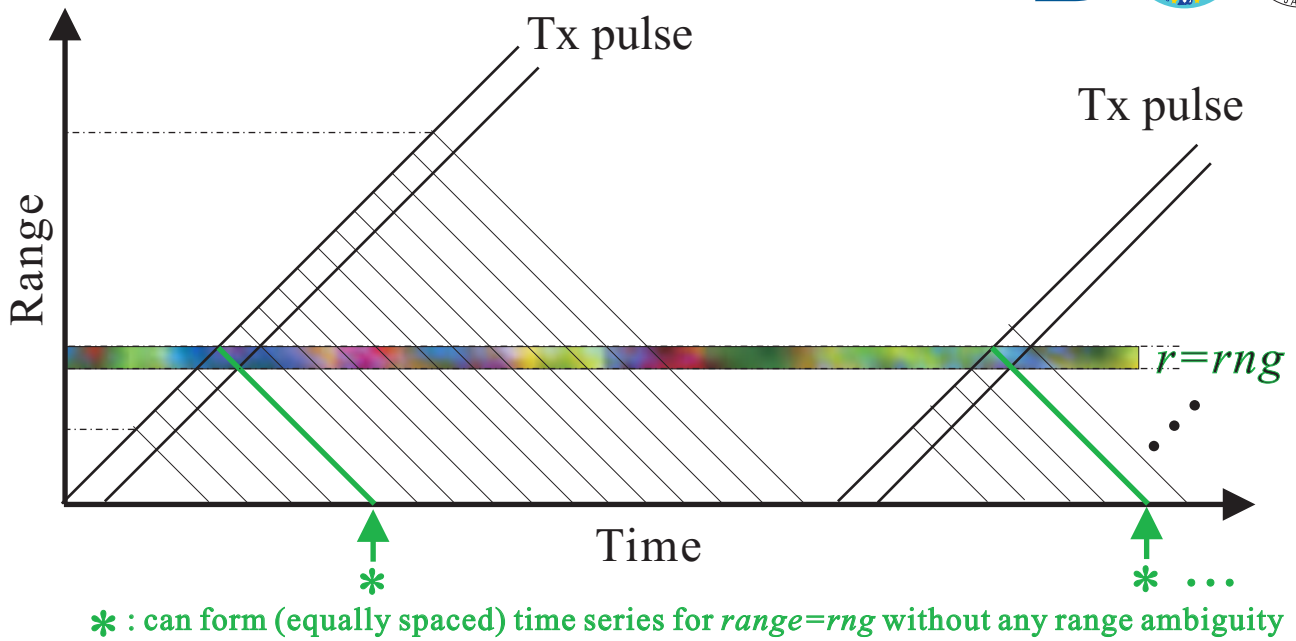
Width



grainy near range echoes (GNREs)

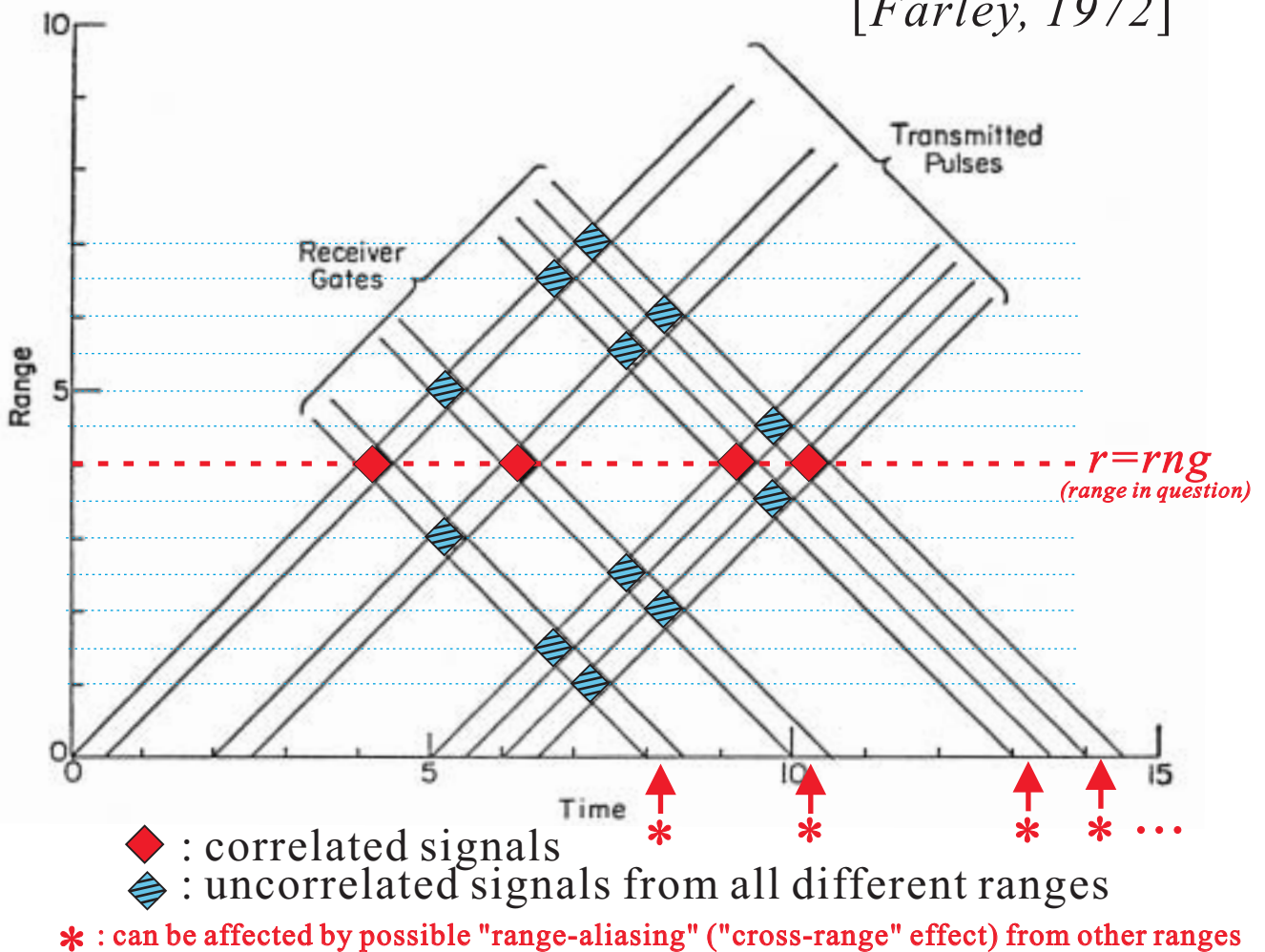


"single-pulse" observation



"unequally spaced multi-pulse ACF method"

[Farley, 1972]



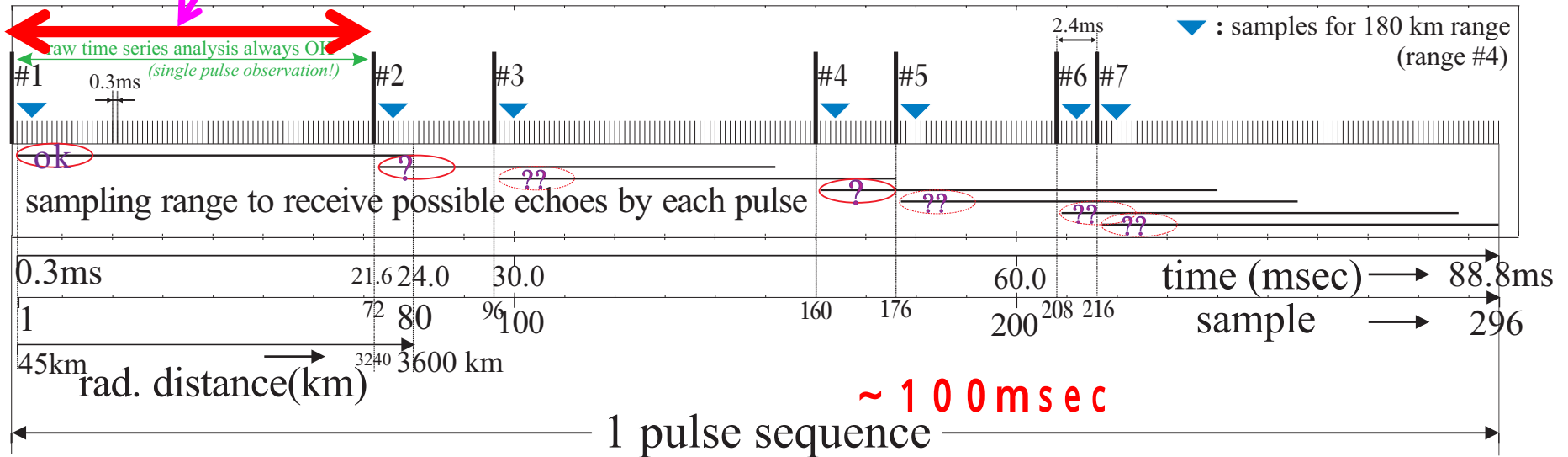
⇒ Is "raw time series analysis" possible??

Can these * samples be treated as single pulse obs. data??

just a single pulse obs.

SuperDARN pulse sequence and sampling points

mppul=7, mpinc=2400us, ppat[7]={0,9,12,20,22,26,27}, txpl=300us (rsep=45km)
 smsep=300us(45km), lagfr=300us(45km), nrang=80, maxrng=3600km, nsmp=296, seqtime=88.80ms



Possible Maximum Radial Velocity : $\lambda \cdot f_N/2 > \underline{150\text{m/s}}$

(required for neutral wind measurements in mesopause region to study MLT region dynamics)

➔ Nyquist Frequency(f_N) : $> 10\text{Hz}$ (in case of $TxFreq=10\text{ MHz}$)

➔ Sampling Frequency : $> 20\text{Hz}$

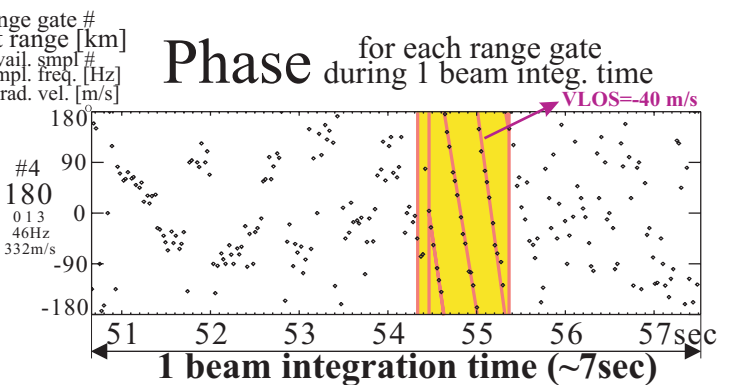
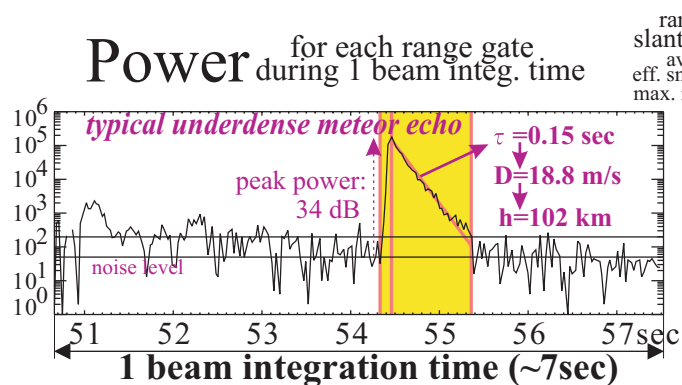
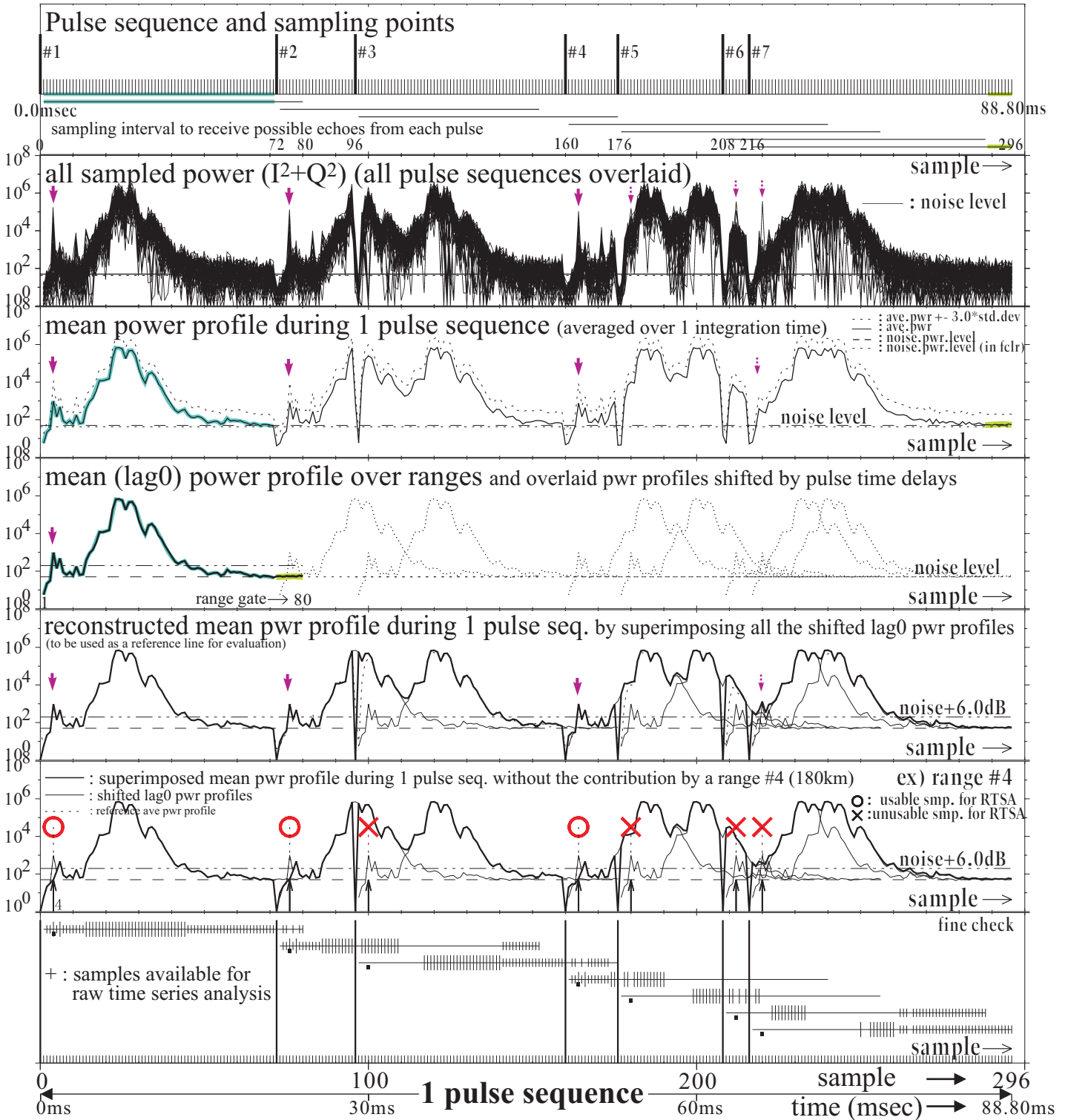
➔ # of usable samples required : ≥ 2 (per 1 pulse seq (~100 ms))



