北海道レーダー2基運用で期待すること
Hokkaido twin radar operation and what to be expected

A. S. Yukimatu (NIPR)

HOP Hokkaido radars

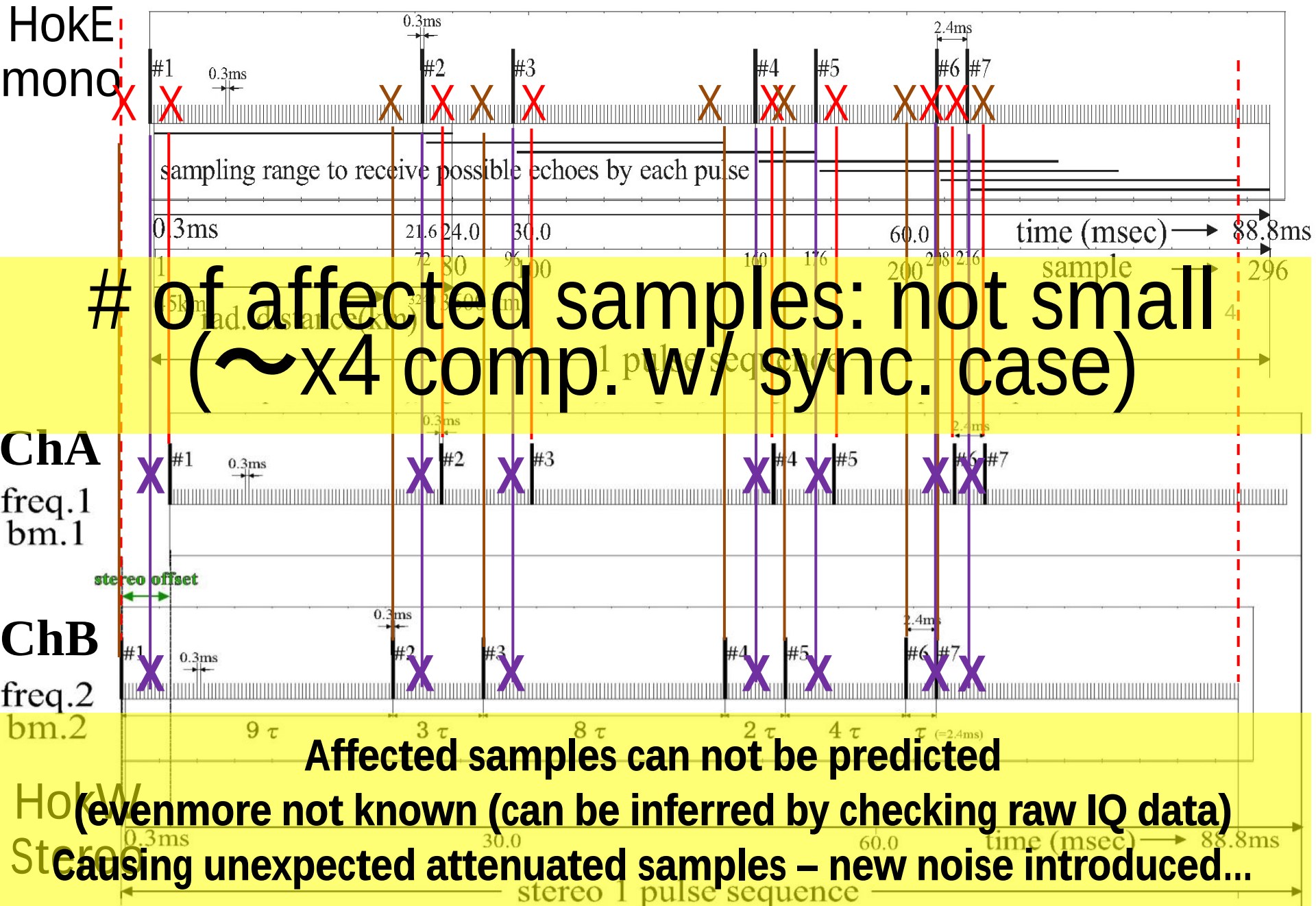
- Twin radar operation
- Interferometer reliability
- I-M mapping?
- ERG modes (inc. trigger method...)?
- Higher temporal resolution mode?

Twin radar operation

A new stereo radar added to the original 1st radar, meaning…

- FOV is doubled
- independent Tx channels tripled. (current ROS: ptab/lags & intt not independent. Beam, Tx freq, txpl etc independent.
  But 3 Tx freqs should be all different (at least Rx bandwidth))
  Of course, 1 beam confined in E-FOV, 2 others confined in W-FOV.
- One channel free from SD scheduling / PI agreemet – 1 freedom!.
  High temporal camping beam(s) modes - easy at any time
- Blanking signals and/or simultaneous Tx required to avoid interference (or possible damage) between the 2 radars.
- Blanking sig – possibly causing worse quality (if not synchronosed)
- simultaneous Tx – quality not degraded basically compared with single radar but obs modes need to be the same as the other. (Moreover, 1st radar still needs to be Rx attenuated when one of stereo 2 channels Tx but affected range can be estimated – much better than random blanking signals causing random unexpected interference (worse quality))

Blanking sigs with no synchronization



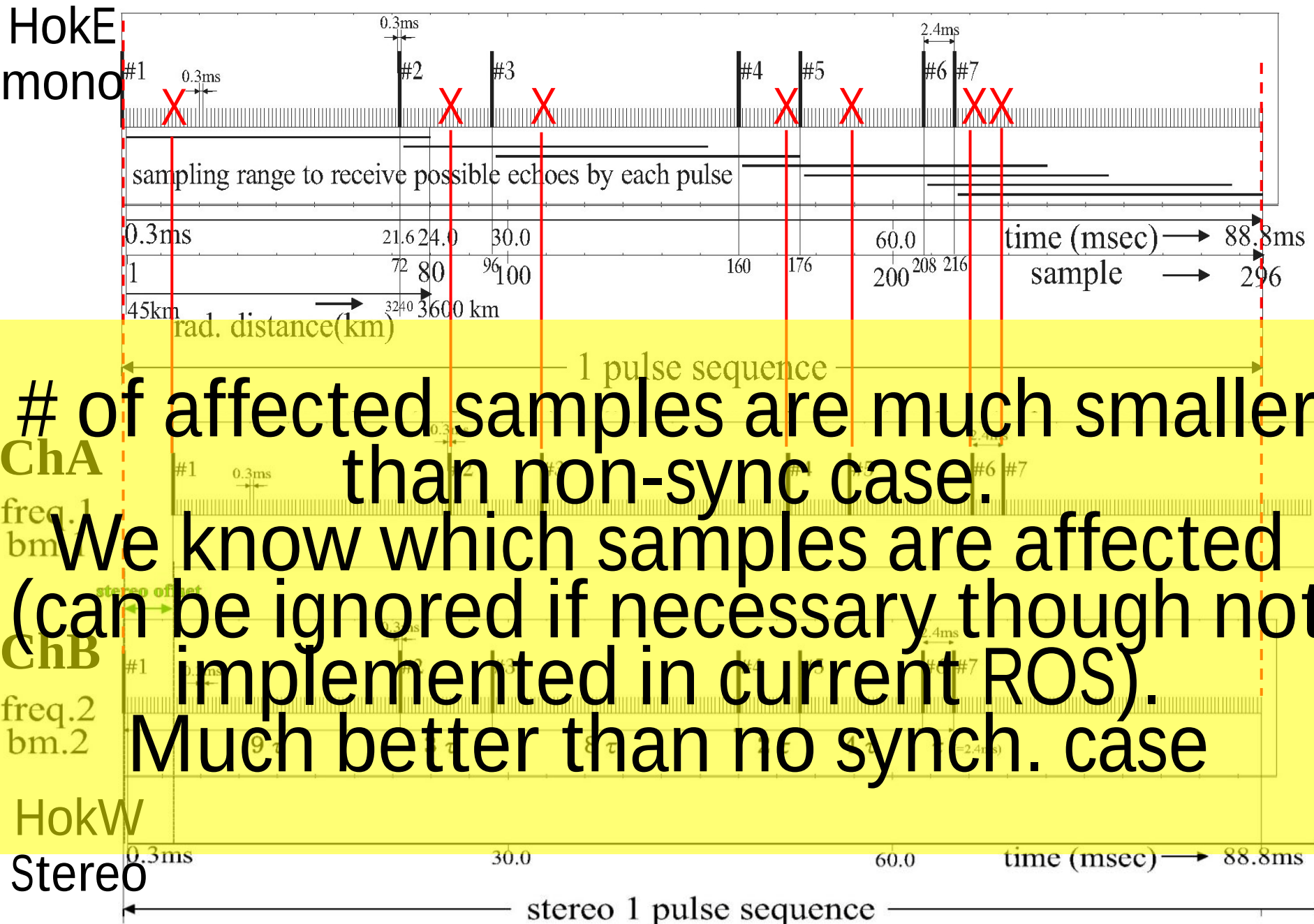
of affected samples: not small (~x4 comp. w/ sync. case)

Affected samples can not be predicted

(evenmore not known (can be inferred by checking raw IQ data)

Causing unexpected attenuated samples – new noise introduced...

Synchronised Tx case...



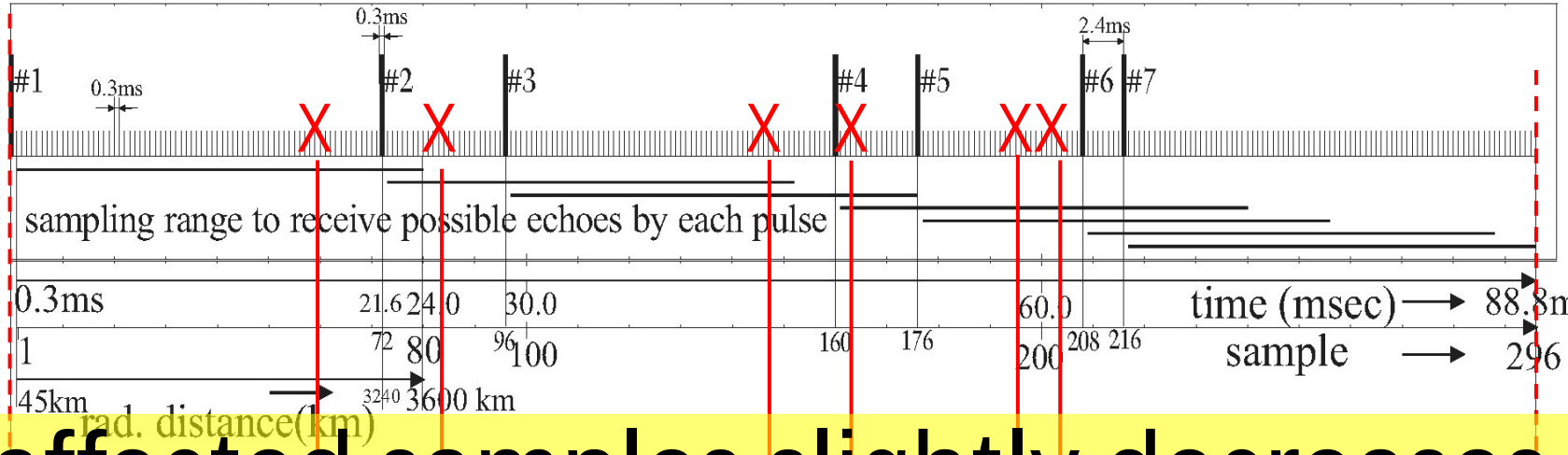
# of affected samples are much smaller than non-sync case.

We know which samples are affected (can be ignored if necessary though not implemented in current ROS).

Much better than no synch. case

Slightly better (-1 & farther)…

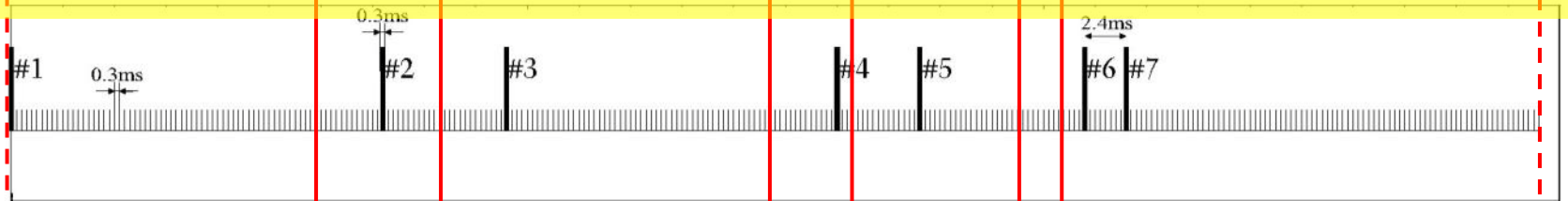
HokE mono



of affected samples slightly decreases

ChA

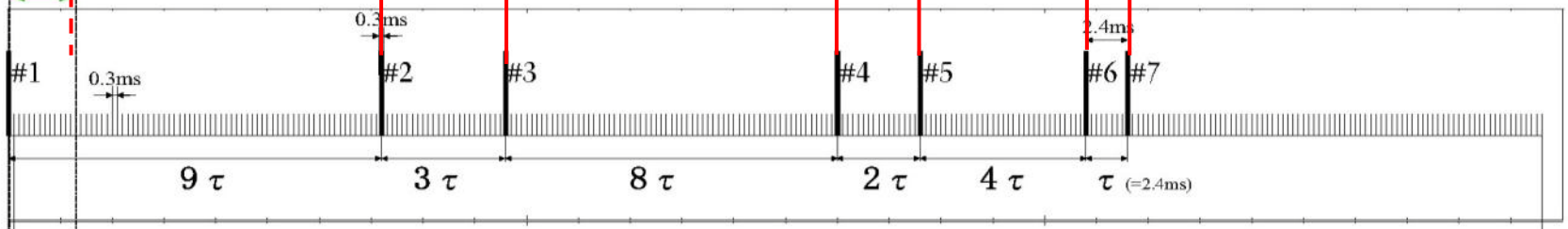
freq.1
bm.1



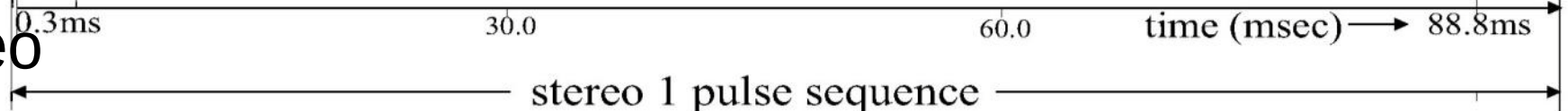
stereo offset

ChB

freq.2
bm.2



HokW Stereo



Interferometer reliability

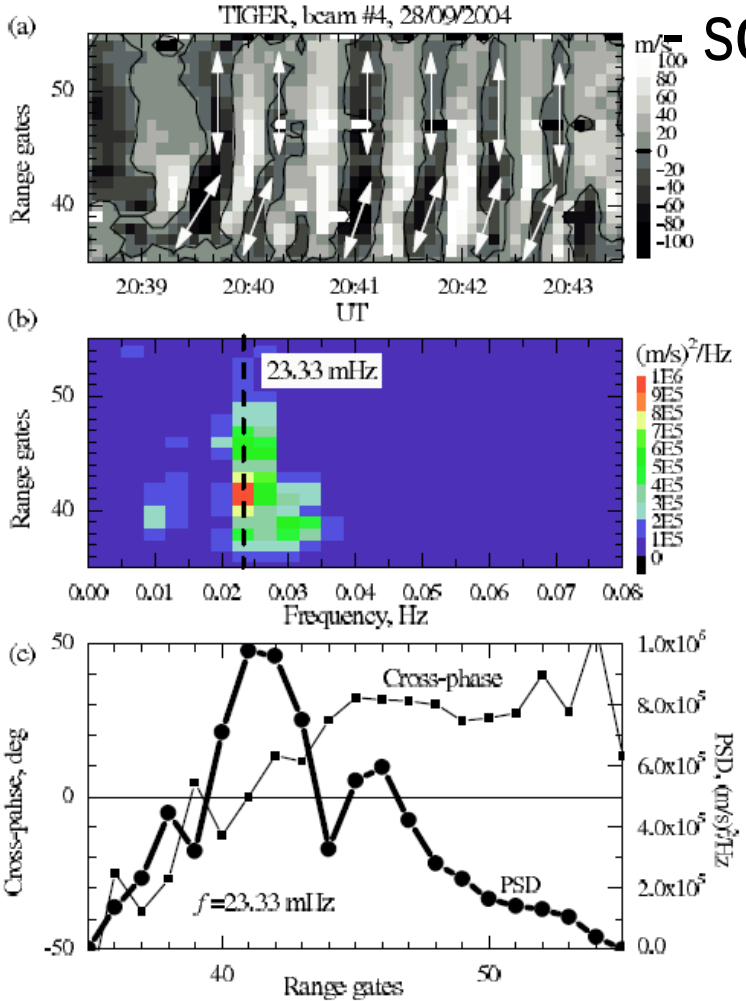
- Tried to calibrate interferometer using meteor echoes so that all the meteor echoes lies flat horizontally (parallel to (round) ground level) with certain altitude width – in vain.
- Inferred that non-flat ground level around HOK antenna could cause the problem – hard task to calibrate it but started to try.
- Pasha gave us other method to calibrate it. Calibrate phase offset so that AOA decreases close to +zero as range increases, and calibrate possible range offset so that “more_badlangs()” not create strange bad data – it works (Pasha and Nozomu said.) – Great!
- Using offsets by new Pasha’s way, we should check if horizontal distributions of meteor altitudes are appropriate!
- Even more, we might be able to improve the accuracy of range/phase offset (Pasha’s range offset accuracy is 15km)
- Also should try to check if PMSE/PMWE/MSE are real…?

I-M mapping?

- Plasma pause

I-M mapping (region identification) PlasmaPause detection with SD?

- SD may possibly detect plasmapuase like SD cusp identification?
  - some trial started in SD community



Range-time plot

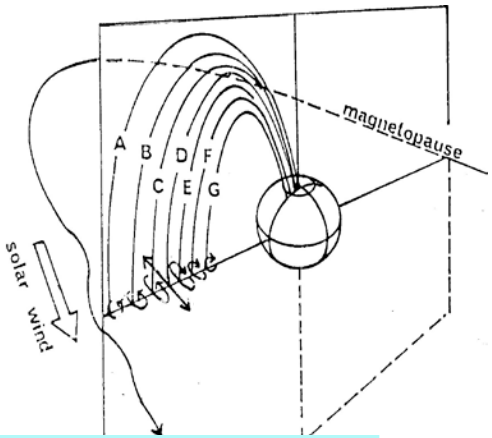
Range-frequency plot of the phase-space density (PSD) of the wave (using all the data in the top panel)

Range-profile of PSD and the wave phase at the vertical line of the middle panel

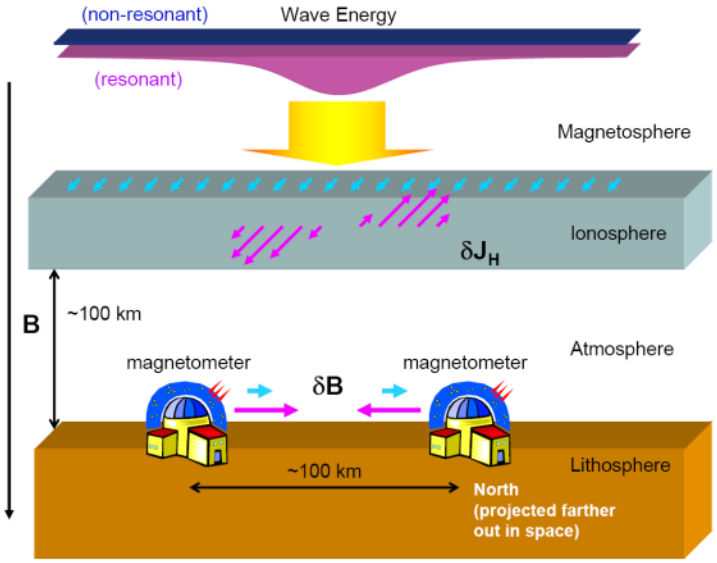
[Ponomarenko et al., ANGEO, 2005]

FLR→Field-line eigen-oscillation →Magnetospheric Density

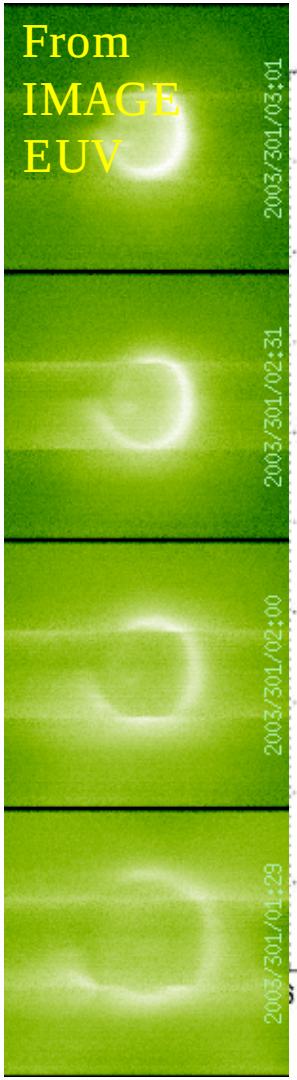
Field Line Resonance (FLR)

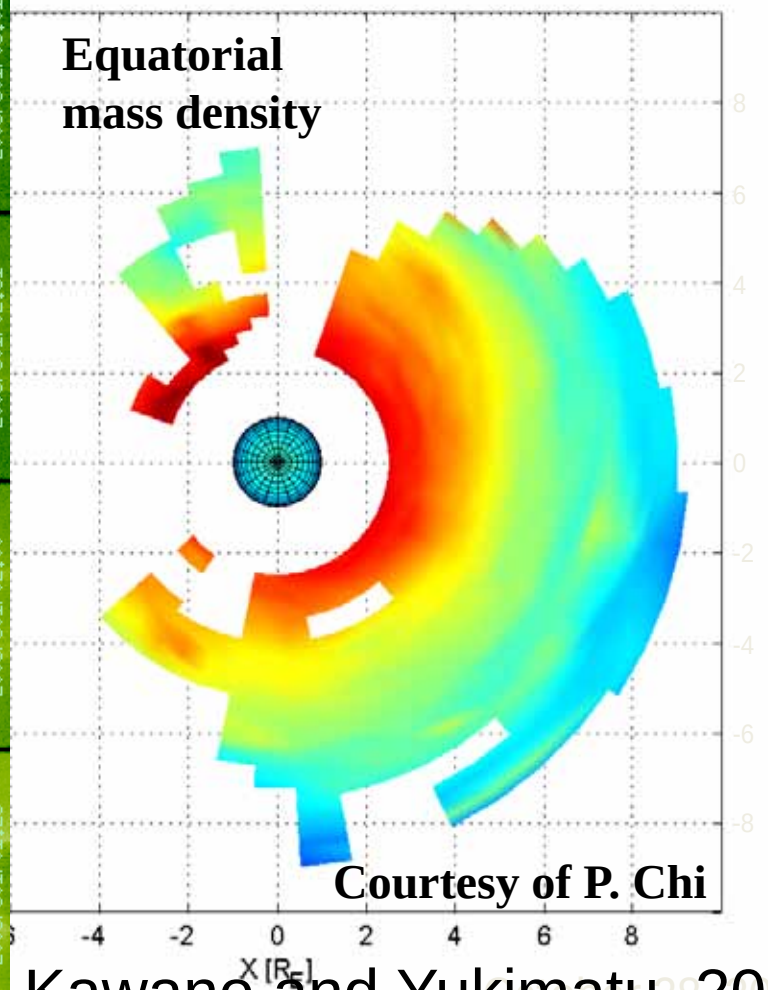


Eigen period
$\propto l, \rho^{1/2}$



From ground FLR
(using 1 day of data)





Kawano and Yukimatu, 2011

ERG modes?

- Target? Pc5? Pi2? EMIC? 1min-Global pattern essential? 2min is enough? Temporal resolution for global scan and camping beams? (e.g., EMIC?!) SCs with high temporal resolution global map_pot?!
- VAP modes – optimized for global Pc5 monitoring with 3 camp beams / radar with 2-min resolution global map_potential.
- Basyouhu? Possibly much better?
  - Global map_pot x1~x8 times higher (though spatial resol. possibly be degraded - but same quality as current VAP mode can always be obtained, so nothing worse, nothing lost!!
- Triggers to initiate VAP/ERG mode
  Many debates…
  Current way: **Simple Dst triggering algorithm**
  Started/triggered by Dst <-50nT
  End countdown started by Dst >-30nT
  Countdown time: 6 hours
  (terminated if Dst stays >-30nT for 6hours)
  Avoid false positive (**誤検出**) – should be investigated using past data!

Detect Pc3-5, Pi2, & even EMIC wave?

- Tomo Hori asked me whether SD can detect EMIC.
- Meaning possibility to detect waves around 1 Hz?
- Answer will be possibly yes (“if you’re lucky”)…

Higher temporal resolution?

- (1) smaller beam integration time (intt)
- (2) rearrange beam sequence - camping beams with global scan (“Nasu”, “Basyouhu”,...)
- (3) rearrange beam sequence with stereo merit - camping beams only (“only_you” mode)
- (4) scan required beams after each pulse sequence and integrate each beam data until “fitacf” algorithm can fit, i.e., ACF reaches good shape (high S/N and cross range effect can be ignored) for each range gate
- (5) raw I/Q time series analysis - directly analyze temporal variation of (unevenly sampled) I/Q samples (in time domain) which are not affected much by cross range effect.

Higher temporal resolution?