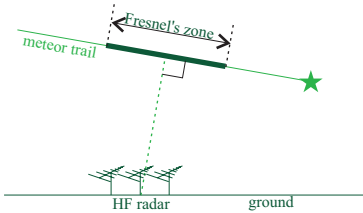
SENSU SuperDARN Raw Time Series Plot



Syowa East 2001/10/16 04:42:50UT, cpid 150, bm 7, frq 10455kHz, intt 7sec (nave 76), xcf 0
 mppul 7, mpinc 2400us, txpl 300us (rsep 45km), smsep 300us (45km), lagr 300us (45km), nrang 80, maxrng 3600km, nsmpl 296, seqtime 88.80ms
 ppat[7]={0,9,12,20,22,26,27}, noise 49 (fclr 42), att 0 (0->0), DCofs I1: 1, Q1: 0 (removed), ercod 0x0000, MaxBadRng 45km, pwrthr 6.0dB(20.0dB, finechk)



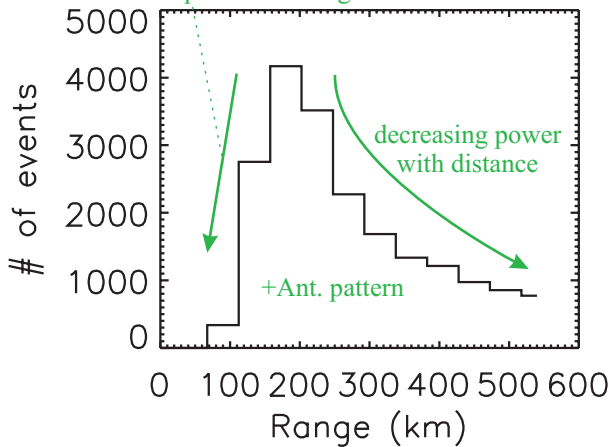
Distribution of underdense meteor echoes



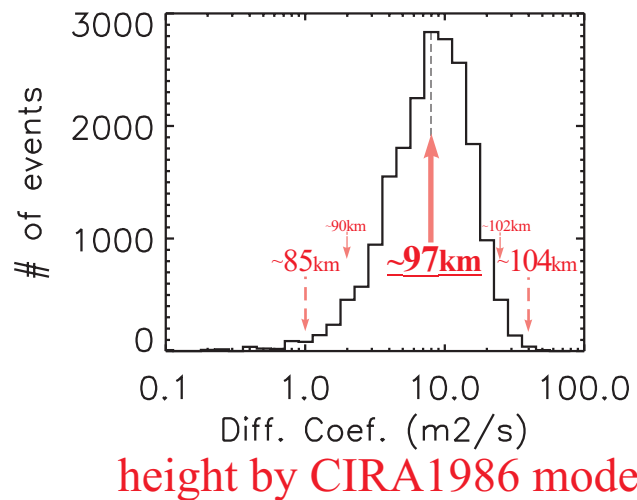
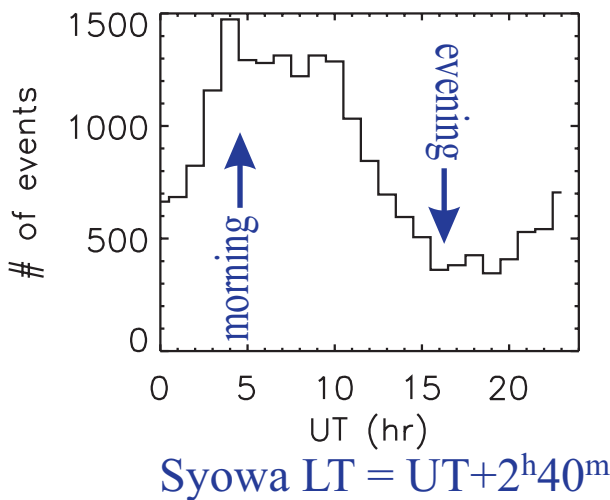
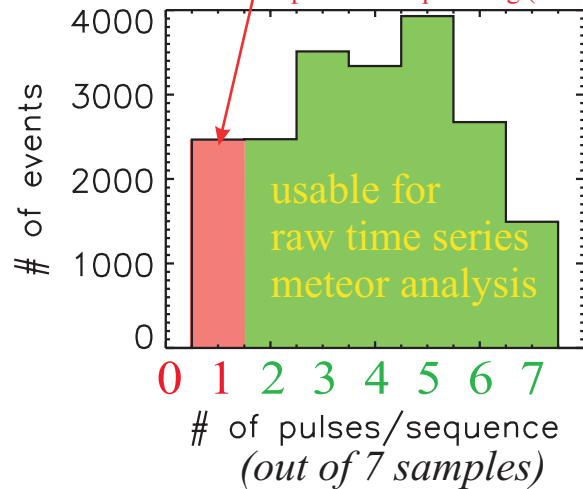
SENSU Syowa East
October 15-21, 2001

(2000~3000 meteors/day)

almost no meteor echoes whose trails are parallel to the ground



not used for raw time series analysis due to possible freq-aliasing (~10Hz)

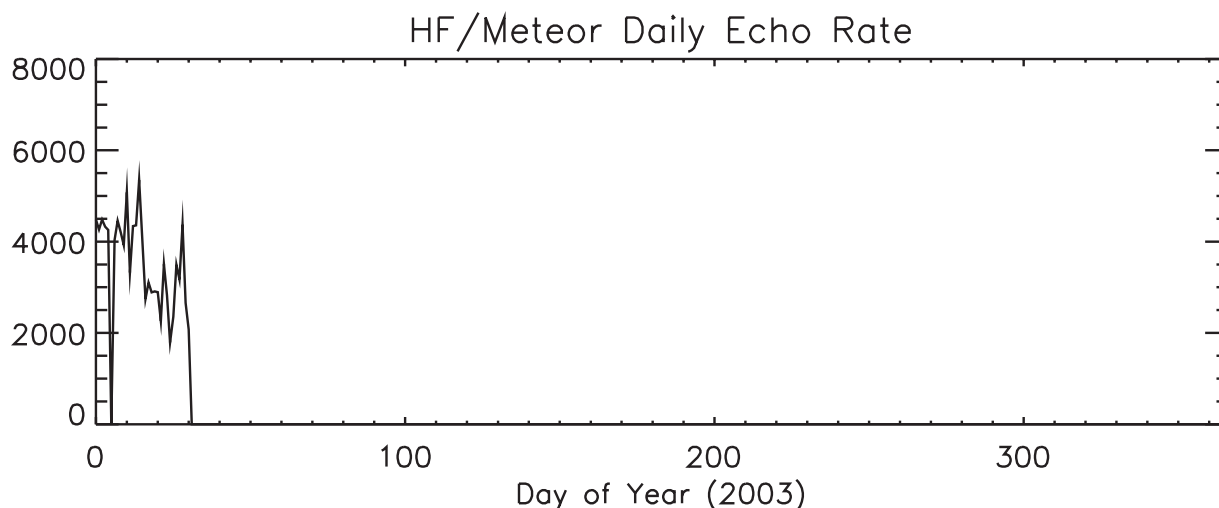
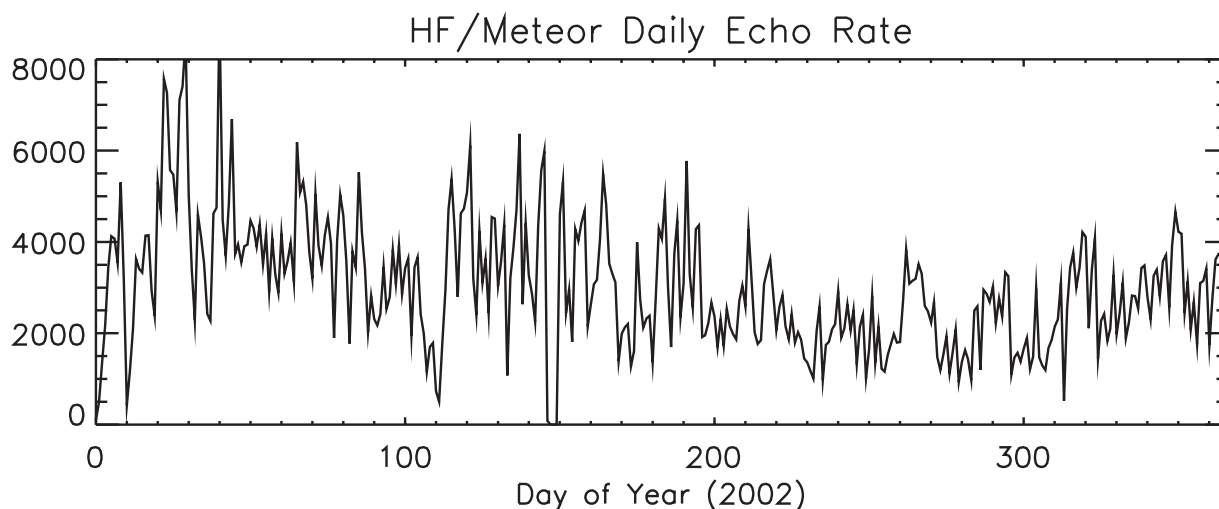
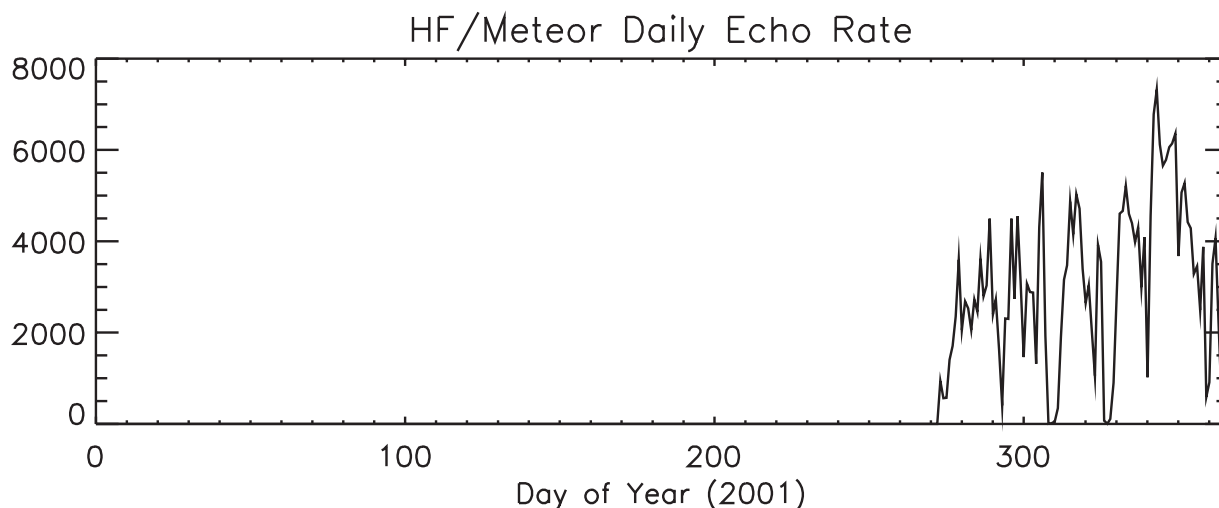


All these are expected and reasonable for meteor echoes

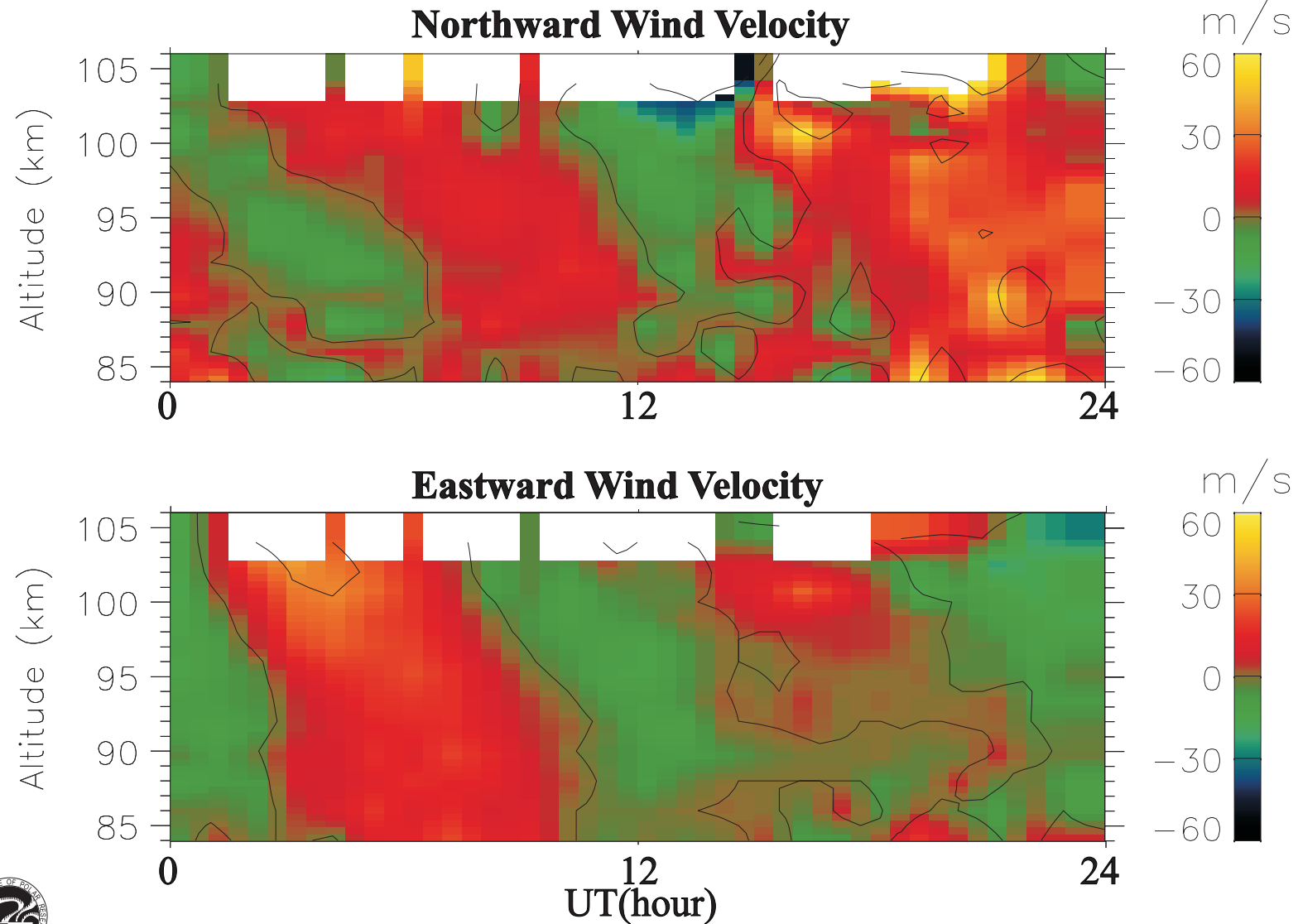
~85 - 105 km peak @ ~97 km
in case of freq~10.4 MHz (slight TxFreq dependency..)