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- (2) rearrange bm sq w/camping beams with global scan
  ⇒ ~6sec (intt=3s)
- (3) rearrange bm sq. stick on a fixed beam (only_you)
  ⇒ ~3sec (dep. on intt)
- (4) scan required beams every time after each pulse sequence completed
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- (5) raw I/Q time series analysis
  → mpinc(min. IPP〜1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough

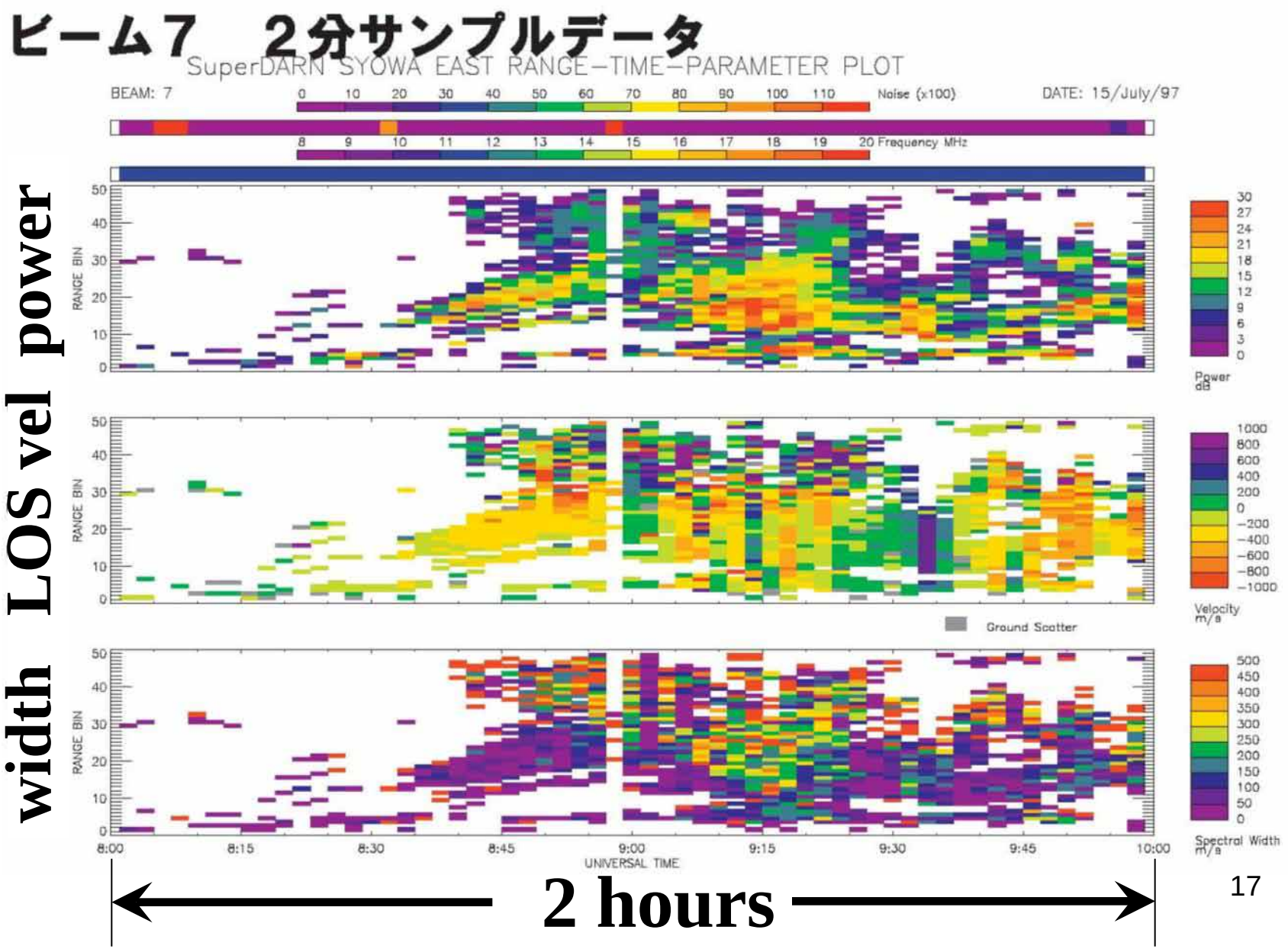
Higher temporal resolution (1)

- **(1) shorter beam integration time (w/ bm sq)**
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- (2) rearrange bm sq w/camping beams with global scan
  ⇒ ~6sec (intt=3s)
- (3) rearrange bm sq. stick on a fixed beam (only_you)
  ⇒ ~3sec (dep. on intt)
- (4) scan required beams every time after each pulse sequence completed
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- (5) raw I/Q time series analysis
  → mpinc(min. IPP〜1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough

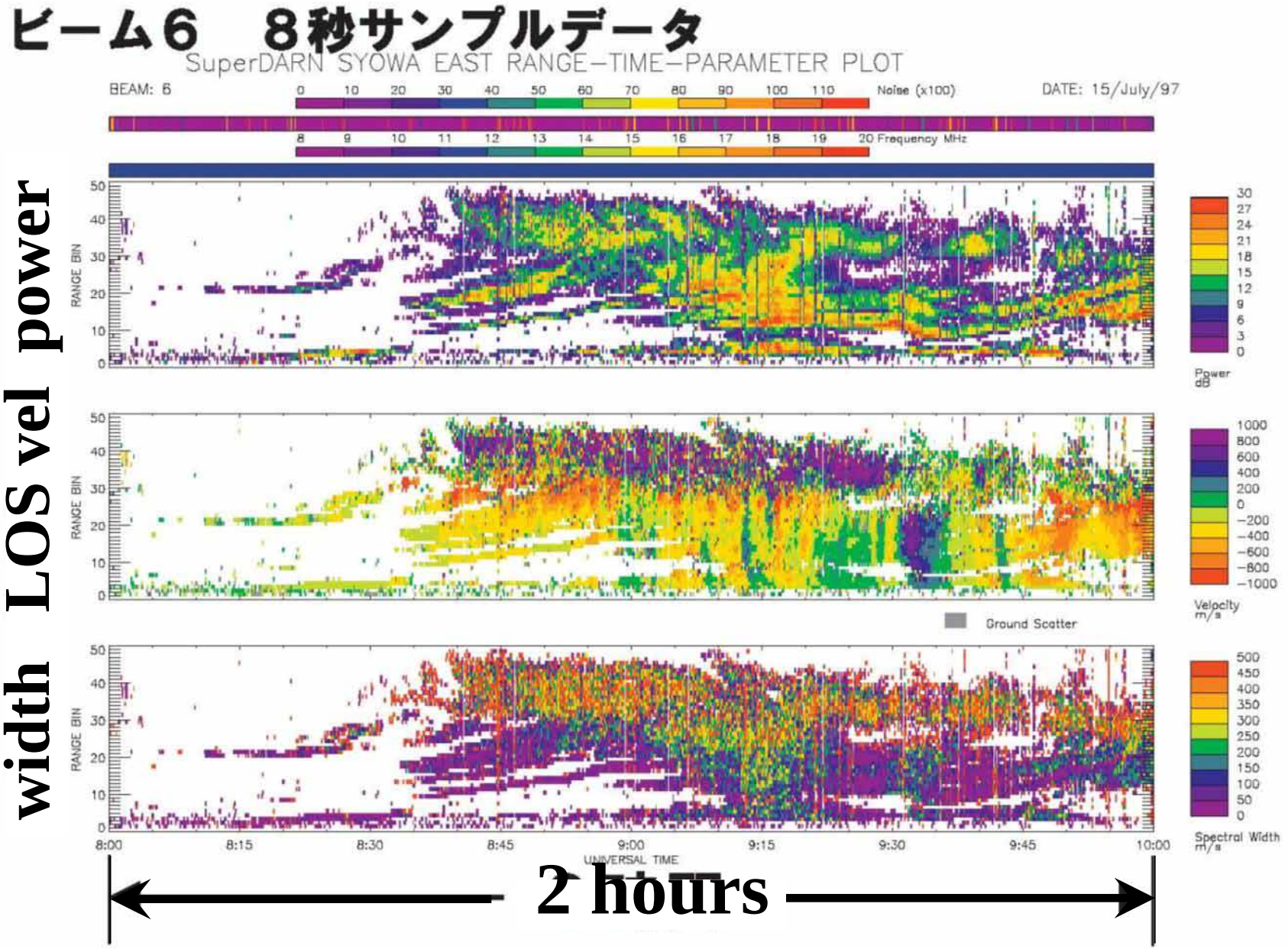
Higher temporal resolution (2)

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- **(2) rearrange bm sq w/camping beams with global scan**
  ⇒ ~6sec (intt=3s)
- (3) rearrange bm sq. stick on a fixed beam (only_you)
  ⇒ ~3sec (dep. on intt)
- (4) scan required beams every time after each pulse sequence completed
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- (5) raw I/Q time series analysis
  → mpinc(min. IPP〜1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough

Global scan with camp. beam(s)



Global scan with camp. beam(s)



Higher temporal resolution (2)

- **Basyouhu scan – try to getting higher temporal resolution of global scan by interleaving GS beams as well as camping beam(s)**
- Normal: 0,1,2,3,4,5,6,…,14,15 (48-60s)
- Modified: 0,2,4,6,8,10,12,14, 1,3,5,7,9,11,13,15
  ⇒ Global scan temp res x2 (spatial res. ½) (24-30s)
- Modified: 0,4,8,12, 2,6,10,14, 1,5,9,13, 3,7,11,15 (12-15s)
  ⇒ Global scan temp res x2x2 (spatial res. ¼)
- Cut bm15:0,4,8,12, 2,6,10,14, 1,5,9,13, 3,7,11
- Add Sp Bs: 7 5 7 9 7 5 7 9 7 5 7 9 …. (24-30s)
  (⇒ Global scan temp res x 2x2x½)
- Modfied: G 0,4,8,12, 2,6,10,14, 9,1,13,5, 3,7,11
  S 7 5 7 9 7 5 7 9 7 5 7 9
- Final Basyouhu scan:
  ⇒0,7,4,5,8,7,12,9,2,7,6,5,10,7,14,9,1,7,13,5,3,7,11,9
- ⇒Global scan : temp. res. x2 (spatial res. ¼)
  (or temp. res. x1 (spatial res. ½)
  or same as normal scan x½ (spatial res. 1))
- ⇒ Camp. Beams: temp res. Intt x2 (x N)
  (e.g., bm7: t.r. Inttx4, bm5&9: tr. Inttx8)

Higher temporal resolution (2)

- Basyouhu scan

bs3-1) *0, 7, 4, 5, 8, 7, 12, 9, 2, 7, 6, 5, 10, 7, 14, 9, 1, 7, 13, 5, 3, 7, 11, 9,*

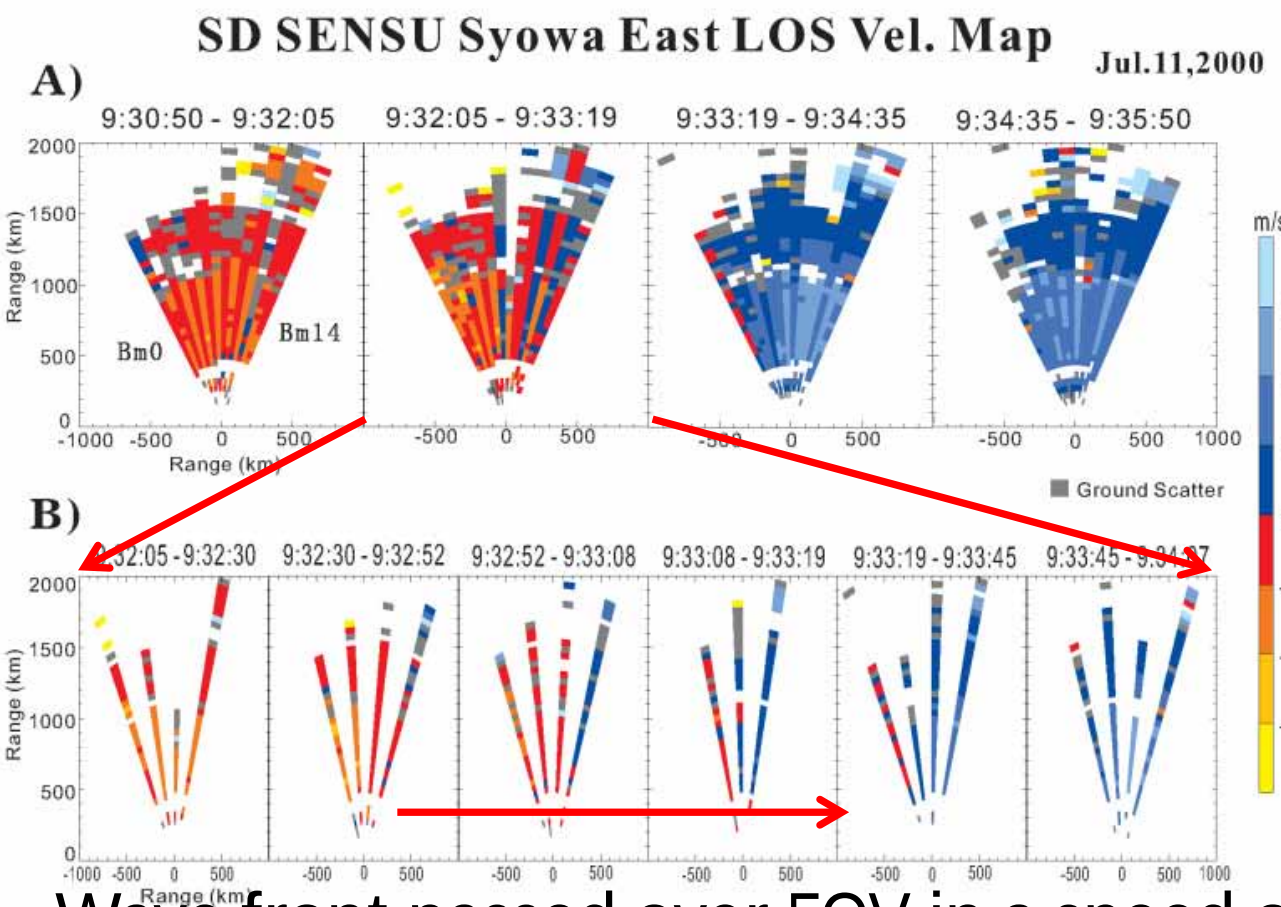
(G 0, 4, 8, 12, 2, 6, 10, 14, 9, 1, 13, 5, 3, 7, 11,)