Daily Meteor Echo Rate SENSU Syowa East Radar

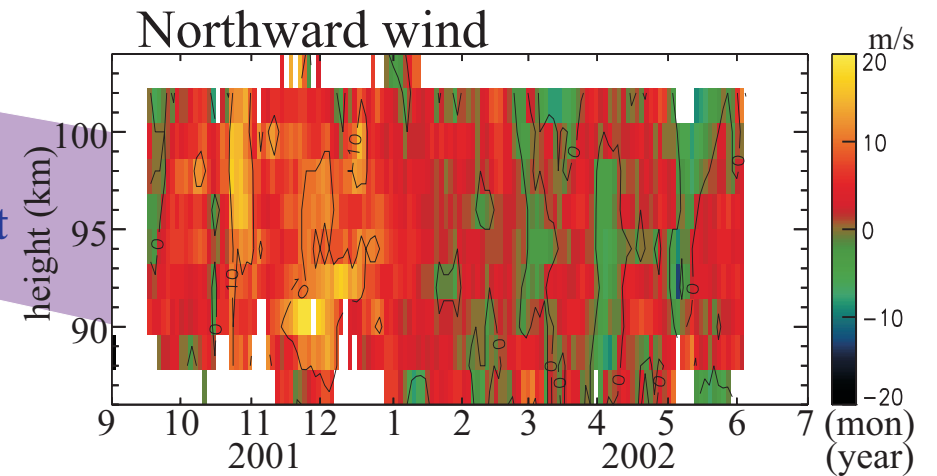
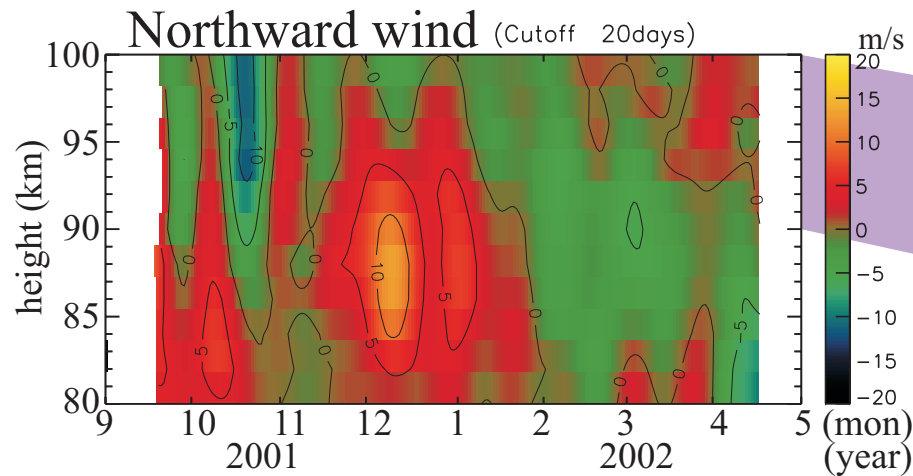
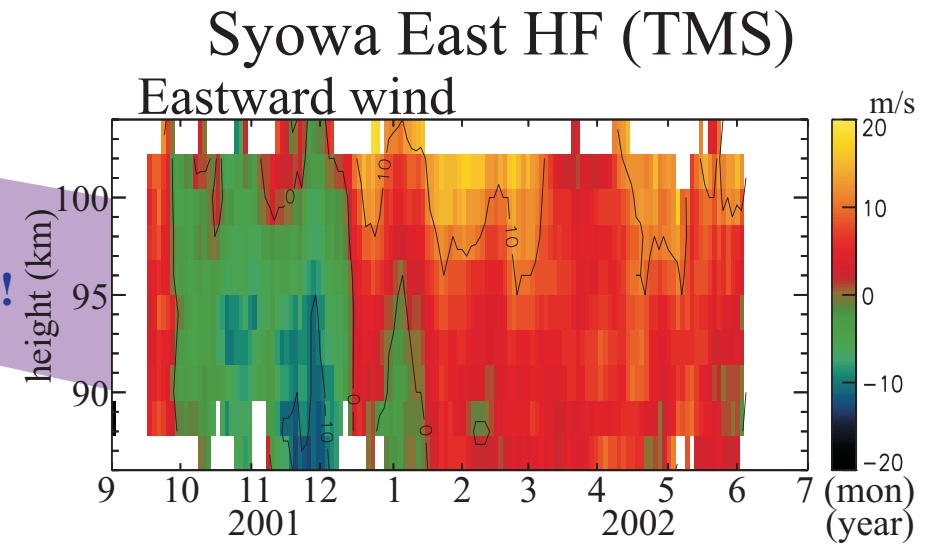
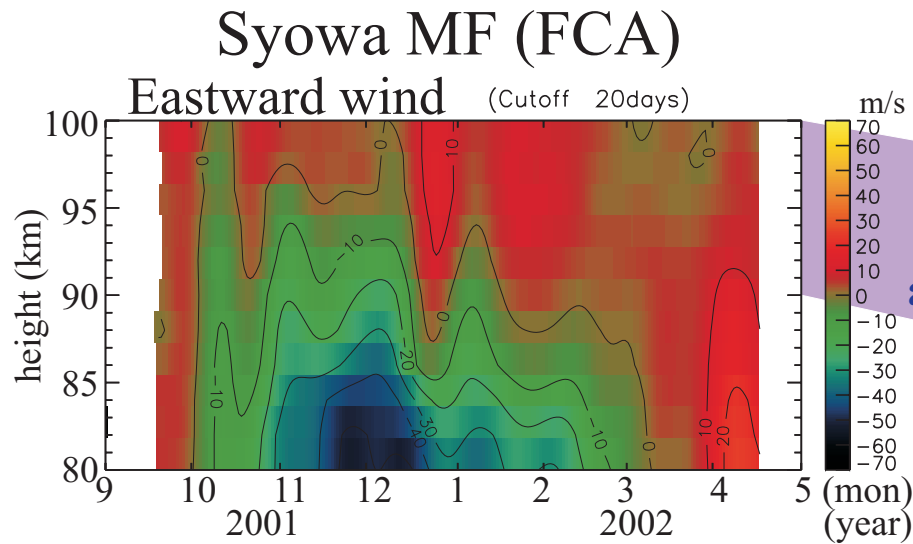


Mean diurnal variation of 2-D neutral wind altitude profile at mesopause region using beam-swing tech. (svdfit) by SENSU Syowa East radar in October, 2001 (monthly mean)



Comparison of mean neutral wind altitude profiles between MF(FCA) & HF(TMSmet)

Syowa, Antarctica Oct. 2001 - Apr. 2002

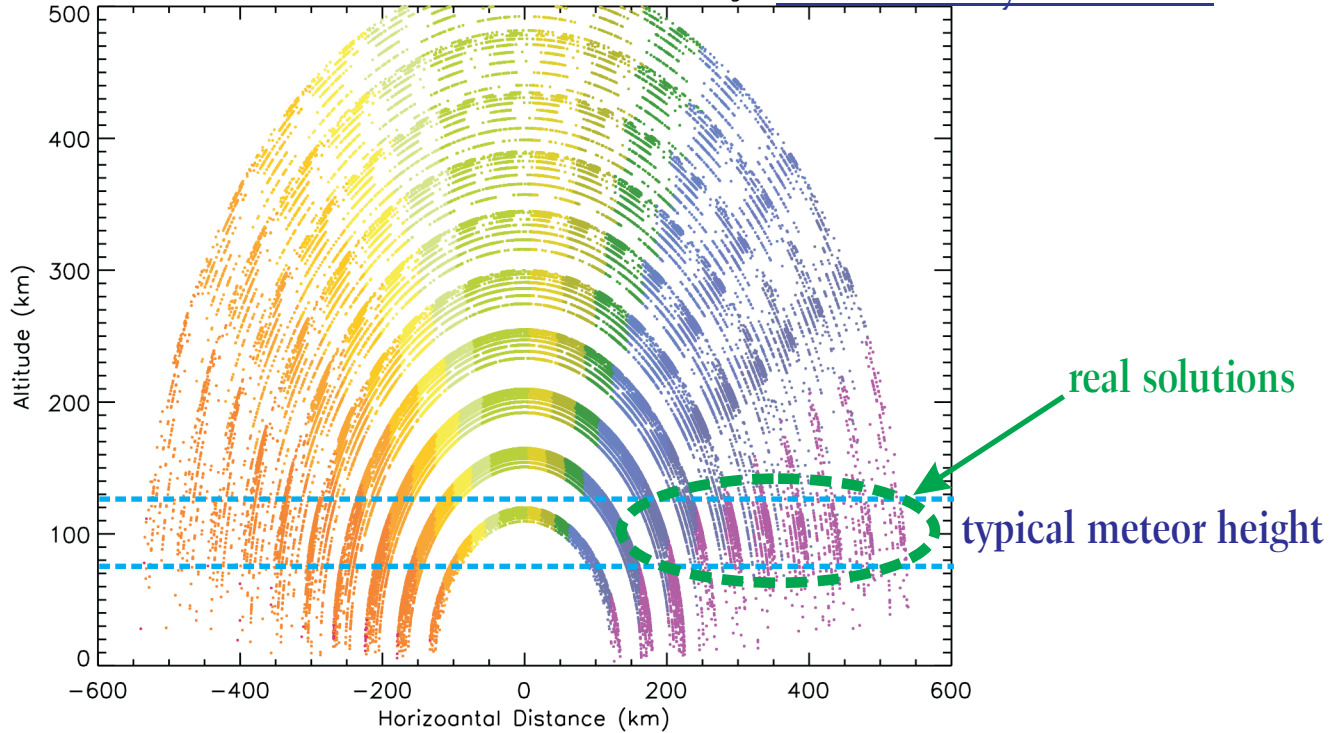


TMS Meteors & Wind with Interferometer CUTLASS Finland 2003/03/25

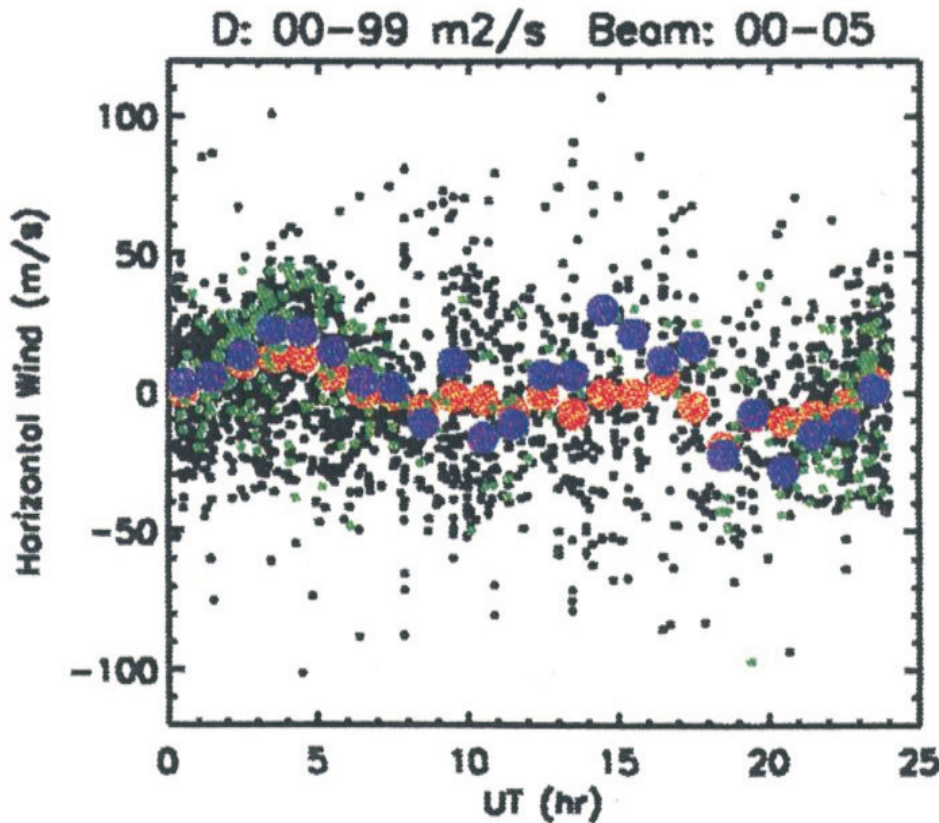


$2n\pi$ -ambiguities of elevation angle solution (assuming echoes coming back from the main-lobe beams)

030325.hffmet offset= 240deg **calibrated by meteors!!**



Test Results



all data

- each meteor
- hourly average

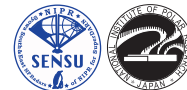
**main-lobe
echoes only**

- each meteor
- hourly average

clear semi-diurnal comp
can be seen!!! Good!!

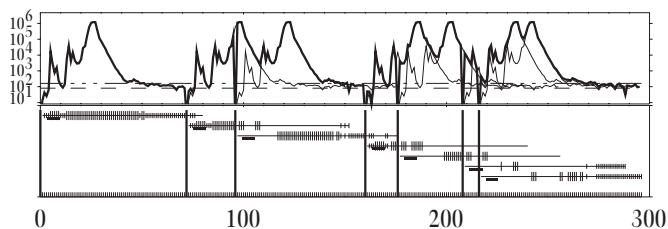
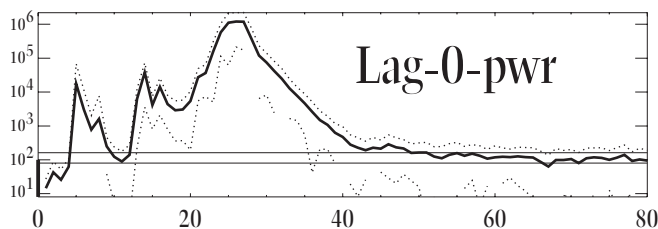


Oversampling



SENSU SuperDARN Raw Time Series NRE Plot

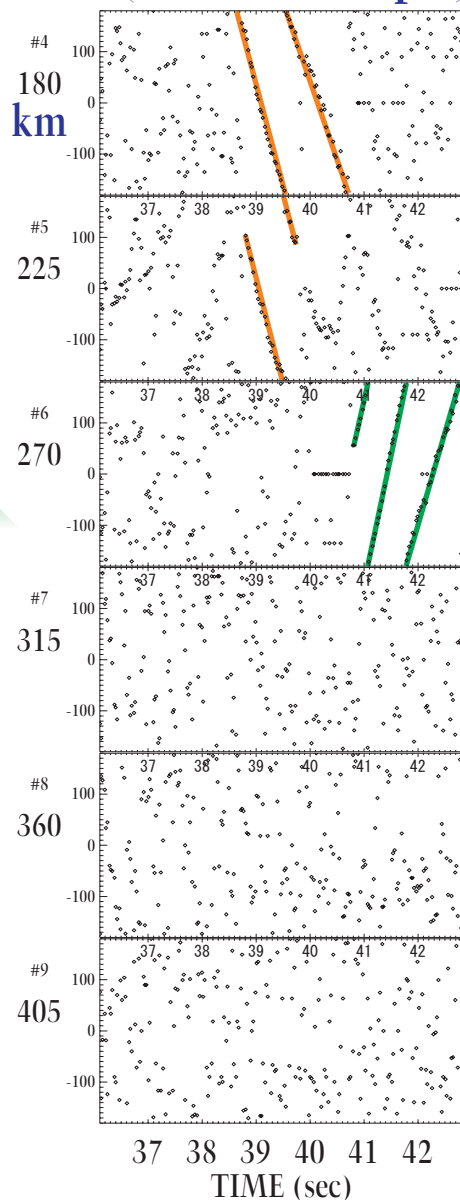
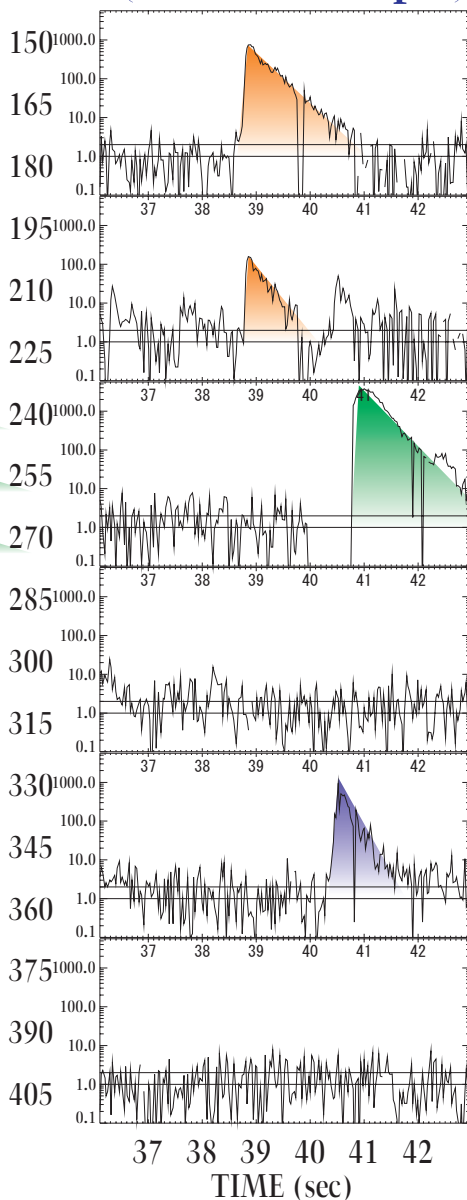
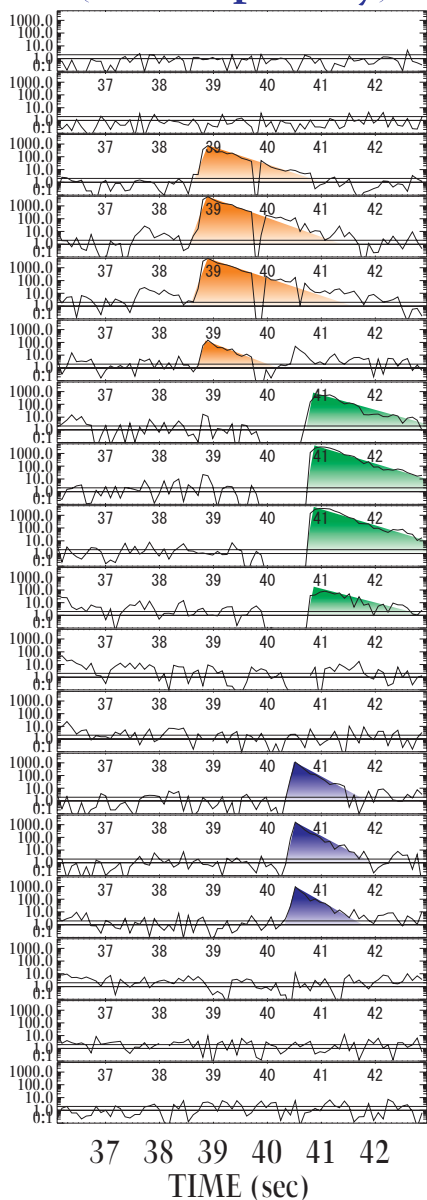
Syowa East 2003/05/05 04:54:36UT, Mono cpid 150, bm 5, frq 10225kHz, intt 7sec (nseq 76), nch 2
 mppul 7, mpinc 2400us, txpl 300us(rsep 45km), smsep 300us(45km), lagfr 300us(45km), lag0nrang 80, nrrang 12(1->12), nsmp 296, seqtime 88.80ms
 ppat[7]={0,9,12,20,22,26,27}, noise 80, att 0(0->0), DCofs:(removed), ercod 0x0000, MaxBadRng 45km, pwrthr 3.0dB(20.0dB,finechk), OVS:1/1/100us



OvsPwr(1smp)
(1st smpl only)

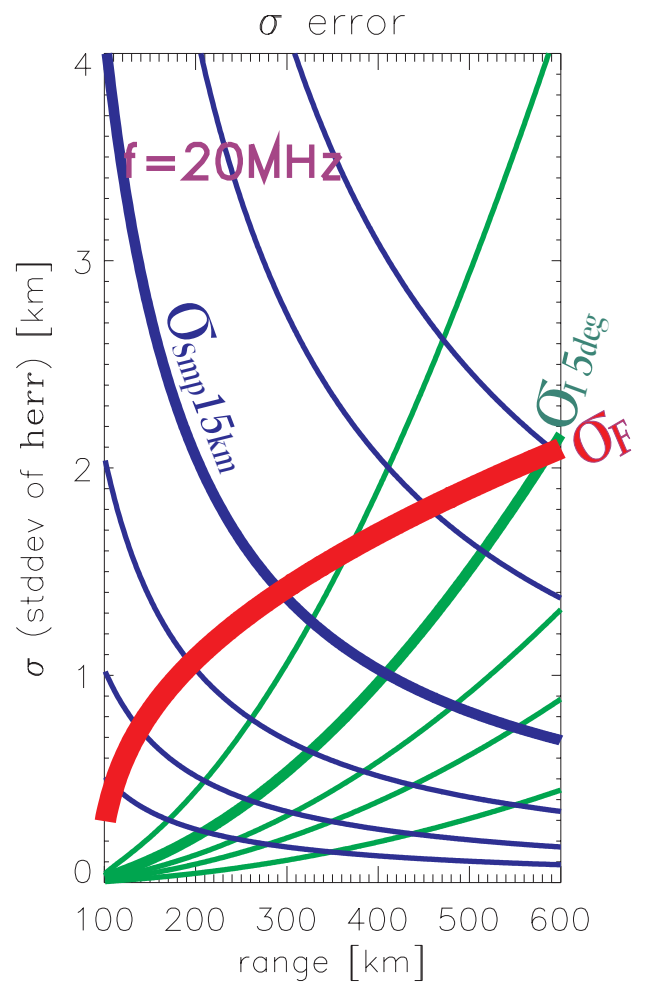
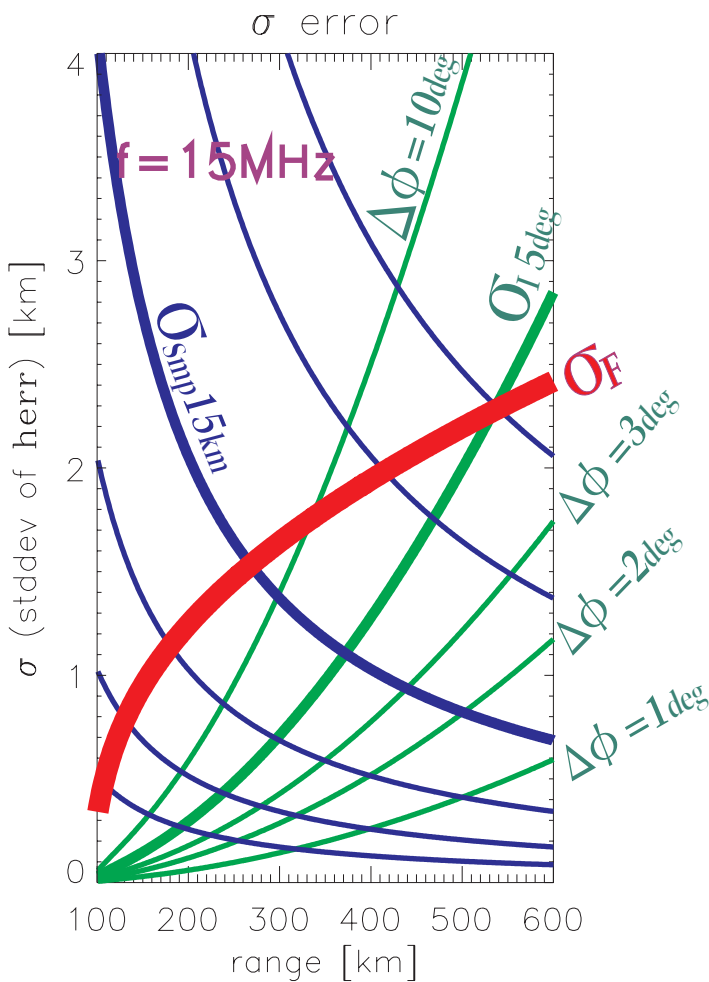
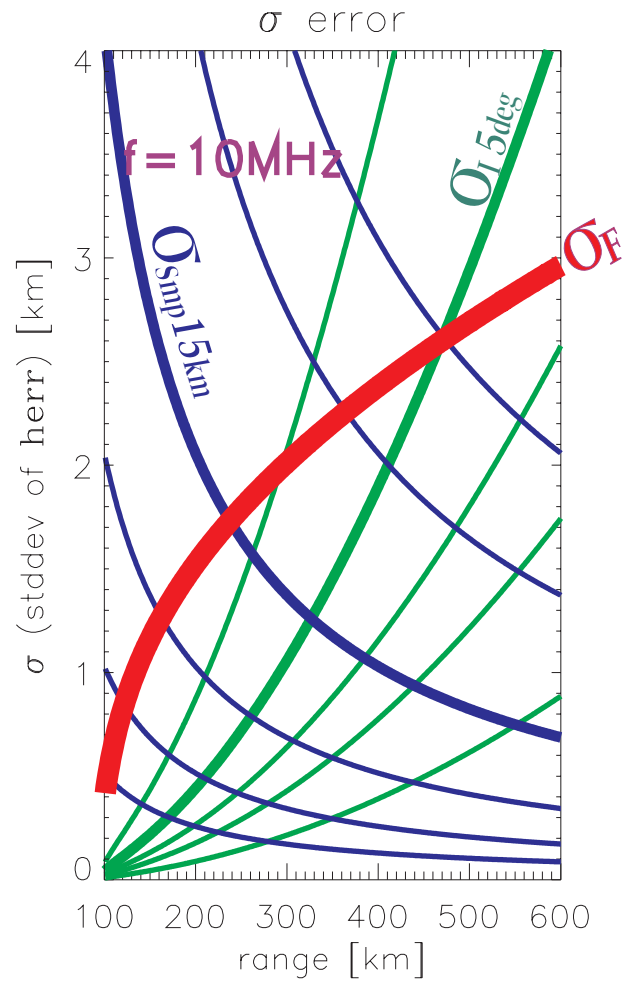
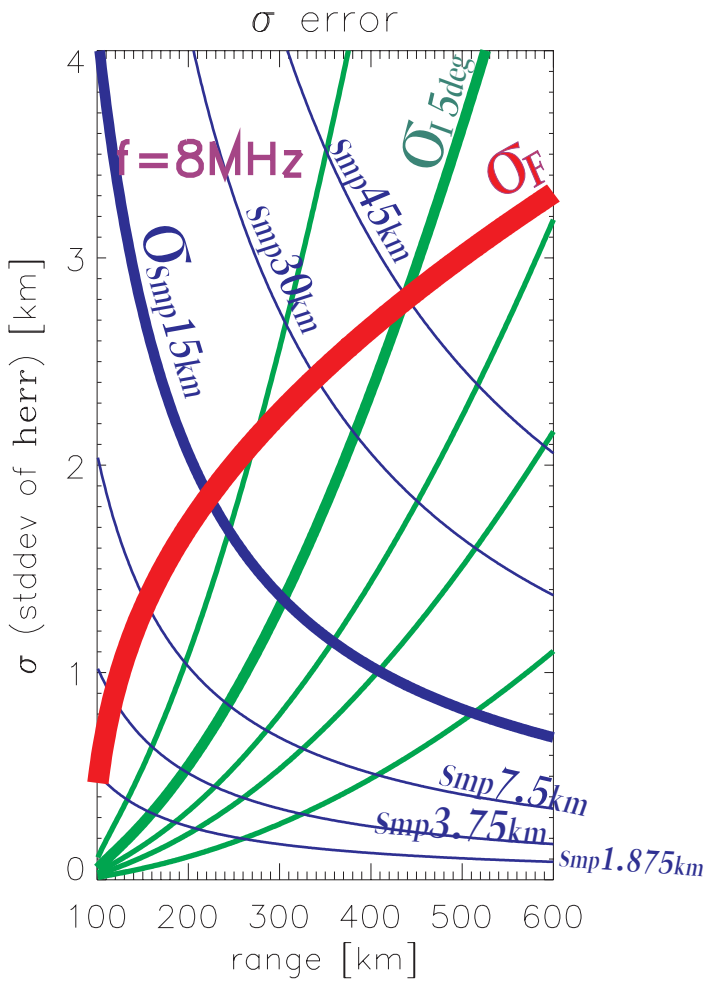
Power
(all avail. smpls)

Phase
(all avail. smpls)