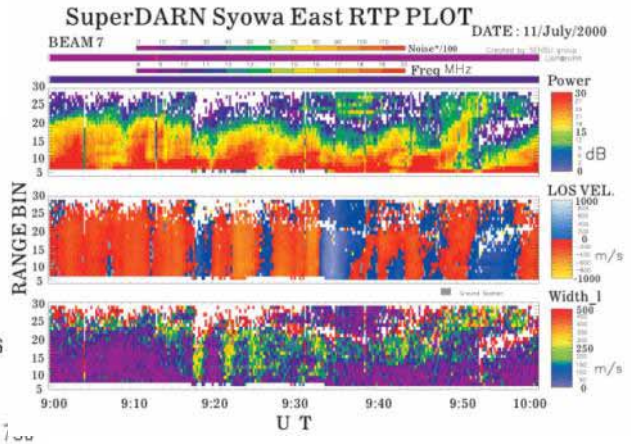
(S 7, 5, 7, 9, 7, 5, 7, 9, 7, 5, 7, 9,)

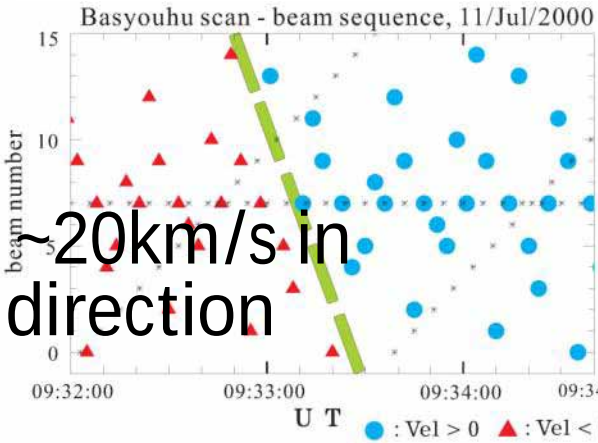
(Beams on the 'G' line can be treated as part of the global scan, while beams on the 'S' line can be treated as special camping beams.)

Higher temporal resolution (2)

- Basyouhu scan



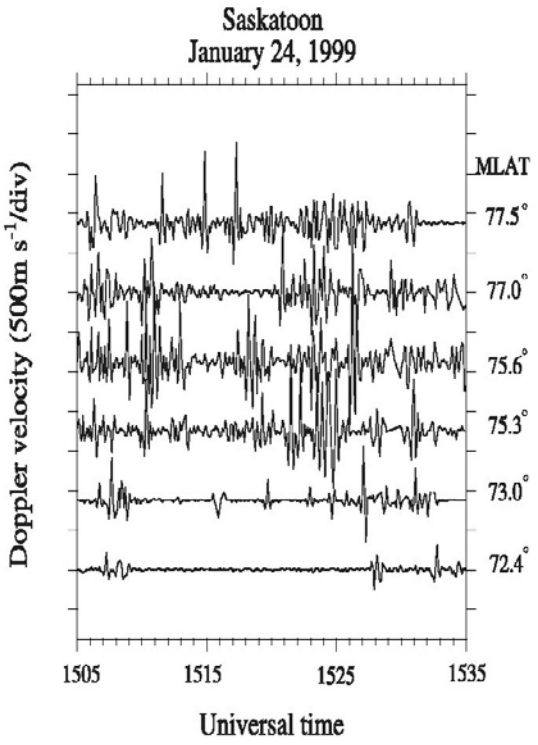


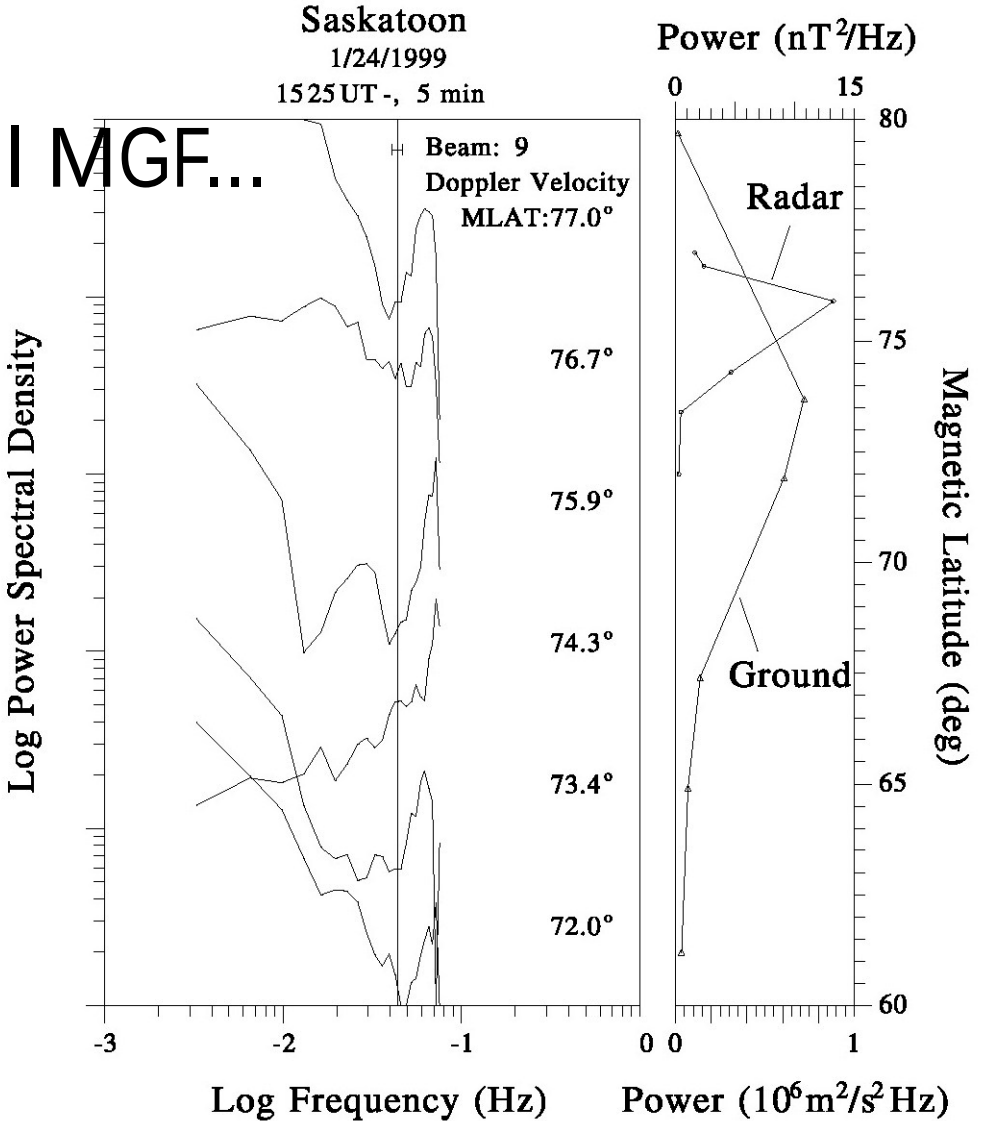


Wave front passed over FOV in a speed of ~20km/s in the direction parpendicular to boresite direction

Higher temporal resolution (2)

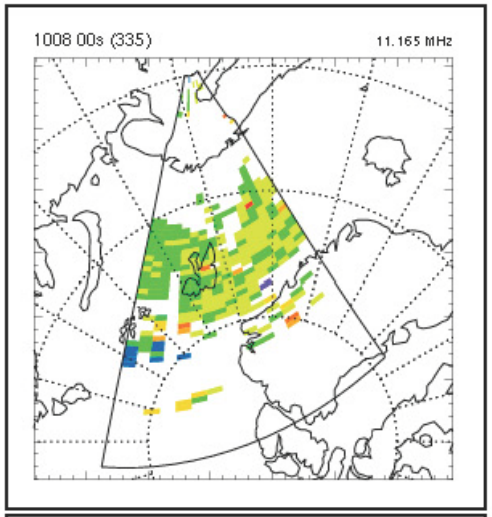
- Matsuoka, et al., JGR, 2002:
- SD – Basyouhu mode compared with Geotail MGF...
- Detect Pc3.

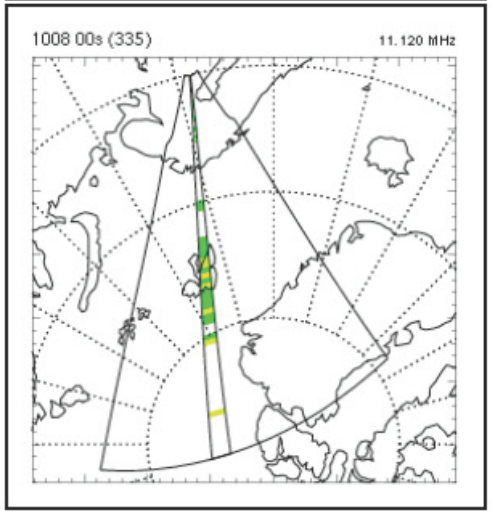


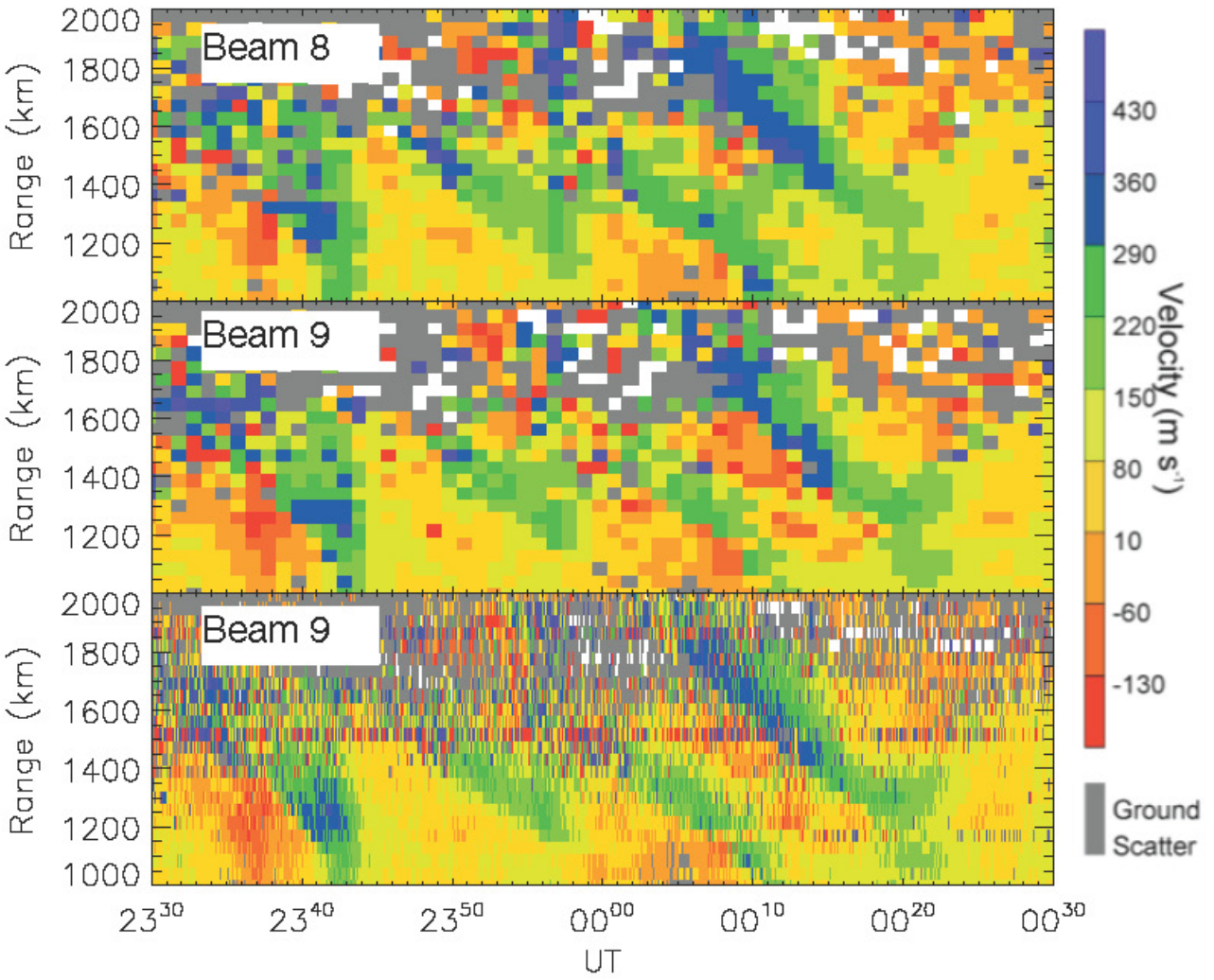


Higher temporal resolution (3)

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- (2) rearrange bm sq w/camping beams with global scan
  ⇒ ~6sec (intt=3s)
- **(3) rearrange bm sq. stick on a fixed beam (only_you)**
  ⇒ ~3sec (dep. on intt) (in stereo mode w/GS)
- (4) scan required beams every time after each pulse sequence completed
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- (5) raw I/Q time series analysis
  → mpinc(min. IPP〜1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough







Stereo Operations

For a standard 1 min scan each of the 16 beams is formed once a minute

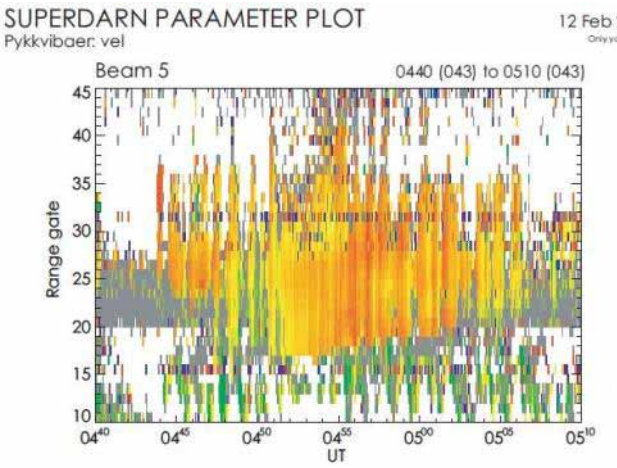
If a single beam is fixed then the temporal resolution of that beam will be 3 s

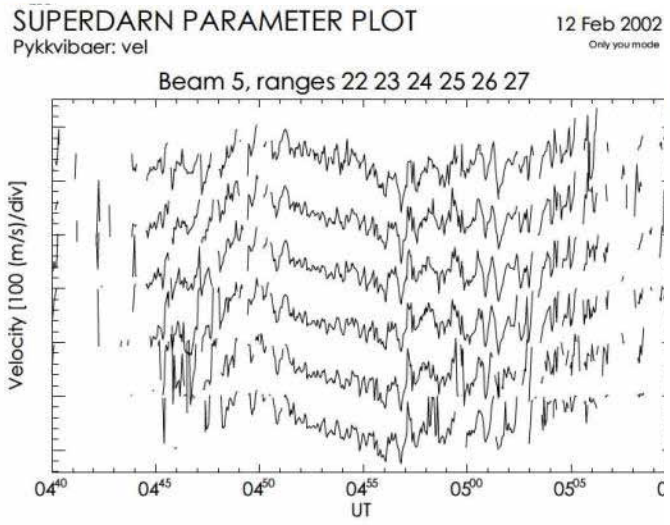
If the radar is Stereo then one channel can camp on a single beam whilst the other performs a full scan

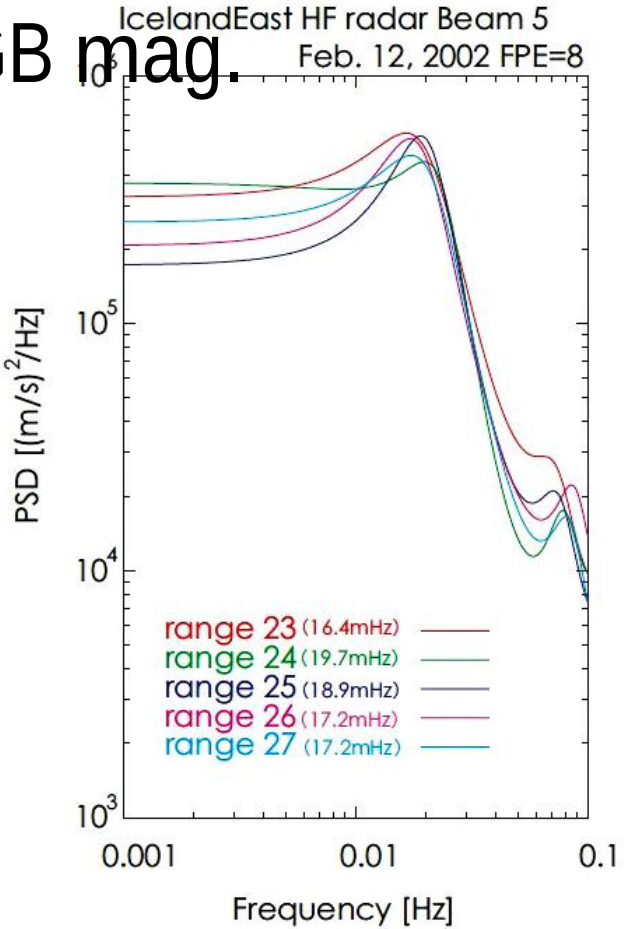
From SD tutorial 2010 @NIPR by Dr. A. Grocott

Higher temporal resolution (3)

- Shinkai, PhD thesis:
- SD – only_you mode (fixed bm intt=3 sec in one of stereo ch, the other ch: global scan (1min resol.)) compared with Geotail MGF and GB mag.
- Detect Pc3-4.







Higher temporal resolution (4)

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- (2) rearrange bm sq w/camping beams with global scan
  ⇒ ~6sec (intt=3s)
- (3) rearrange bm sq. stick on a fixed beam (only_you)
  ⇒ ~3sec (dep. on intt) (in stereo mode w/GS)
- **(4) scan required beams every time after each pulse sequence completed**
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- (5) raw I/Q time series analysis
  → mpinc(min. IPP〜1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough

Instead of being stuck on a single beam for integration,
why not switch beams after every pulse sequence!?!

1st pulse seq: beam 5 (~0.1sec)
2nd pulse seq: beam 6 (~0.1sec)
3rd pulse seq: beam 7
4th pulse seq: beam 8
5th pulse seq: beam 9
6th pulse seq: beam 10 (~0.1sec)
(this beam scan sequence takes only ~0.6sec)

and then repeat this beam sequence (w/ Tx freq fixed (no fclr)).

If echo power or S/N ratio for ranges of interest enough high, and if CRI (cross range interference) is enough low, smaller nave (number of integration for each beam) is sufficient to get meaningful and reliable physical parameters.
At least fitacf algorithem will work well in case of at least nave>=3.

→2-D Vel/E field for bm 5-10 can be obtained every ~1.8sec!
(2-D 16bm global field every ~5sec.) (in case of nave=3)
Theoretically possible every ~0.1sec for 1-D Vel/E, but takes more for Width essentially.
If fitted results are not preferable, just increase *nave* later using recorded *IQdat* to get more stable solution in offline process if you like.

September 2009 NIPR conjugate aurora campaign

Optical all-sky TV camera (ASC) at Tjornes in Iceland (~30Hz) under FOV of CUTLASS Iceland East radar.
(installed by Keisuke@UEC and Tetsuo Motoba @ NIPR)

Iceland East Stereo CUTLASS radar:

chA: conventional camping beam mode (mono myopic):

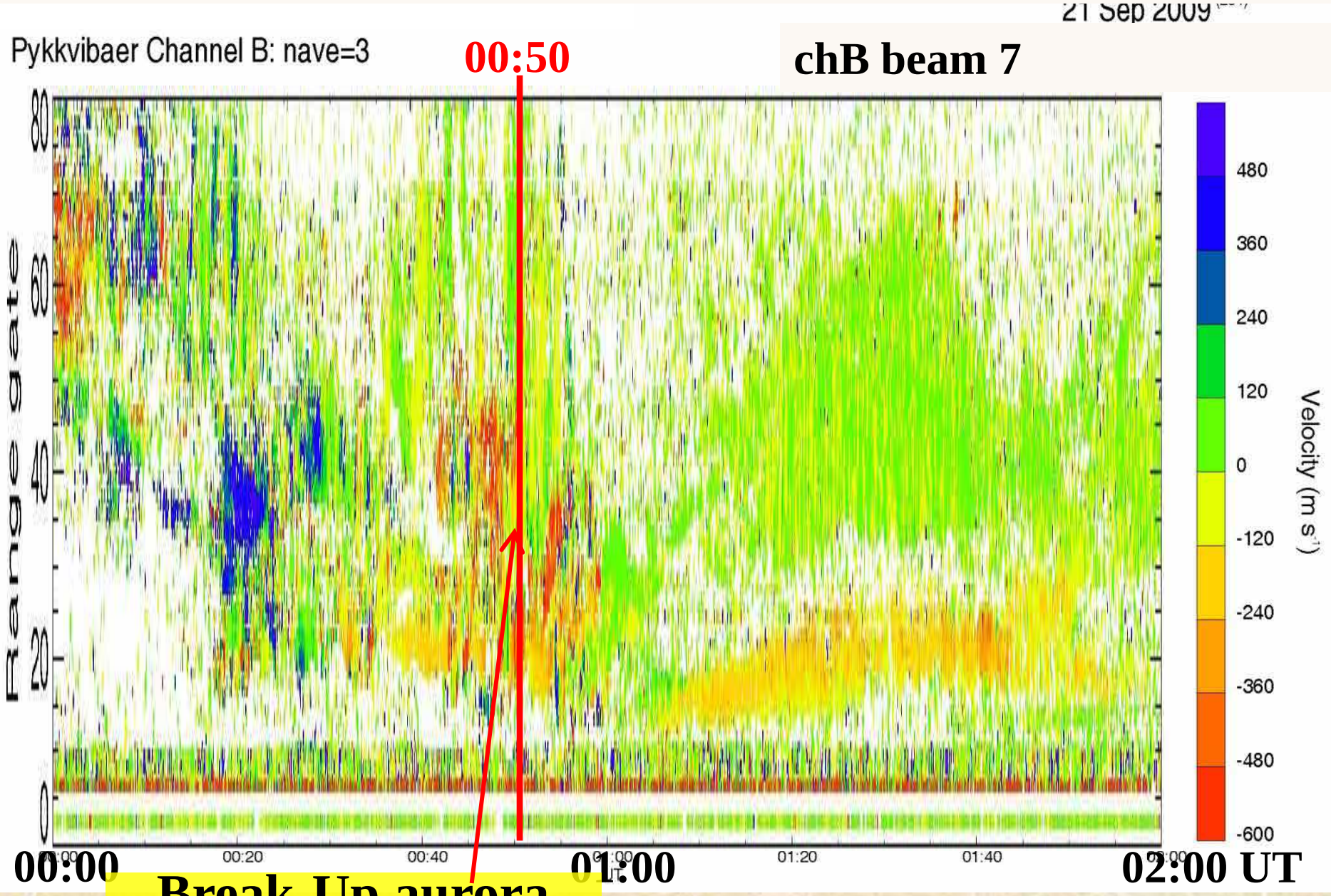
bm: 5, 7, 6, 7, 8, 7, 9, 7, 10, 7
intt: ~2sec (~1.8sec)
rsep=15km, first range=15km, nrang=240 (15-3600km)
→ global 2-D image every 20 sec AND
4-sec temp. resol. data along beam 7 (only)

chB: new operation mode ("BeamScanInIntt")