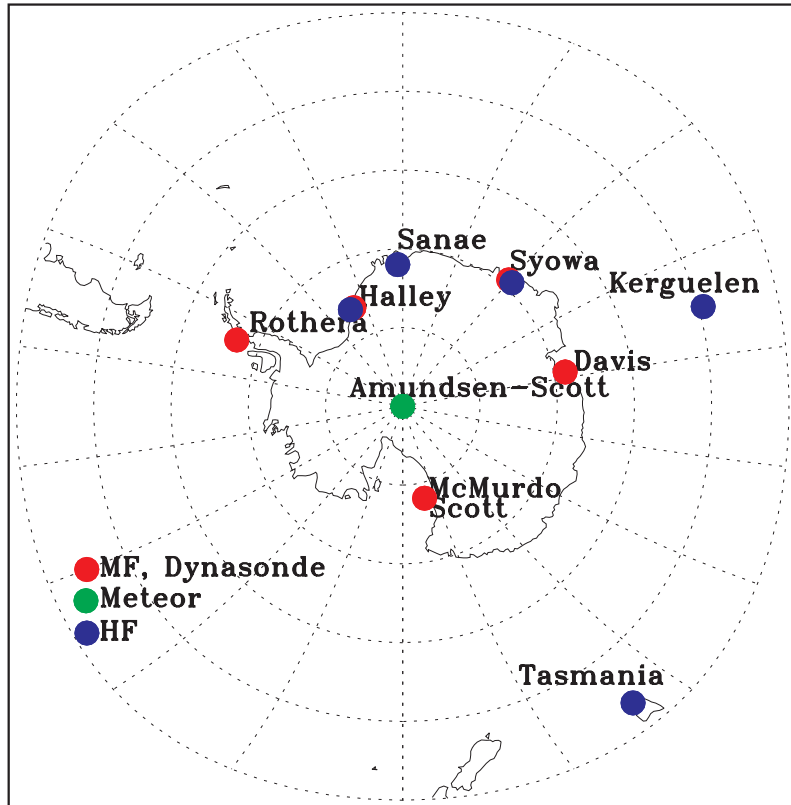




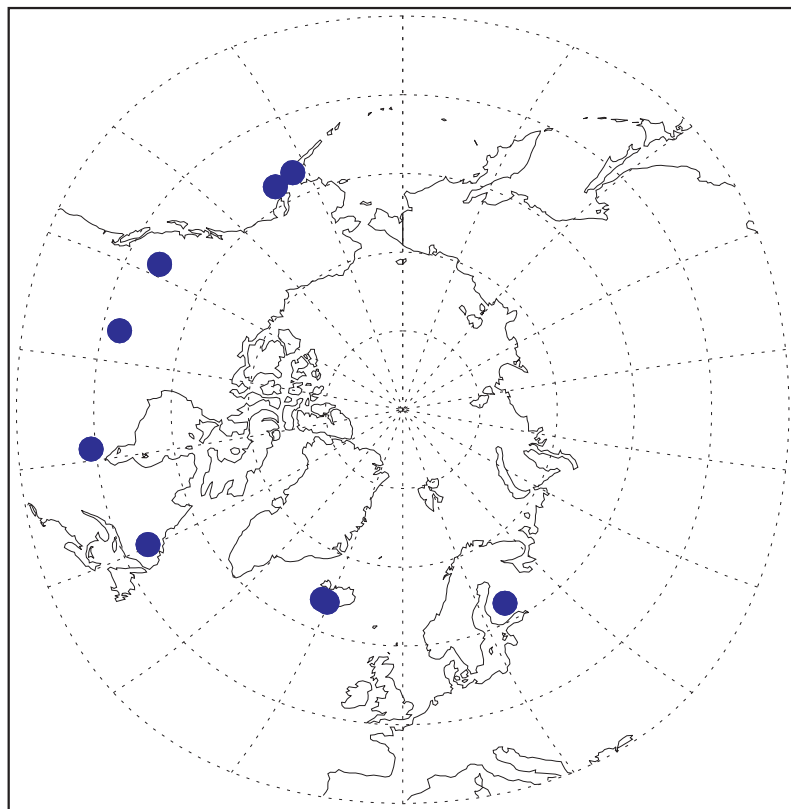
Meteor height ambiguities



Antarctic MLT Radars



Arctic HF Radars



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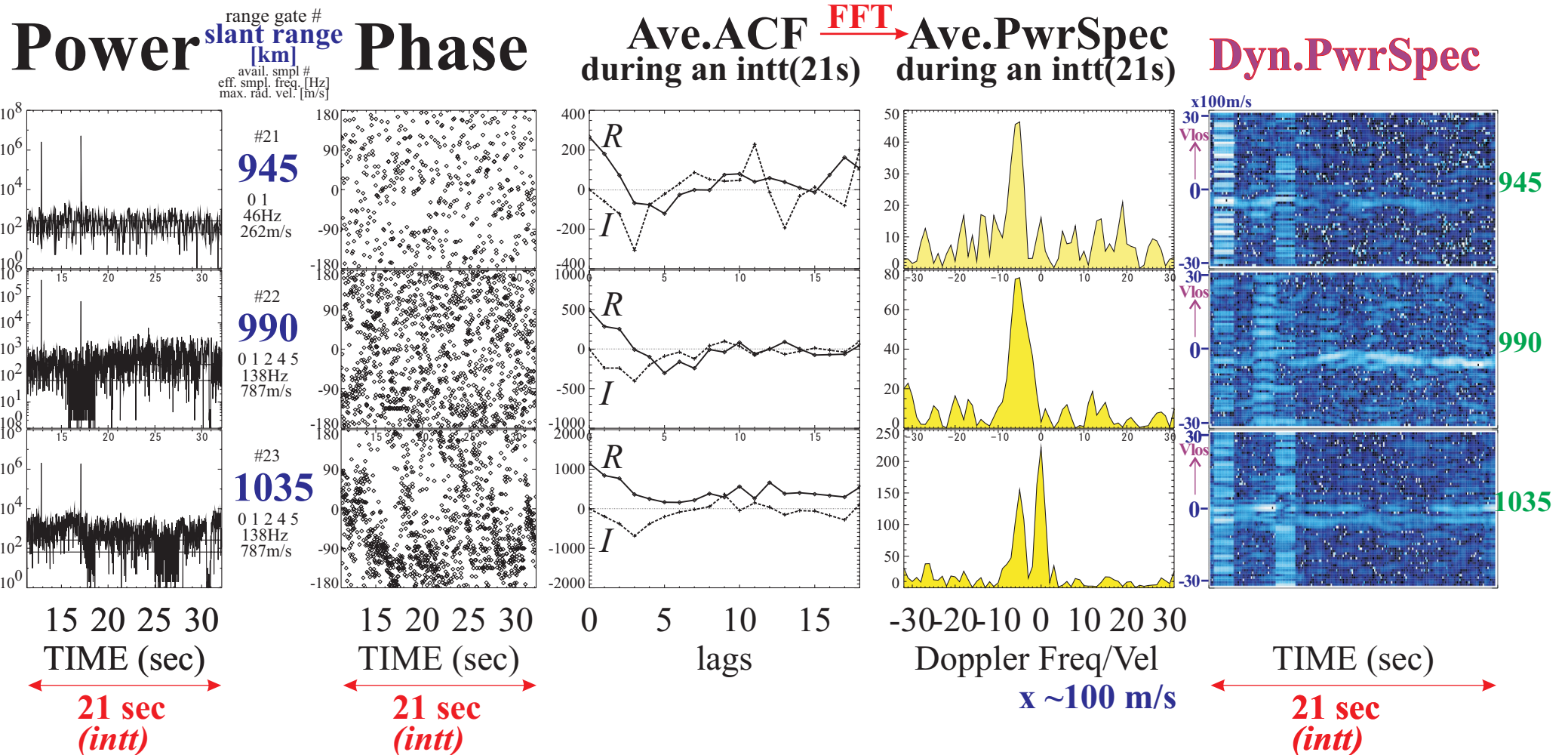
電離層研究への応用

FAI 研究、M・I マッピング / カップリング研究

SENSU SuperDARN Raw Time Series Plot

Syowa East 2003/01/18 06:08:11UT, Mono cpid 5257, bm 7, frq 13220kHz, **intt21sec** (nave231), xcf 0

mppul 7, mpinc 2400us, txpl 300us(rsep 45km), smsep 300us(45km), lagfr 300us(45km), nrang 80, maxrng 3600km, nsmp 296, seqtime 88.80ms
 ppat[7]={0,9,12,20,22,26,27}, noise 65(fclr 75), att 0(0-> 0), DCofs 11: 0, Q1: 0 (removed), ercod 0x0000, MaxBadRng 45km, pwrthr 6.0dB(20.0dB,finechk),tmwin15



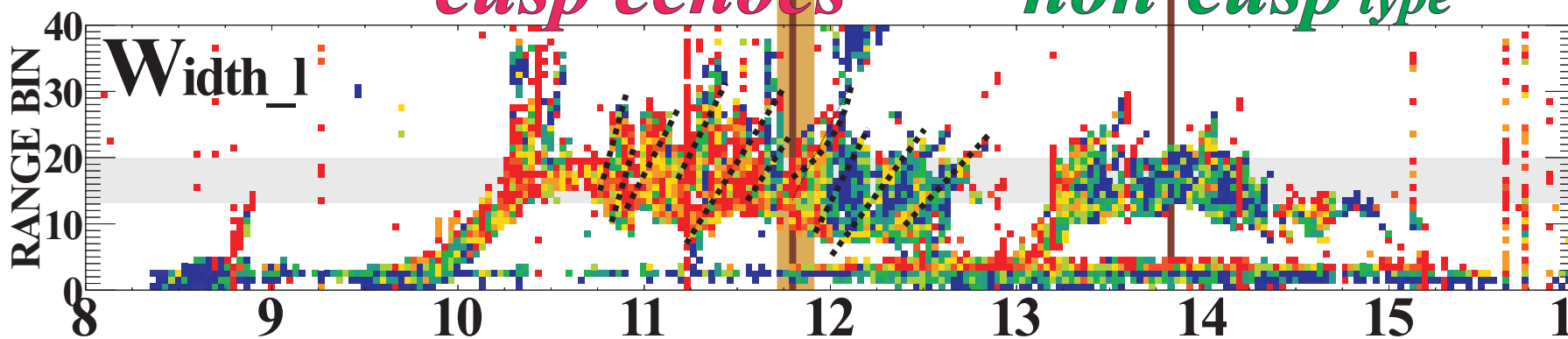
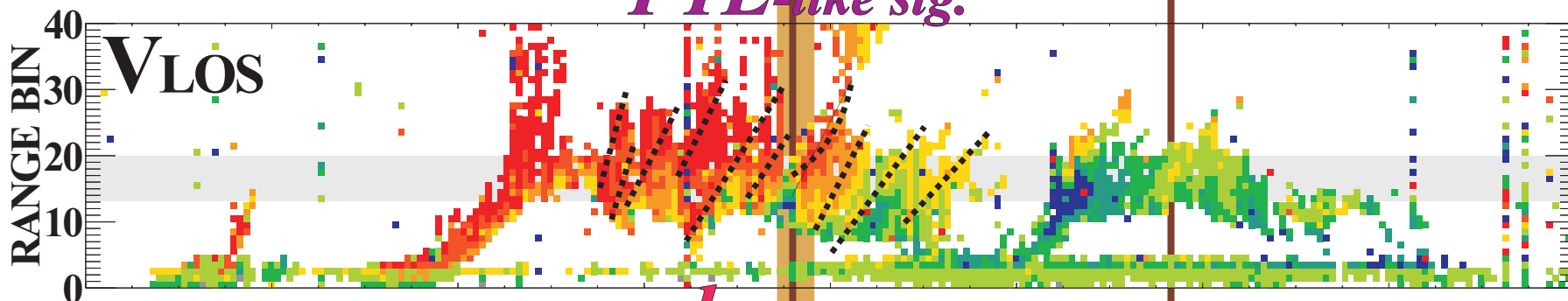
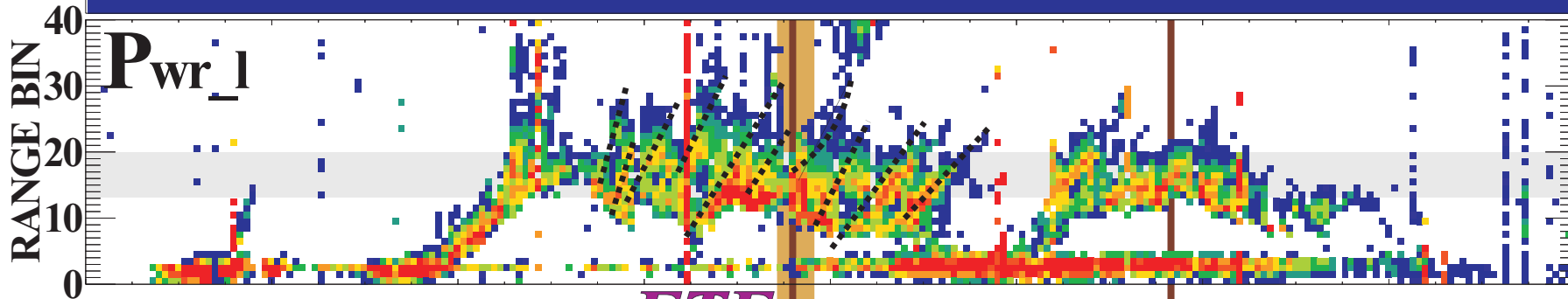
SENSU Syowa East Beam7 (every 2min intt 7sec) 2001/10/01

0 10 20 30 40 50 60 70 80 90 100 110 Noise* /100

8 9 10 11 12 13 14 15 16 17 18 19 20 Frequency MHz

frang 180 km
rsep 45 km

Created by SENSU group
UAP@NIPR



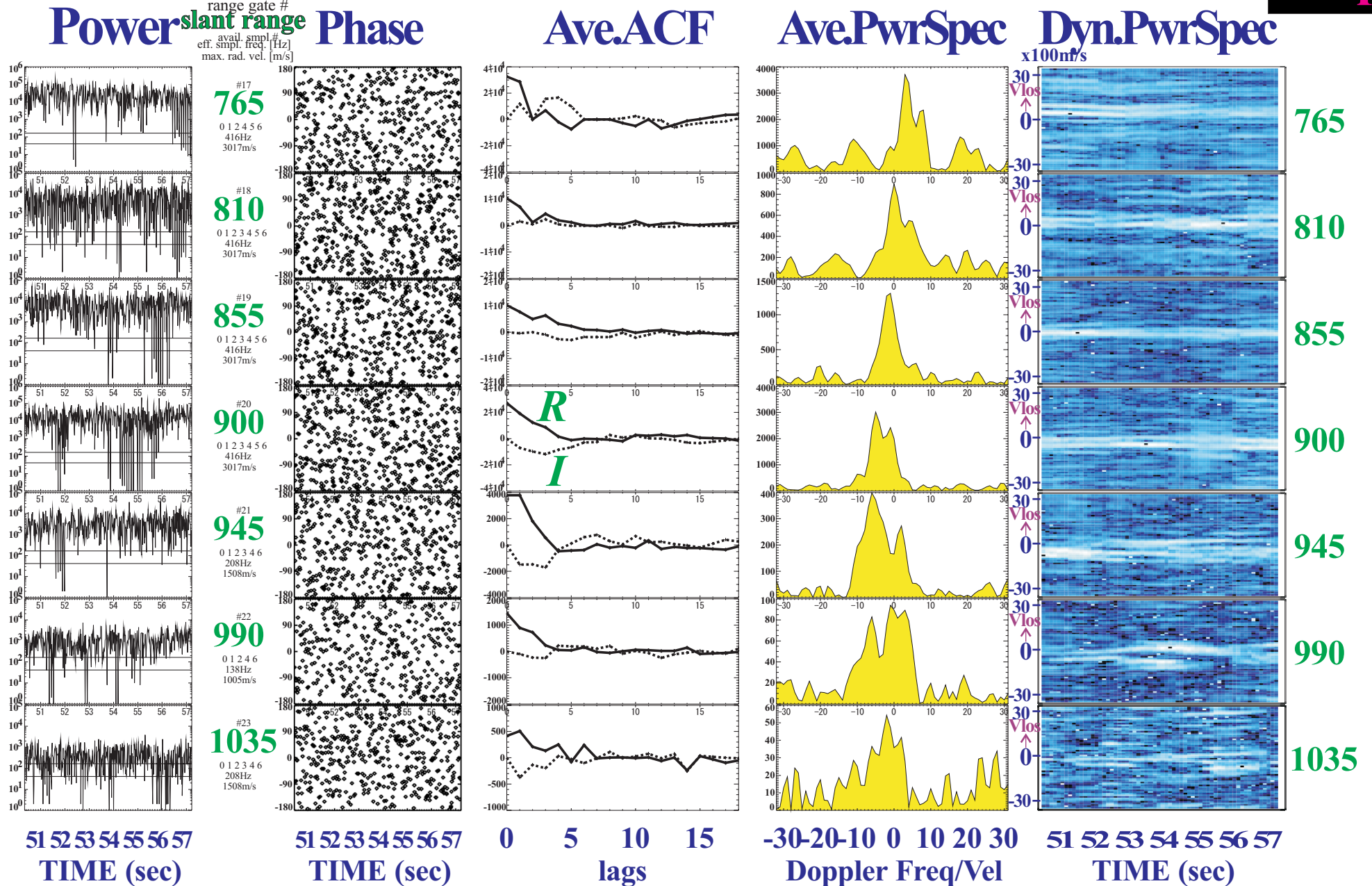
SENSU SuperDARN Raw Time Series Plot



Cusp

Syowa East 2001/10/01 11:46:50UT, Mono cpid 150, bm 7, frq 10355kHz, intt 7sec (nave 76), xcf 0

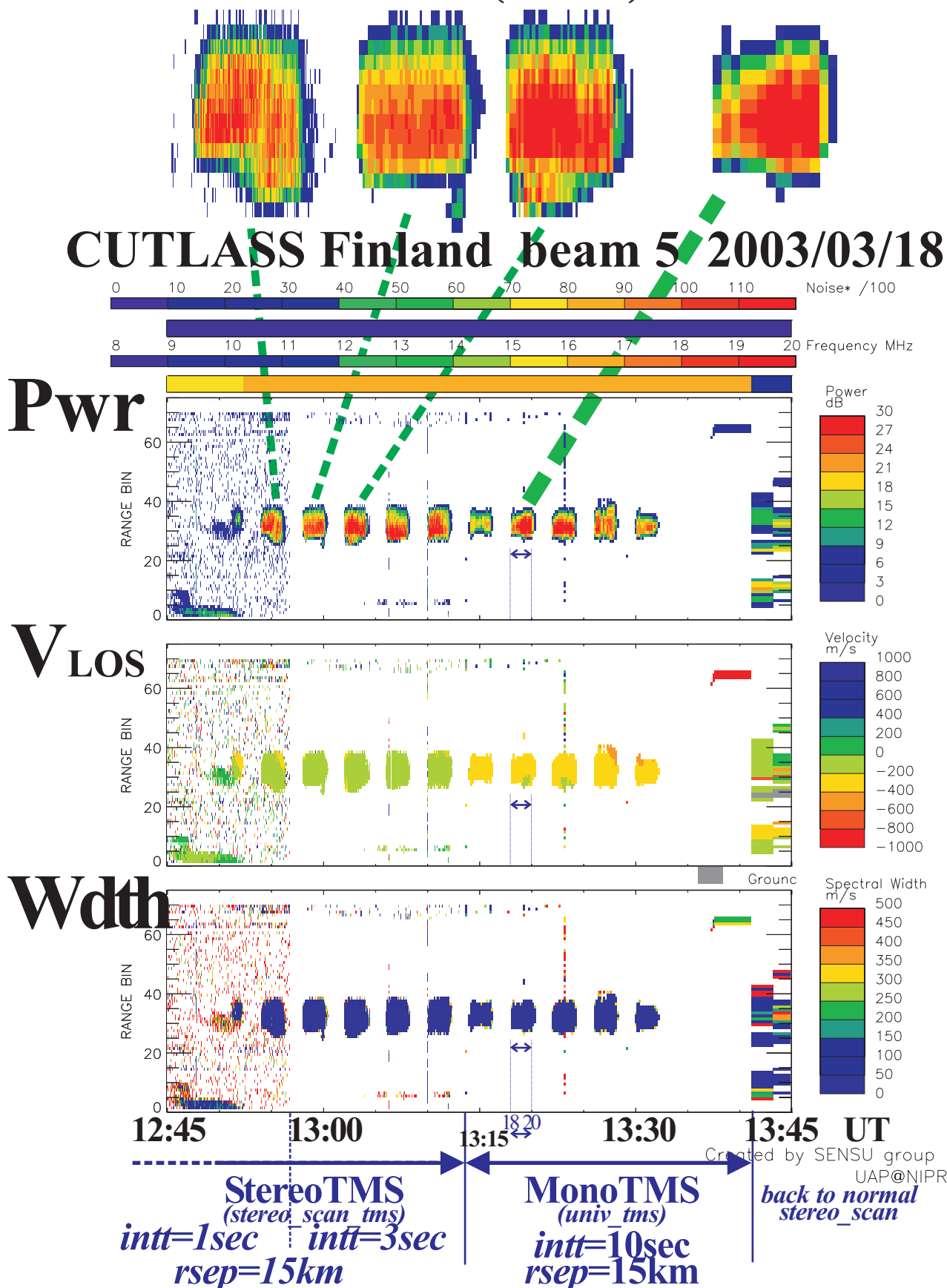
mppul 7, mpinc 2400us, txpl 300us(rsep 45km), smsep 300us(45km), lagfr 300us(45km), nrang 80, maxrng 3600km, nsmp 296, seqtime 88.80ms
 ppat[7]={0,9,12,20,22,26,27}, noise 41(fclr 50), att 0(0->0), DCofs I1: 0, Q1: 0 (removed), ercod 0x0000, MaxBadRng 45km, pwrthr 6.0dB(20.0dB,finechk),tmwin15