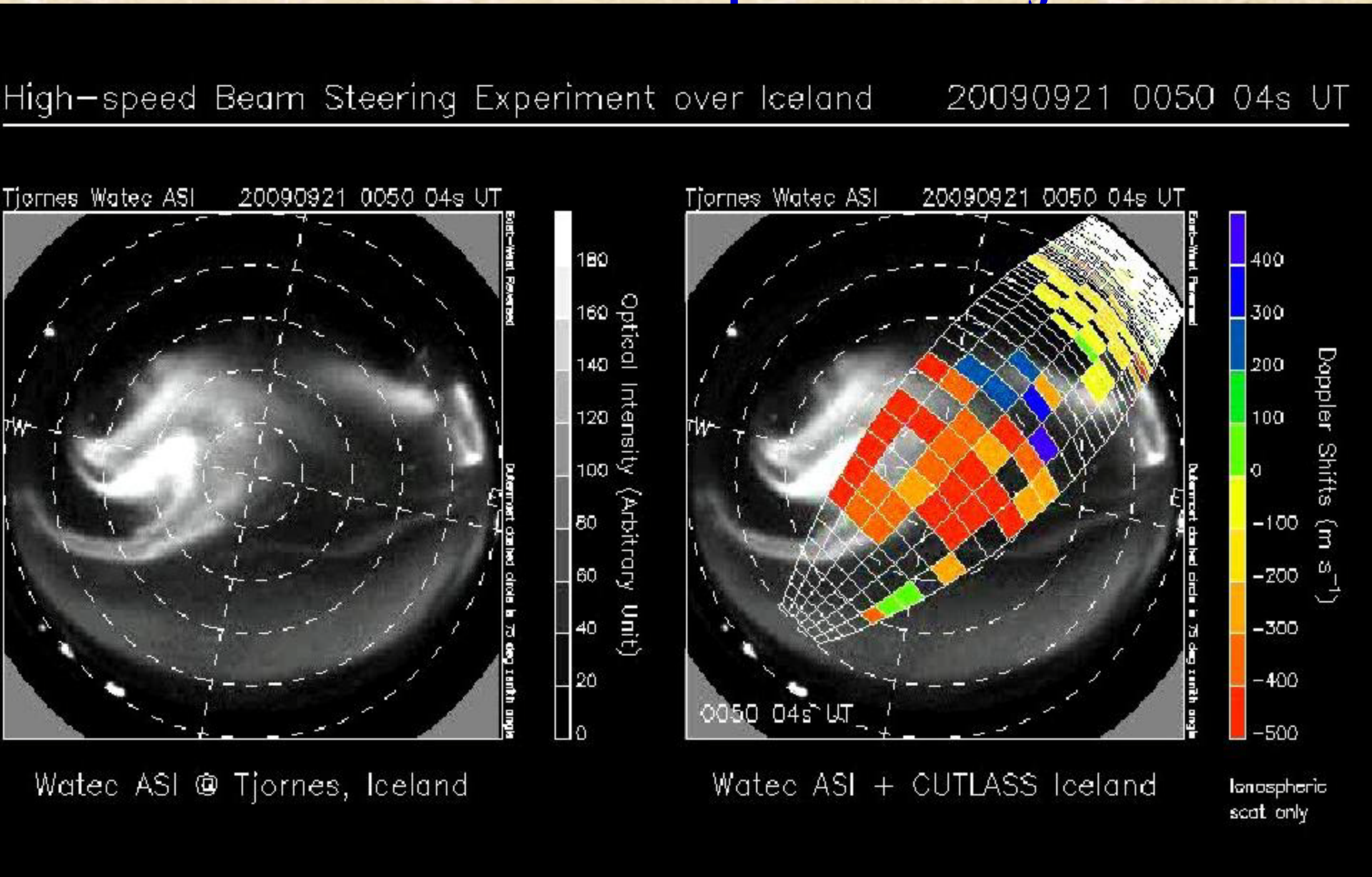
bm: 5~10 (6beams): change every pulse sequence!!
rsep=frang=15km, nrang=240 (15-3600km)*
(*important to correctly evaluate CRI for any ranges of interest!)
→ chA intt ends when chB 3 beam scan finishes.
i.e., nave for chA = always 6x3=18.
nave for each beam in chB = 3
→gloabl 2-D Vel/E field every 1.8sec!!!

IQ data obtained: for offline analysis,
any rawacf/fitacf can be re-made.
nave can be selected at any value later...

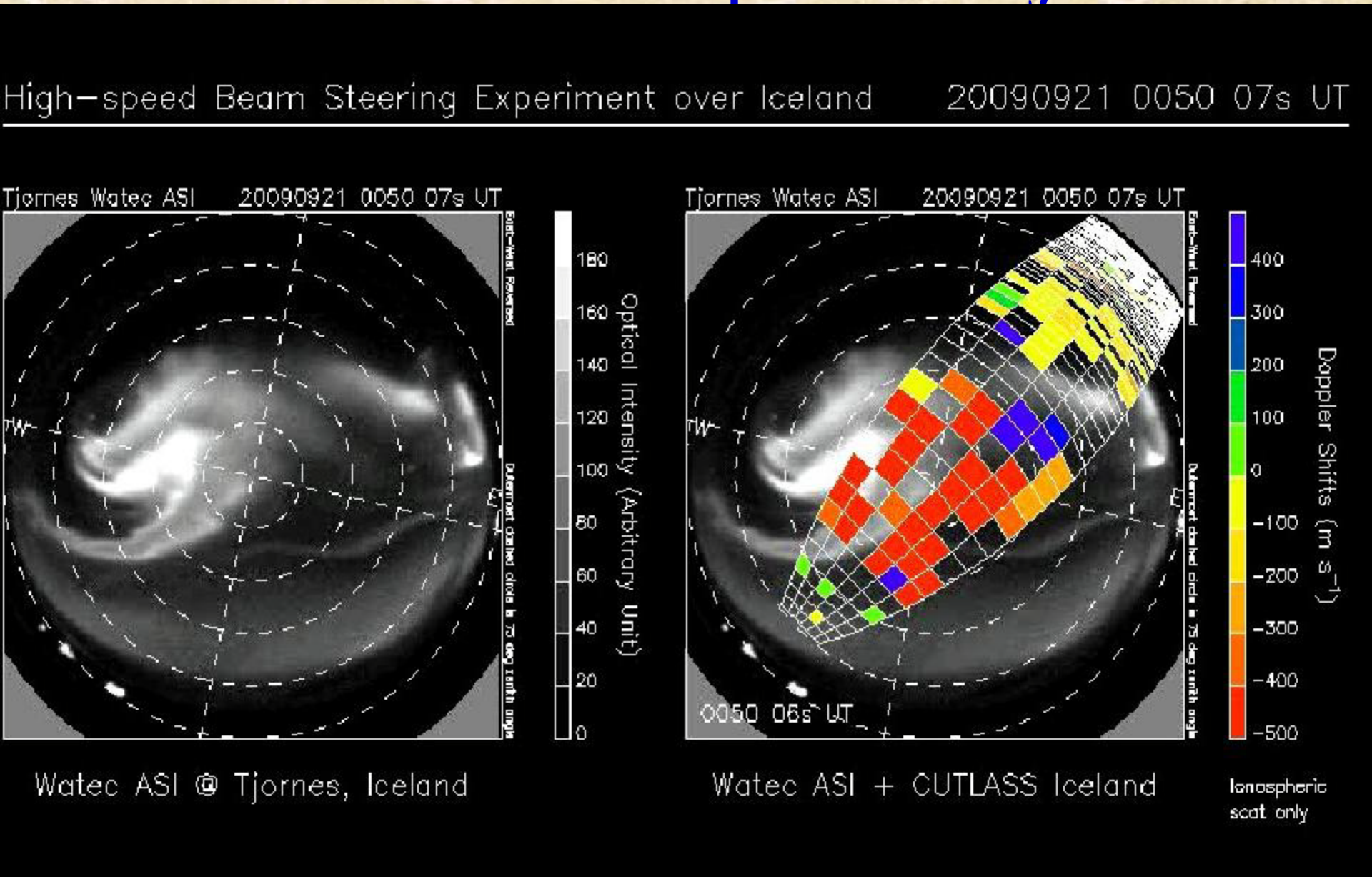
~2 sec temp. resol. for a single beam 7



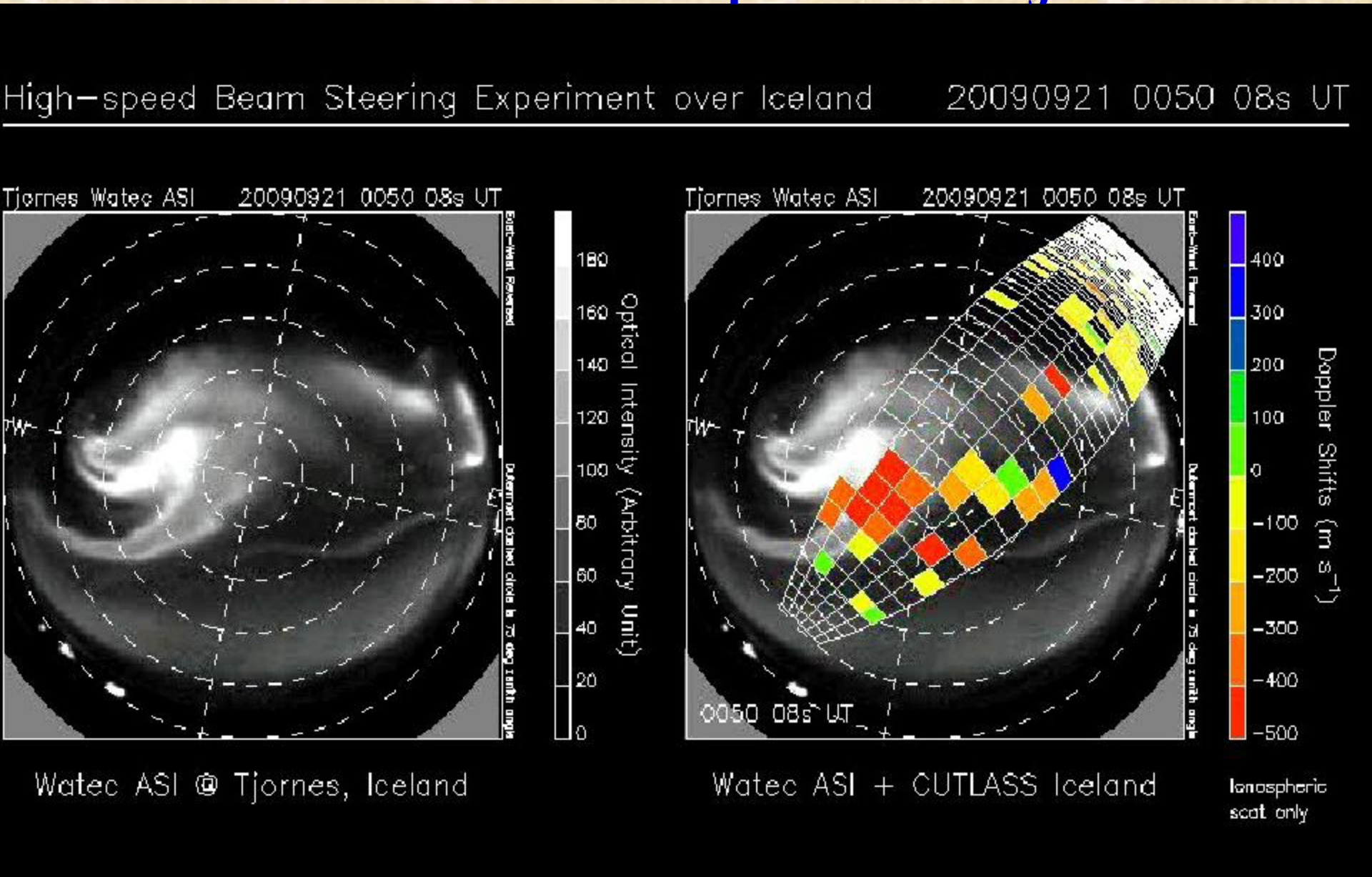
Active aurora assoc. with substorm breakup over Tjornes



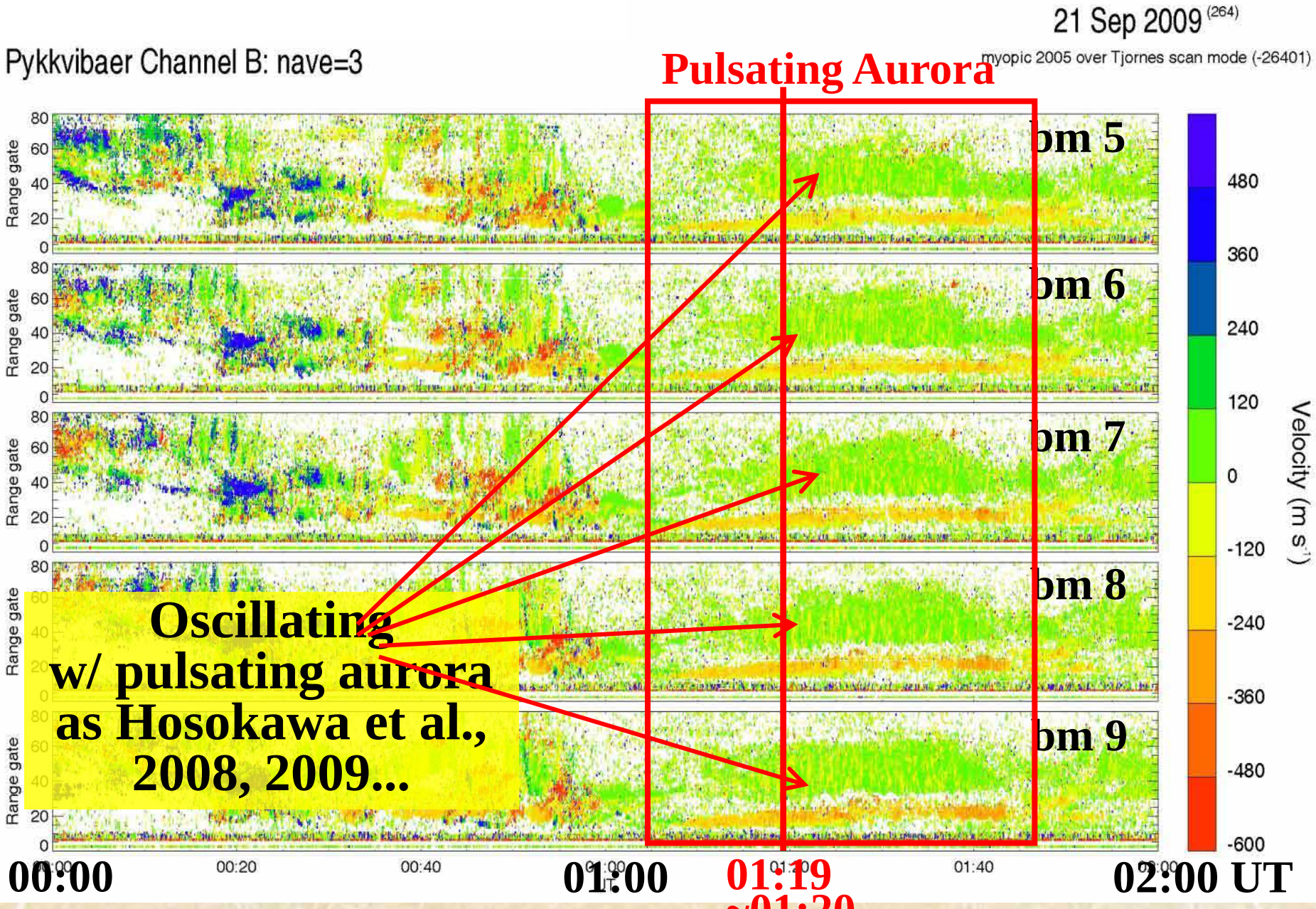
Active aurora assoc. with substorm breakup over Tjornes



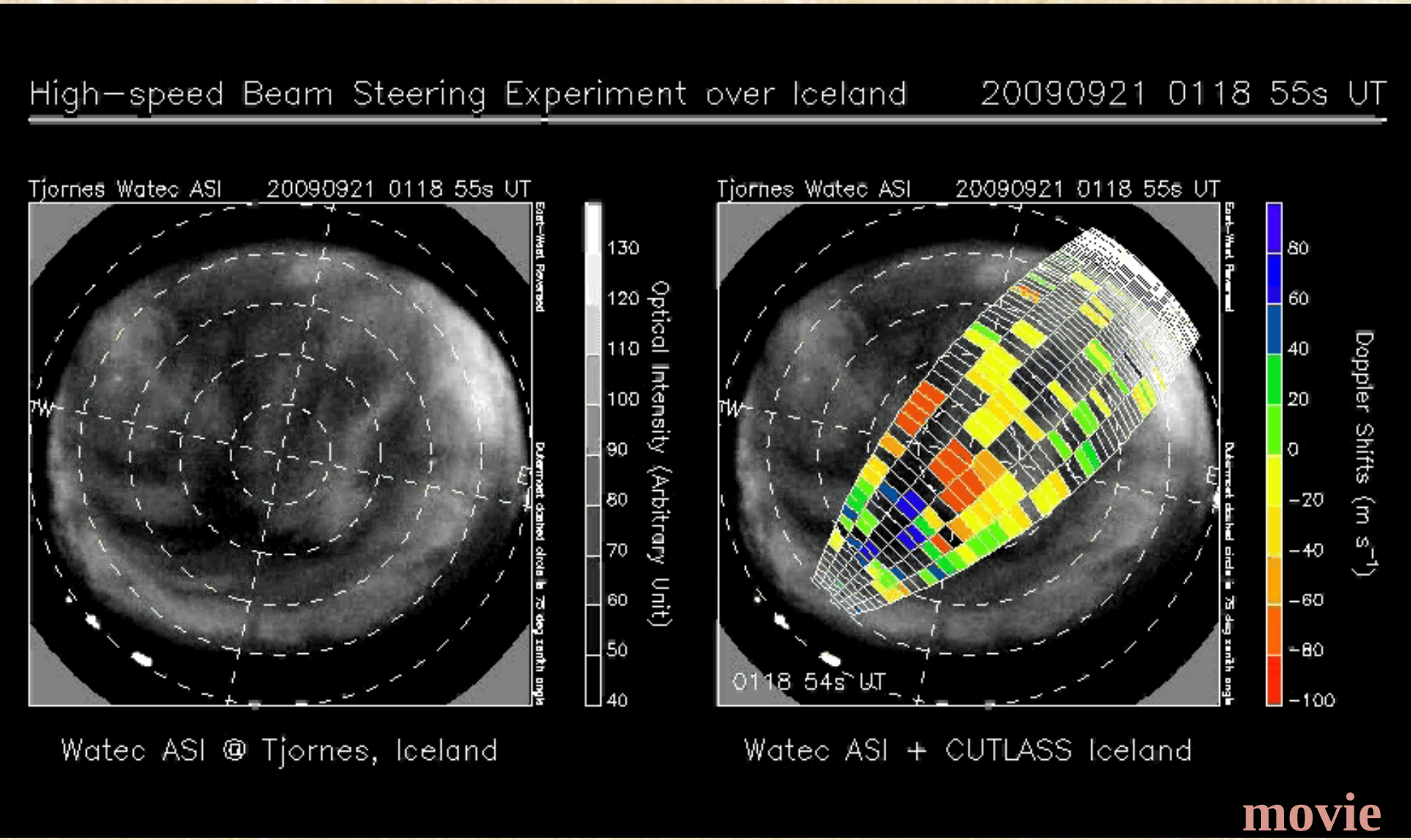
Active aurora assoc. with substorm breakup over Tjornes



~2 sec temp. resol. for all observed beams!

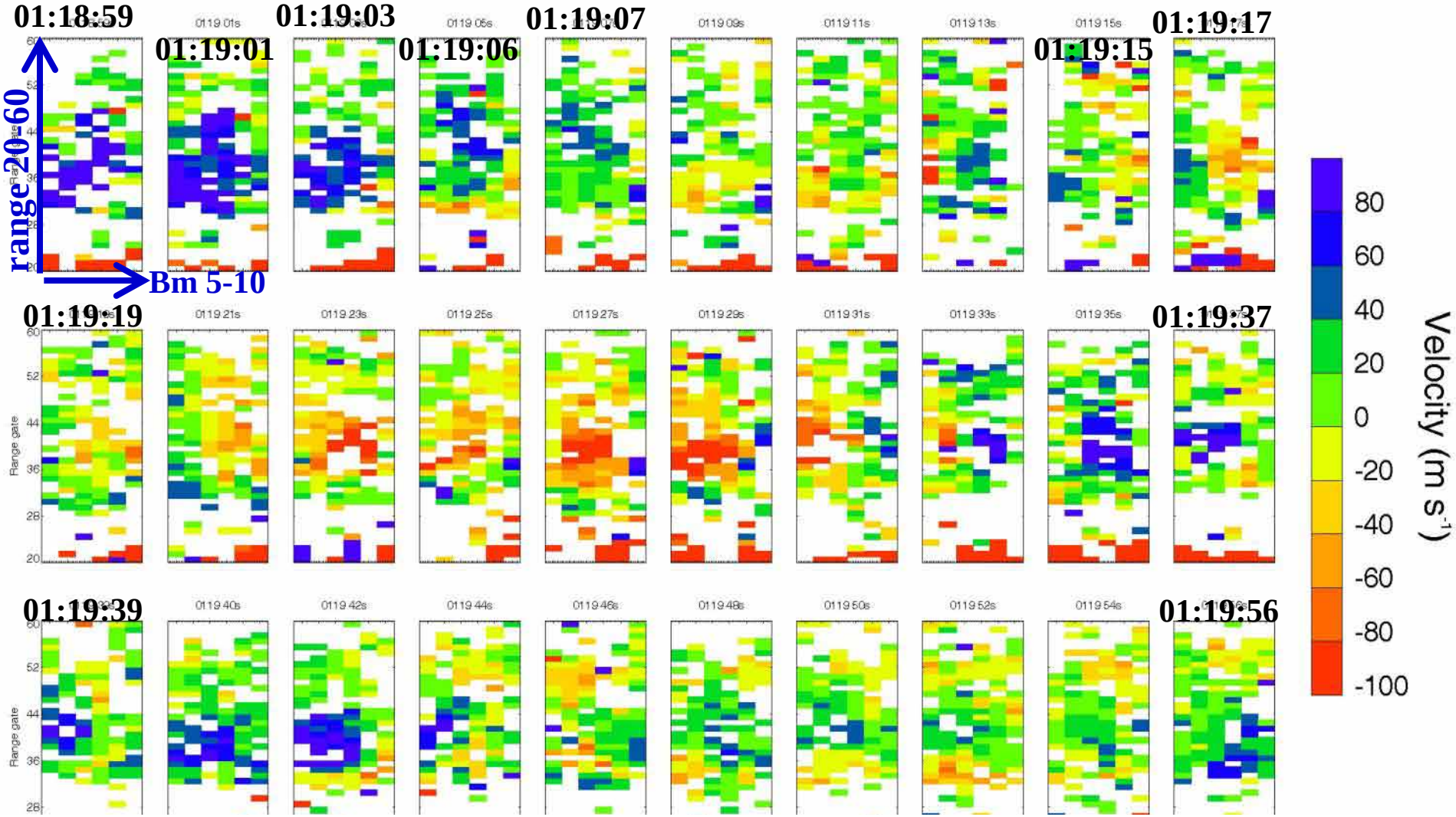


2-D Vel field evolution assoc. with pulsating aurora during 1-min interval with ~2 sec temp. resolution



movie

2-D Vel field evolution assoc. with pulsating aurora during 1-min interval with ~2 sec temp. resolution



If 1 beam is enough, every ~0.3 sec temp resol. Achieved!
Possible but V_err must be evaluated. – Pasha!

Higher temporal resolution (5)

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
- (2) rearrange bm sq w/camping beams with global scan
  ⇒ ~6sec (intt=3s)
- (3) rearrange bm sq. stick on a fixed beam (only_you)
  ⇒ ~3sec (dep. on intt) (in stereo mode w/GS)
- (4) scan required beams every time after each pulse sequence completed
  ⇒ resol. ≧0.1s x # beams x # of averaging
  ⇒ resol. ~0.1s if bm fixed & high SN & no CRN
- **(5) raw I/Q time series analysis**
  → mpinc(min. IPP～1.2msec)≦res＜0.1sec
  if CRN are negligible and S/N is high enough

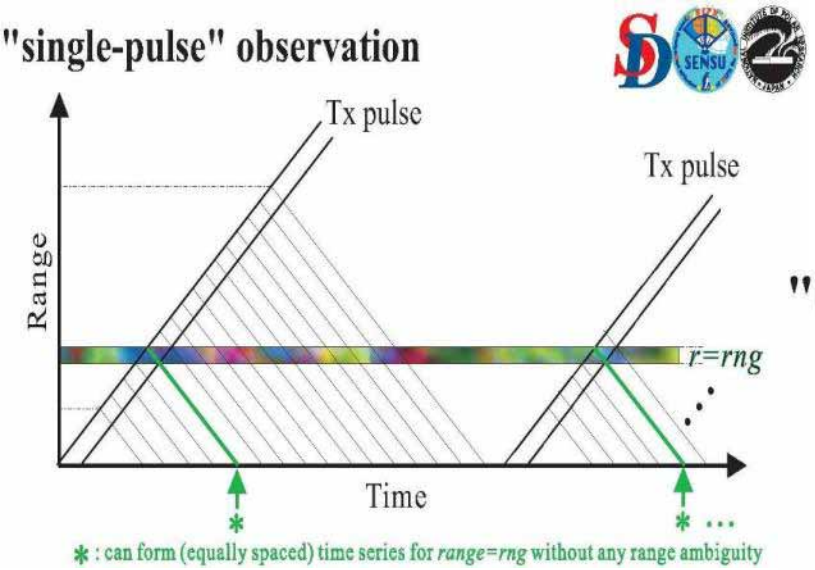
Higher temporal resolution (5)