HF backscatter from irregularities induced by EISCAT Tromsø heater

2-min on / 2-min off
75 kW/Tx * 12 Tx (=0.9MW) / O-mode

CUTLASS Finland beam 5 2003/03/18



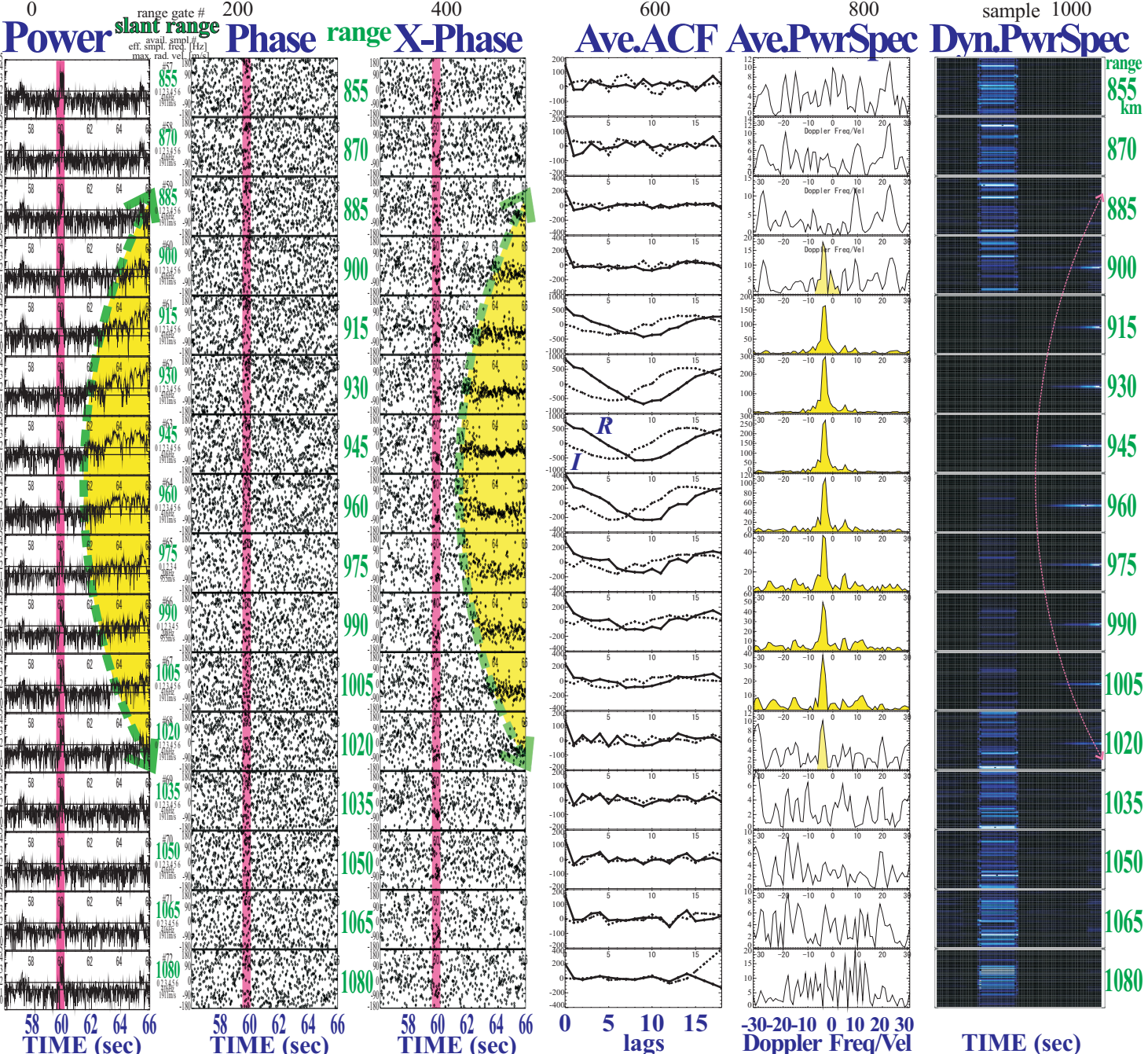
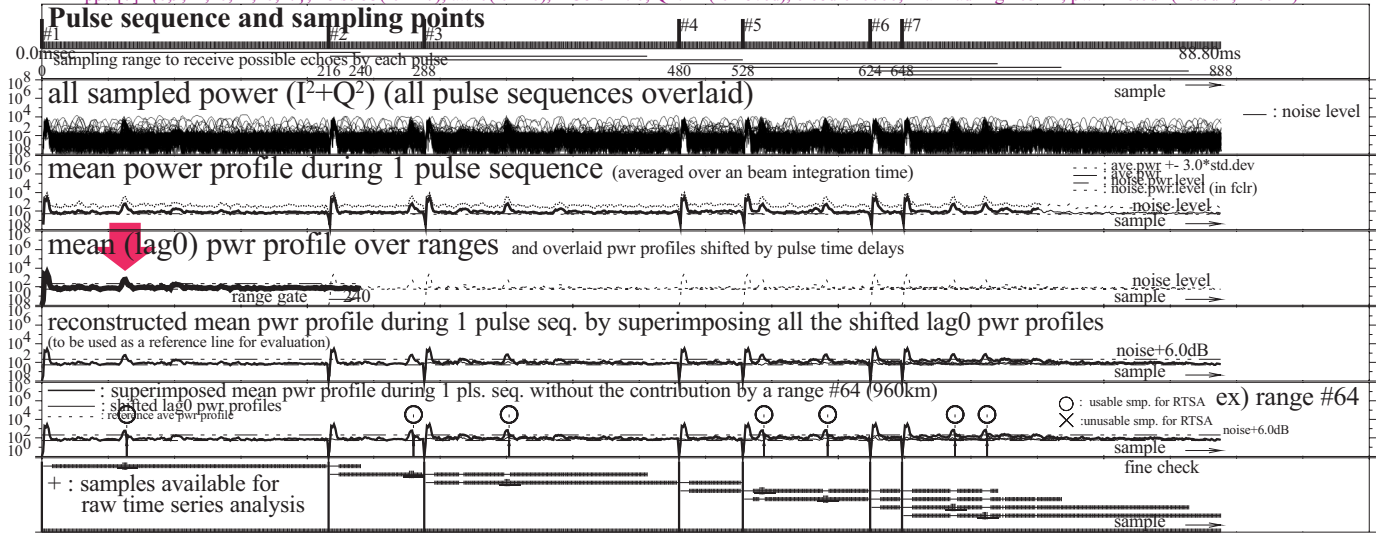


SENSU SuperDARN Raw Time Series Plot

Finland 2003/03/18 13:13:55UT, Mono cpid -6401, bm 5, frq 16345kHz, intt10sec (nave108), xcf 1

mppul 7, mpinc 2400us, txpl 100us(rsep 15km), smsep 100us(15km), lagfr 100us(15km), nrang240, maxrng 3600km, nmsp 888, seqtime 88.80ms

ppat[7]={0,9,12,20,22,26,27}, noise 53(fclr 47), att 0(0->0), DCofs II: 0, Q1: -2 (removed), ercod 0x0000, MaxBadRng 105km, pwrthr 6.0dB(20.0dB,finechk)



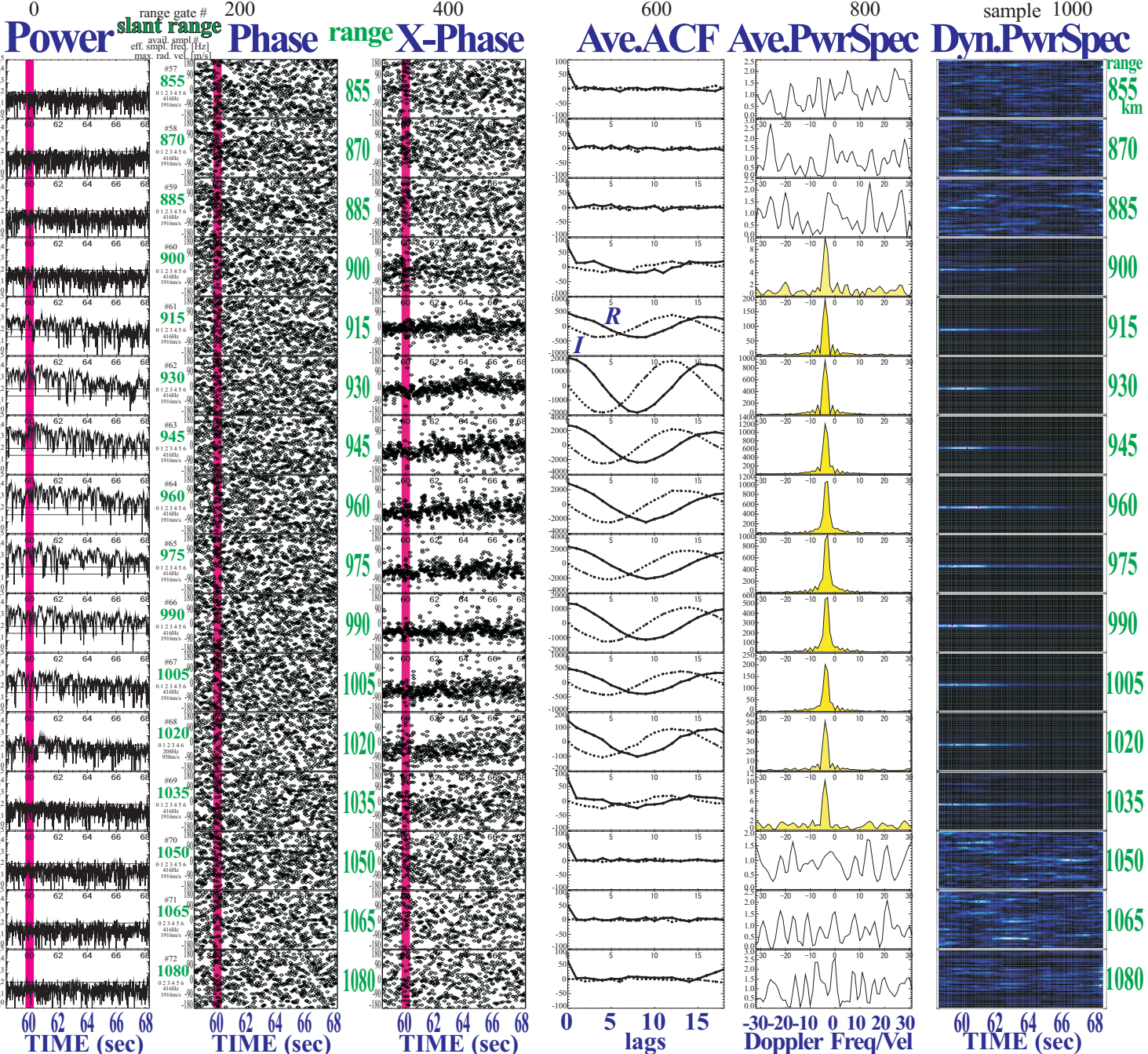
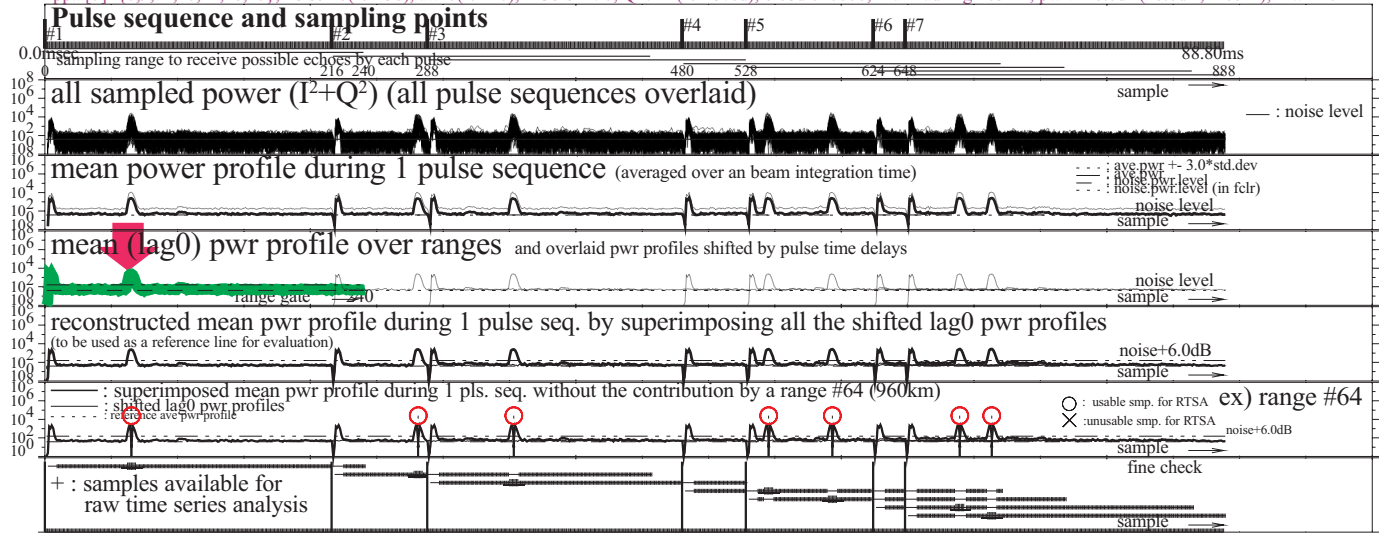
13:16:00 UT The heater is turned off!

SENSU SuperDARN Raw Time Series Plot

Finland 2003/03/18 13:15:58UT, Mono cpid -6401, bm 5, frq 16305kHz, intt10sec (nave108), xcf 1

mppul 7, mpinc 2400us, txpl 100us(rsep 15km), smsep 100us(15km), lagfr 100us(15km), nrang240, maxrng 3600km, nsmpp 888, seqtime 88.80ms

ppatf7={0,9,12,20,22,26,27}, noise 40(fclr 38), att 0(0-> 0), DCofs I1: 0, Q1: -2 (removed), ercod 0x0000, MaxBadRng 105km, pwrthr 6.0dB(20.0dB, finechk), tmwin20



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「 + 」(中緯度 SD 短波レーダー観測に期待すること)

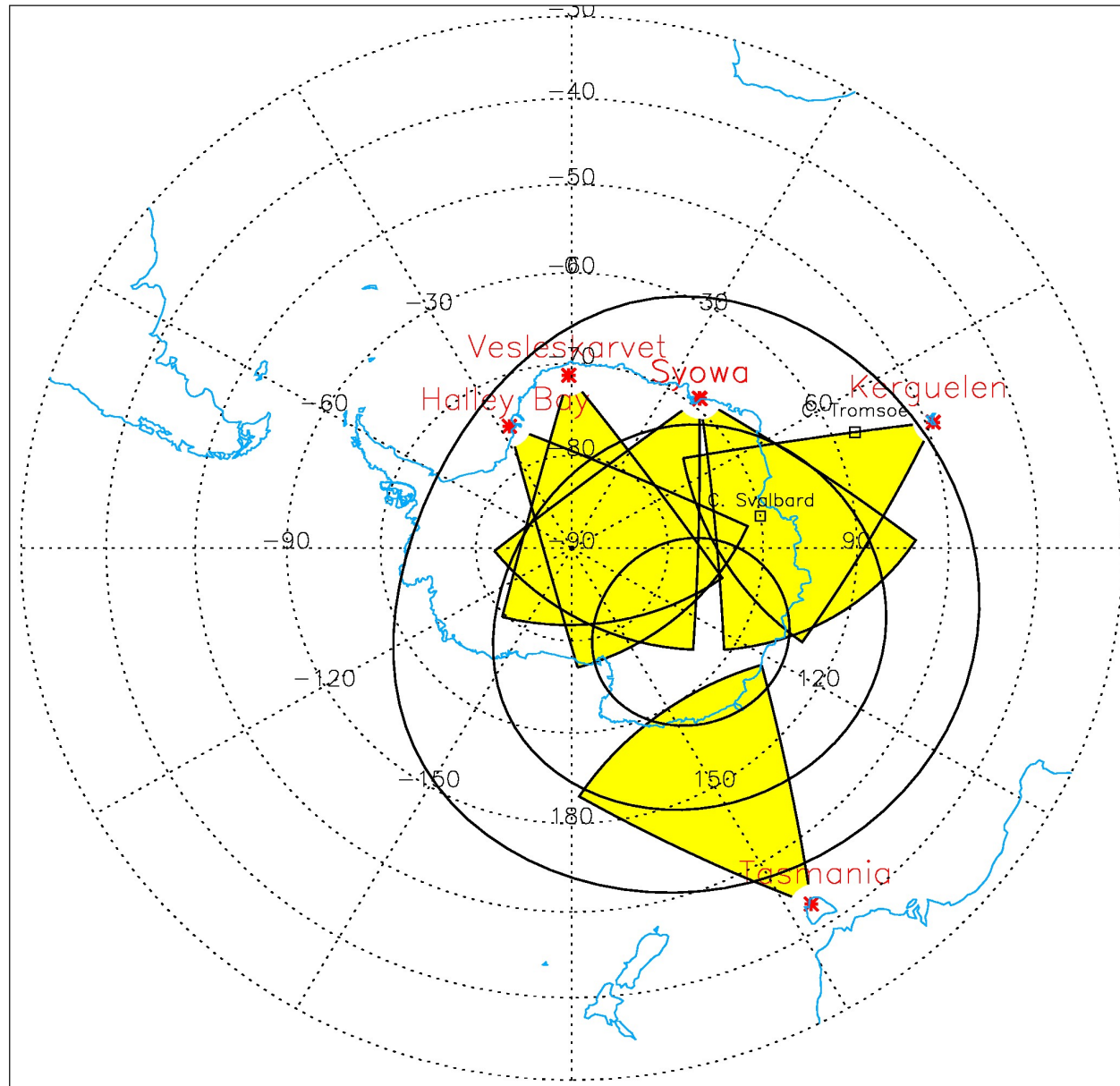
研究面

- ・ サブオーロラ ~ オーロラ帯の物理
- ・ 強い磁気擾乱時等の高緯度から中低緯度への電場の侵入
- ・ 内部磁気圏電場の常時モニター
- ・ プラズマポーズの同定とモニタリング
- ・ 広域流星風ネットワーク
- ・ 高緯度・中低緯度 FAI の相違の本質 (磁場配位、磁気圏との接続・相互作用) ?
- ・ (直交条件を満たさない D・E 層エコー (極域))



SuperDARN : The Future for Southern Hemisphere

2000



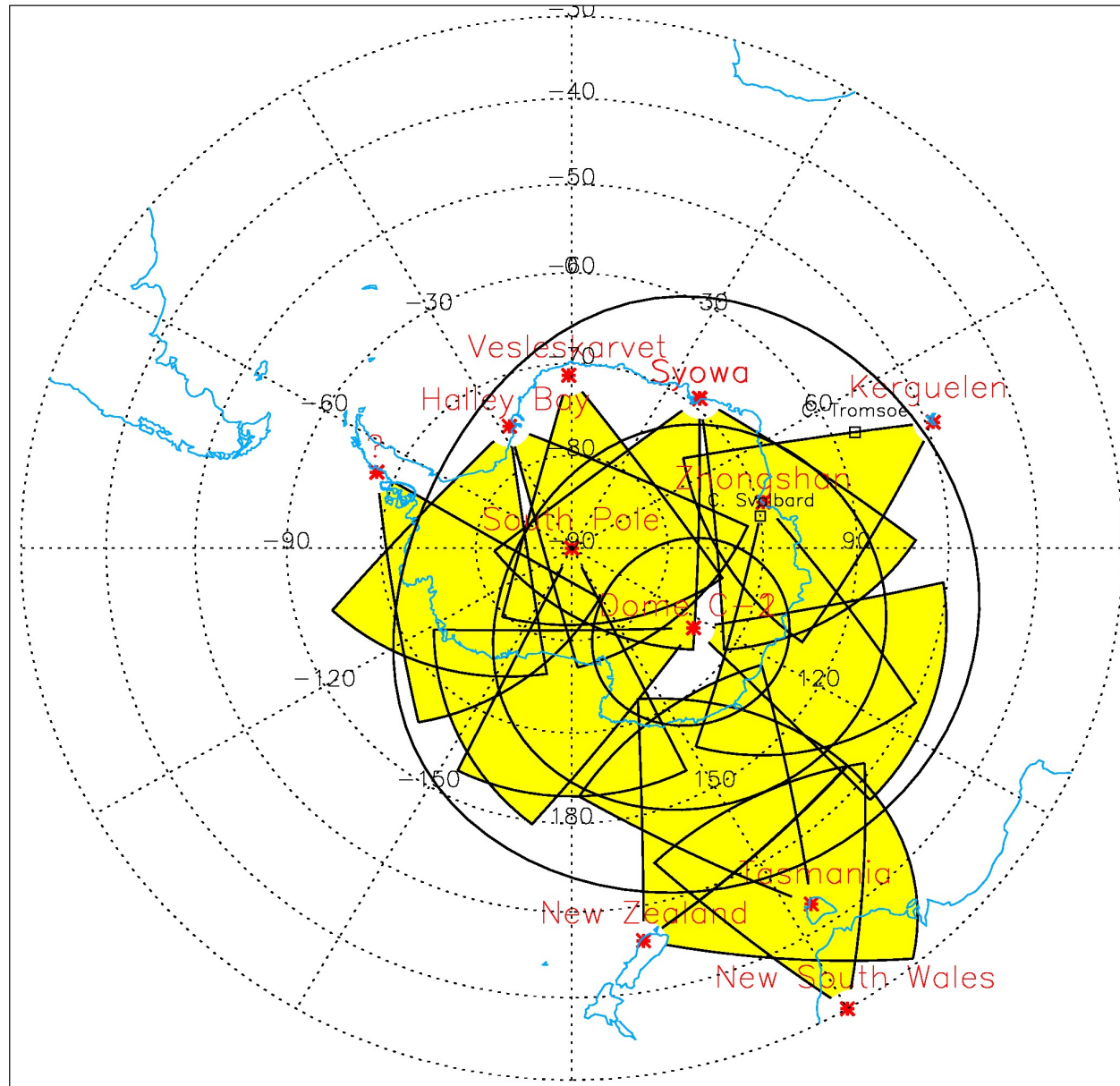
J-P. Villain, Overview of SD development plans in the Southern Hemisphere, □

Proc. SuperDARN workshop 2002, Kiliyev Island (2002.5.10-22)



SuperDARN : The Future for Southern Hemisphere

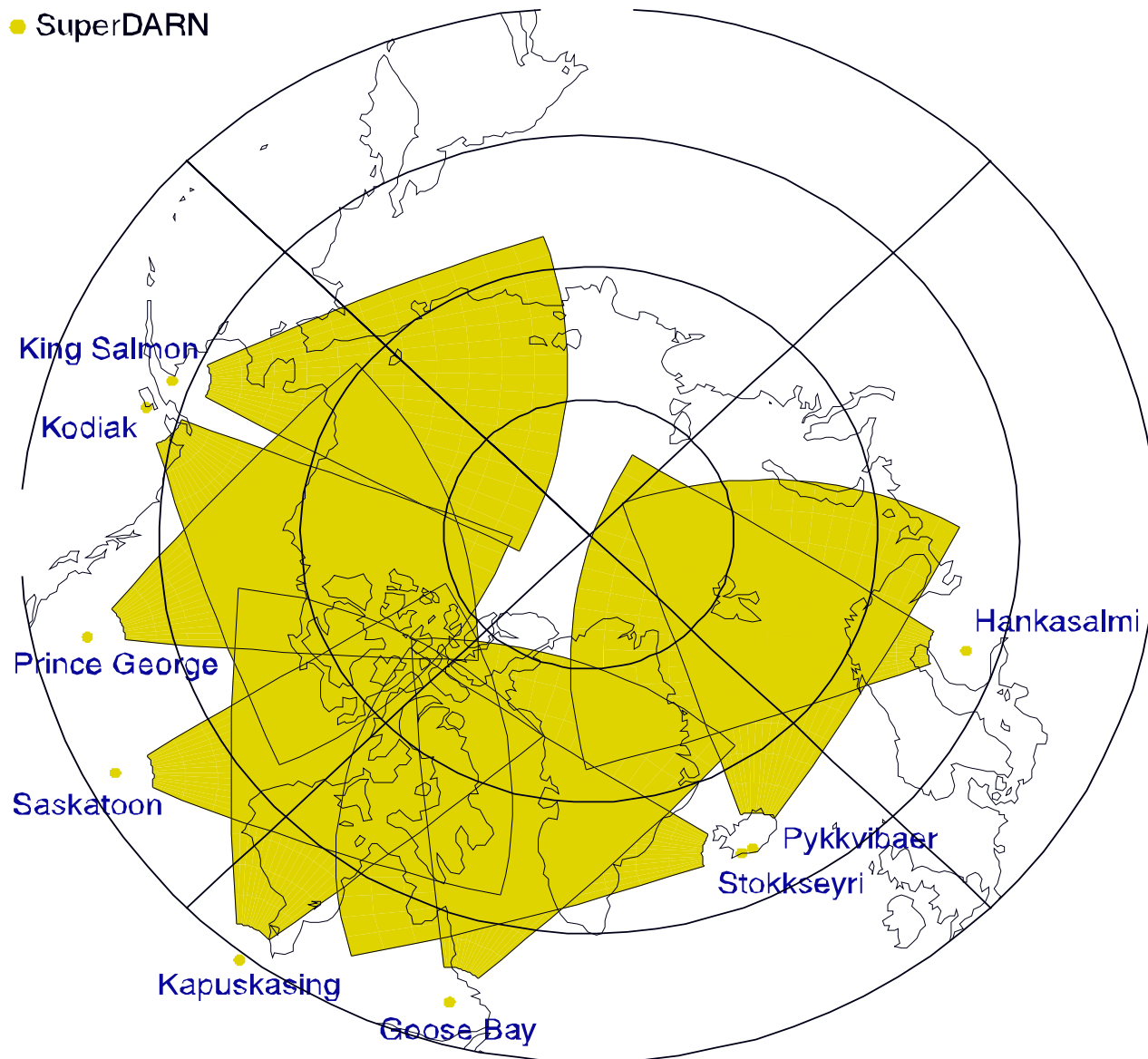
?????

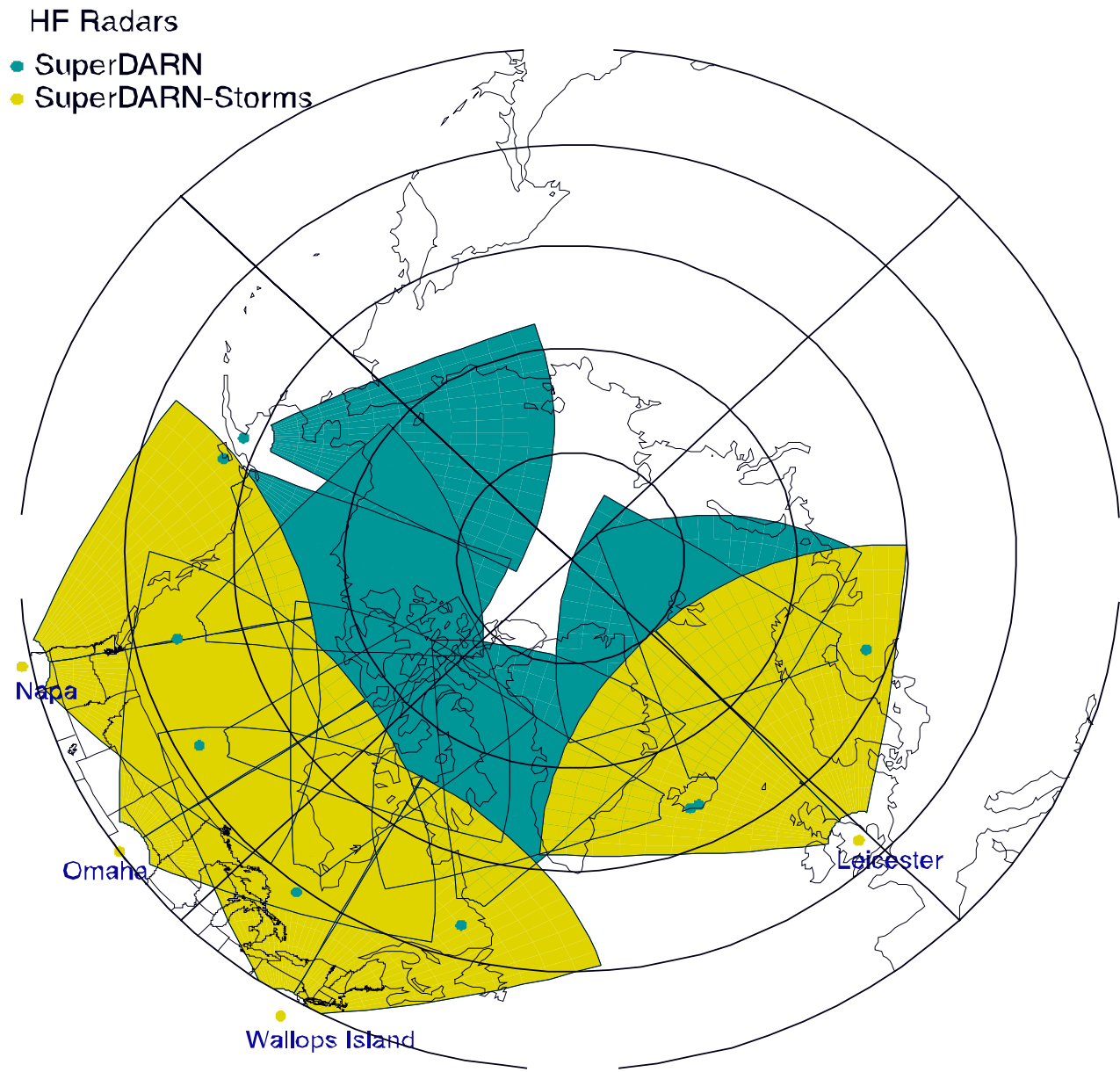


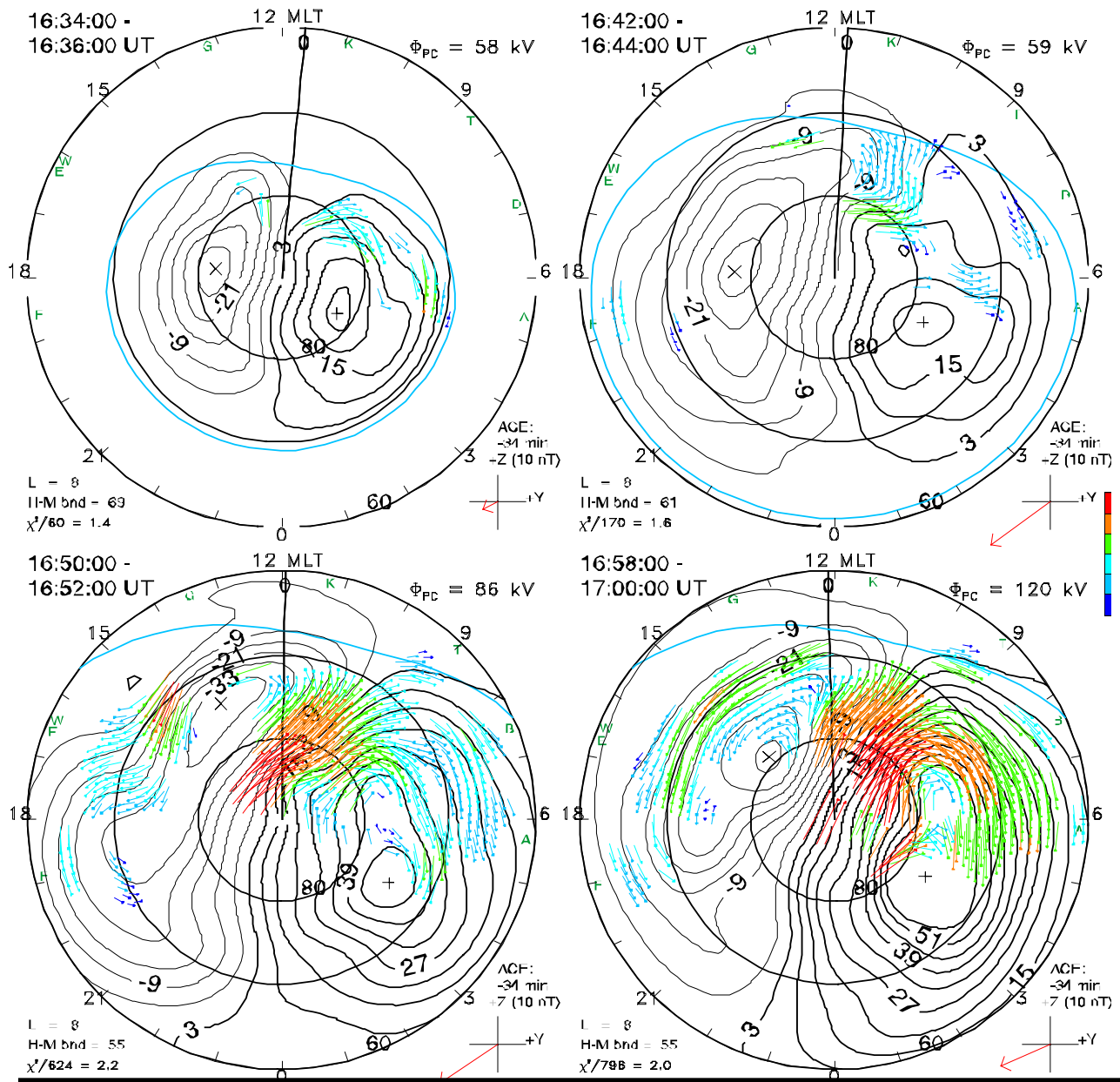
J-P. Villain, Overview of SD development plans in the Southern Hemisphere, □

Proc. SuperDARN workshop 2003, Kiliang, Finland (2003.5.10-23)

HF Radars
● SuperDARN







Science topics (1/2)

- Enhanced coverage of high-latitude physics:
 - storms and substorms
 - the ‘deep’ nightside
 - gravity waves

SuperDARN at Mid-Latitudes

Science topics (2/2)

- New Science at mid-latitudes:
 - SAPS/SAIDs and the penetration of auroral effects to mid-latitudes
 - formation and transportation of irregularities in the mid-latitude ionosphere
 - pulsations
 - neutral winds/planetary waves
 - collaboration with existing mid-latitude instruments

Operational topics

- Continuous tracking of auroral disturbance from high-latitude onset to the mid-latitude zone:
 - mapping of the auroral oval
 - HF clutter and propagation
 - electric currents
- Even in quiet conditions, the observations could monitor
 - the occurrence of mid-latitude irregularities
 - HF propagation conditions

「 + 」(中緯度レーダー設計の考察)

技術面

パルス幅：電離層観測：意味があるなら狭くして空間分解能あげる？

：流星風観測：長いパルス（oversampling）の方が圧倒的に得

：長いパルスでパルスの coding をする可能性？（制御 soft に痕跡あり）

FOV：高緯度を見ると決めることもない？ 2方向 or 全方位型レーダーへの改良？

ステレオレーダー + を買う？

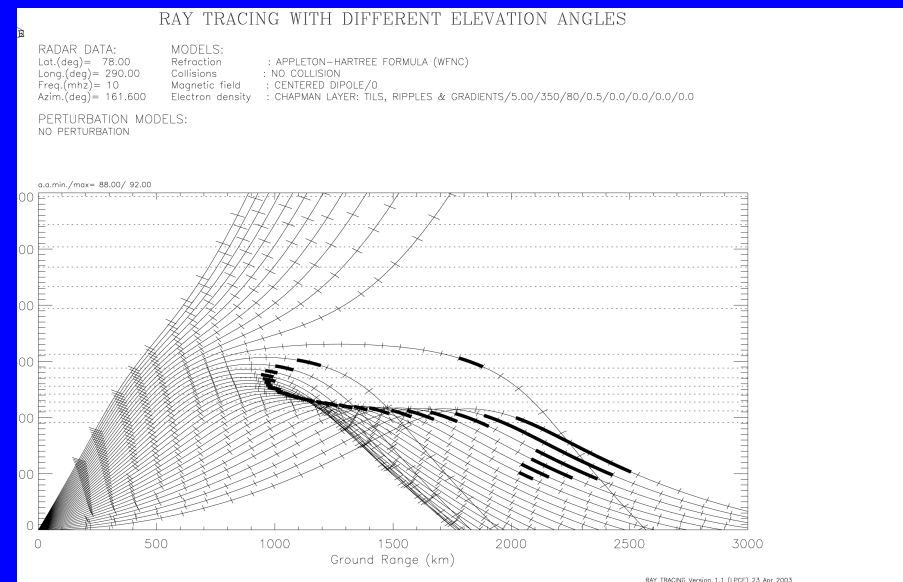
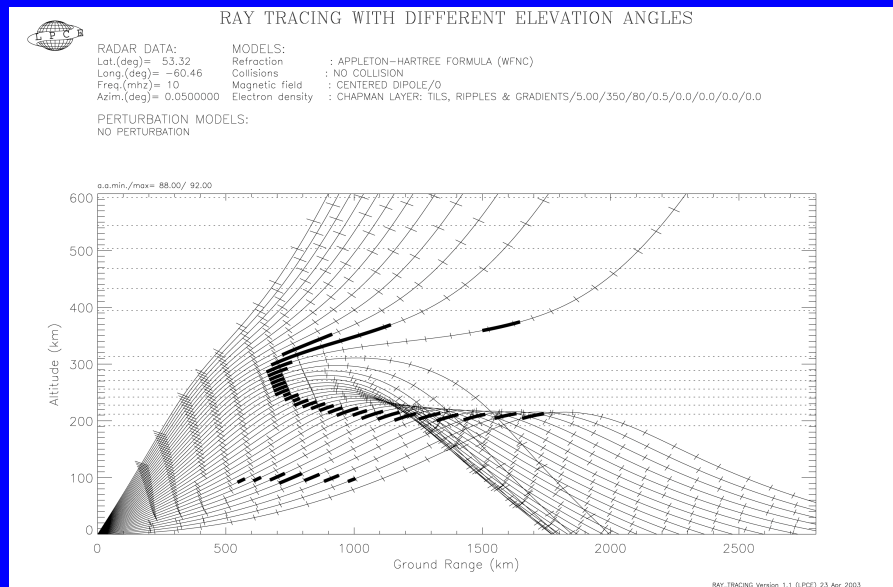
2面で南北両方向観測？（Ray tracing してませんが。）

（Stereo よりも 2周波同時送信で混信やデータ抜けを回避がよい？）

アンテナを円形に並べてやると全方位型レーダーになる（思いつき）？

位相マトリクス of 改良、デジタルラジオの利用等

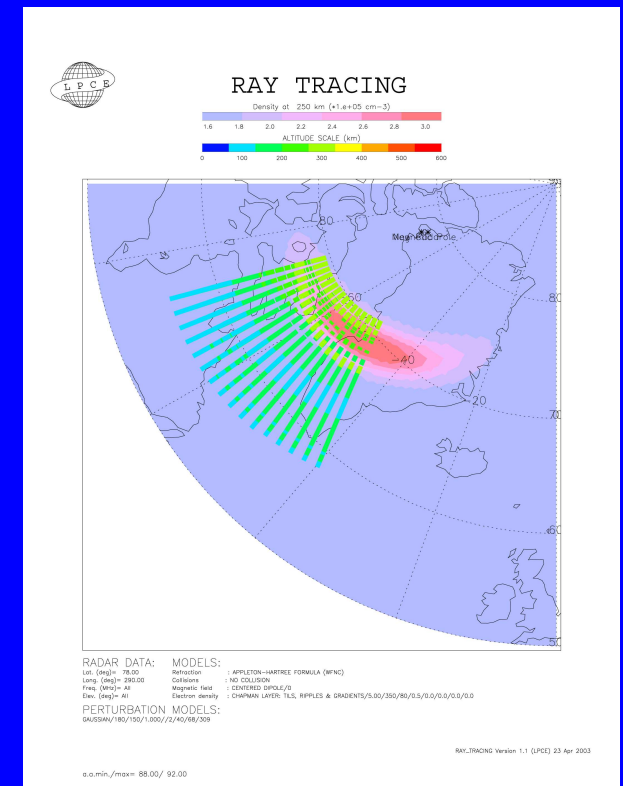
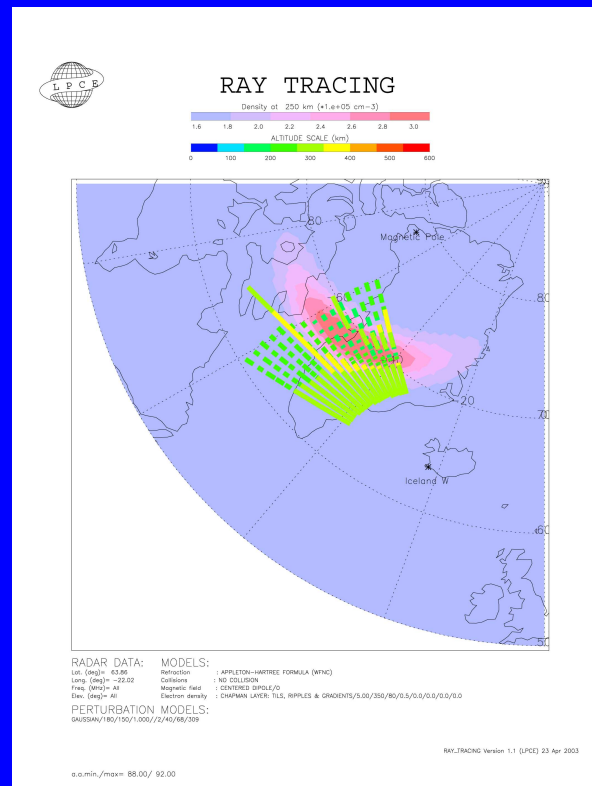
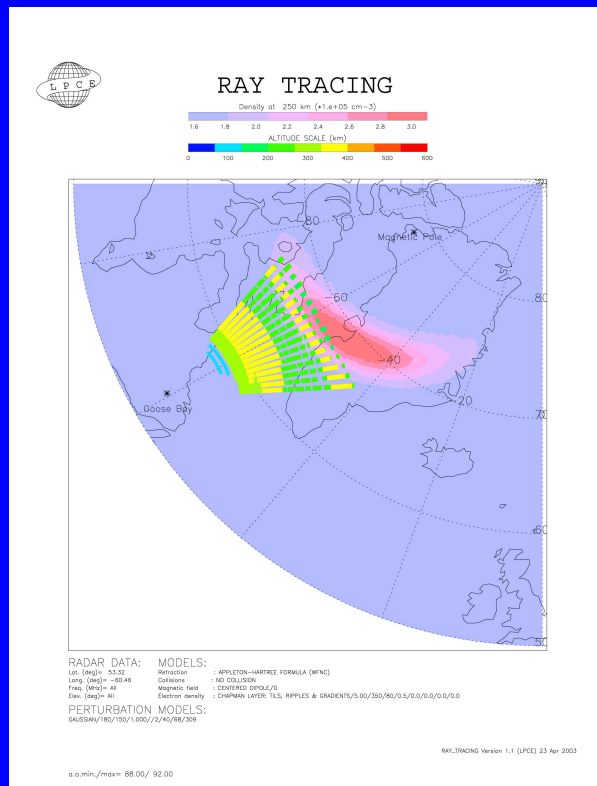
HF propagation: What will an equatorward transmitting radar detect ?



- Perpendicularity at lower altitudes
- Lower operating frequencies ($< F_{max} / \cos \theta$)
- Larger uncertainties

SD2003 - Kiljava (Finland)

HF propagation: What will an equatorward transmitting radar detect ?



SD2003 - Kiljava (Finland)

「 + 」(中緯度レーダー設計の考察)

技術面

パルス幅：電離層観測：意味があるなら狭くして空間分解能あげる？

：流星風観測：長いパルス（oversampling）の方が圧倒的に得

：長いパルスでパルスの coding をする可能性？（制御 soft に痕跡あり）

FOV：高緯度を見ると決めることもない？ 2方向 or 全方位型レーダーへの改良？

ステレオレーダー + を買う？

2面で南北両方向観測？（Ray tracing してませんが。）

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位相マトリクス改良、デジタルラジオの利用等



Doppler radar transmitting HF radio band pulses obliquely to the (E - / F - region) ionosphere, originally designed to obtain coherent backscatter from FAIs up to horizontally over 3000km distance



SuperDARN HF radar

Tx freq.: 8~20 MHz

Tx power: 9.6 kW (600Wx16)

Ant. beams: fan beam by 16 log-periodic phased-array ant.

beam directions: 16 (3.3 deg. beam width each) (\Rightarrow ~50deg. FOV)

pulse length: 300 usec (45km) (100, 200 usec possible, no pulse coding)

pulse sequence: unevenly spaced 7 pulses / sequence
(min. lag=2.4msec, ~90 msec / sequence)

Interferometer: exists (for most radars)

norm operation: frang=180km, rsep=45km, nrang=75, intt=3~7sec, simple beam scan



SENSU Syowa South HF radar

by A. Sessai Yukimatu, M. Tsutsumi, H. Yamagishi, and N. Sato at IUGG200 workshop in Sapporo, Japan, 2003.6.30-7.11.



ステレオ SuperDARN 短波レーダーシステム