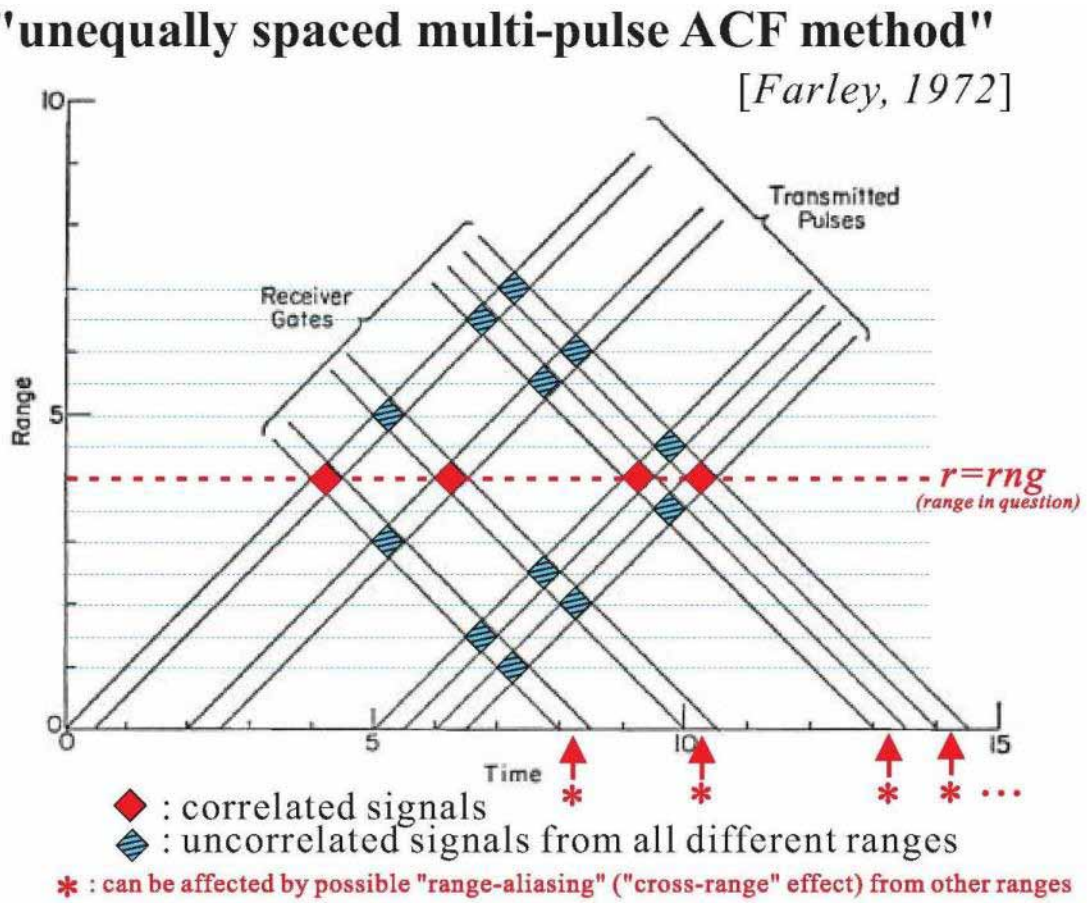
(5) raw I/Q time series analysis - directly analyze temporal variation of (unevenly sampled) I/Q samples (in time domain) which are not affected much by cross range effect.

⇒ Threshold must be clearly understood⇒Pasha!

⇒ If it is good enough to obtain just one examples of EMIC, it will be possible, but it will be not easy to monitor them always (dep. on SN & CRI).

Raw I/Q time series analysis





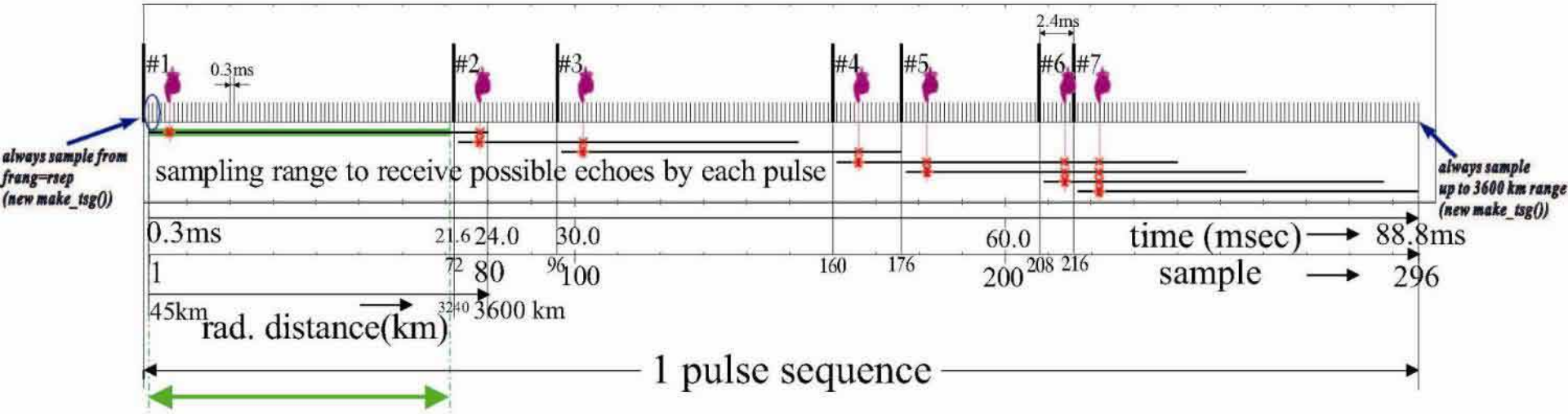
=> *Is "raw time series analysis" possible?!?*

SuperDARN pulse sequence

最近のSuperDARN multi-pulse

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



just a "single-pulse" observation!!

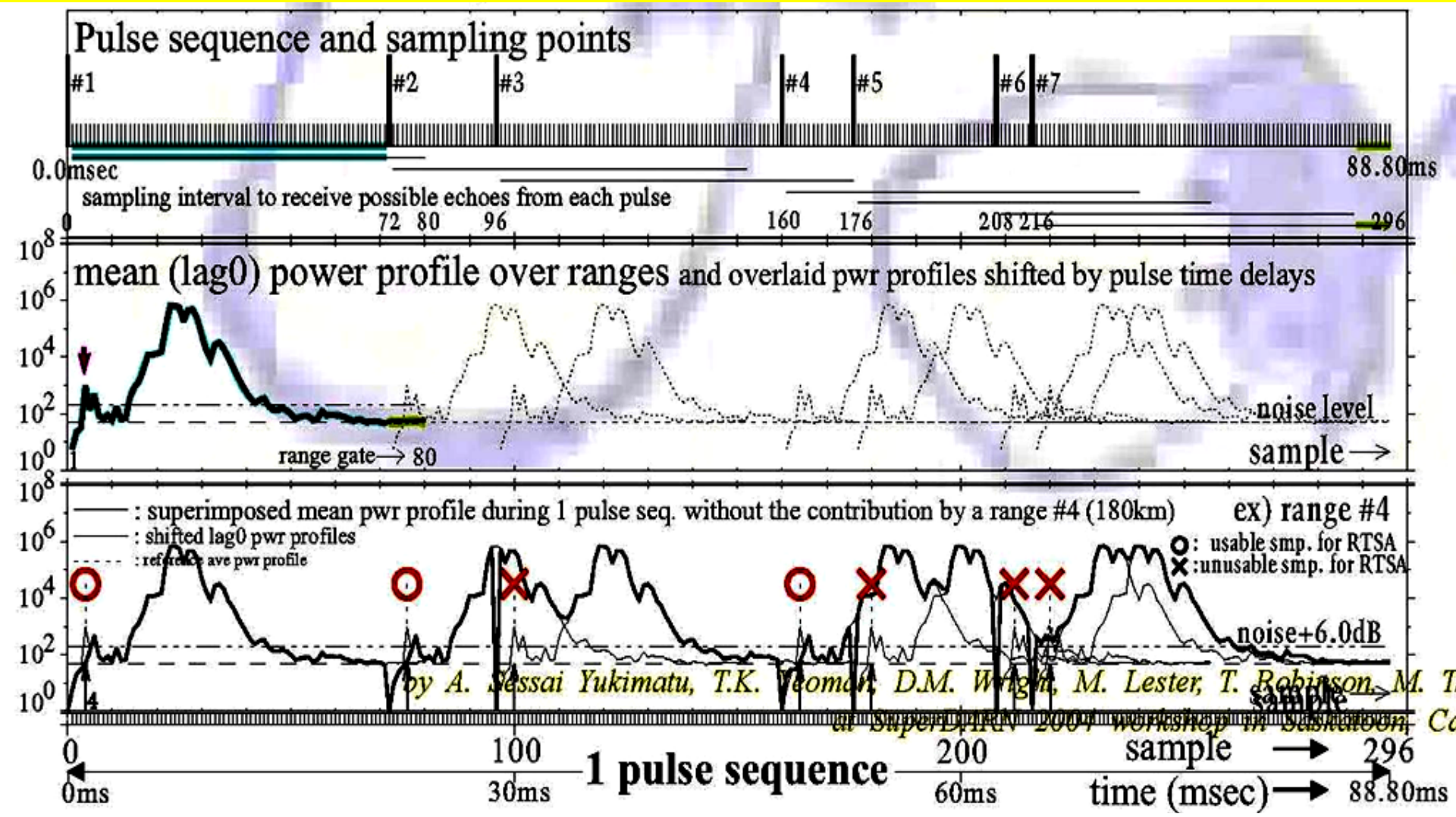
i.e., at least ~10 Hz sampling raw time series analysis are always possible! (for 45~3195 km ranges in this case)
(though 10 Hz is not enough for most studies due to freq-aliasing)

: 7samples for 270 km ramge (range #6) as an example.
All of these except the 1st sample can be a mixture of echoes from the range in question (range #6) and from other ranges by prev. pulses.

CRI can be estimated using IQ samples between 1st and 2nd Tx pulses,

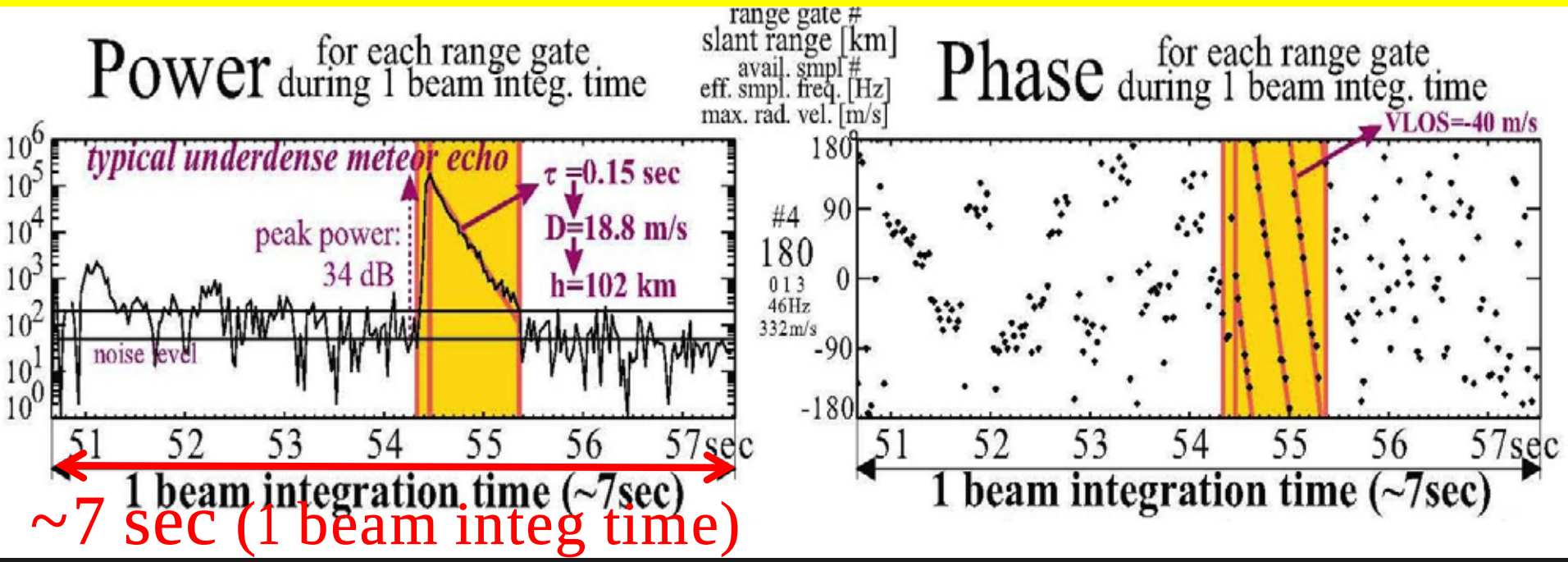
Raw I/Q time series analysis

Reconstruct (unequally sampled) raw IQ time series for each range gate, not affected much by cross range noises by checking lag0-pwr range profile.
⇒ Very high time resolution (>10Hz, ~400Hz) time series analysis can be performed.



IQ raw time series analysis (TMS)

Reconstructed raw time series for a range gate (Power and Phase)
during 1 beam integration time of ~7 sec



~7 sec (1 beam integ time)

ACF(frequency domain)観測と平行して、
全IQ samplesを記録し、
cross range effectのないsamplesのみ抽出し、
時系列(time domain)解析も可能とした。
(TMS mode、Yukimatu & Tsutsumi, GRL, 2002)

Higher temporal resolution for EMIC?

- (1) shorter beam integration time (w/ bm sq)
  ⇒too small intt -> SN w/CRN disappear, increase Verr
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  ⇒ ~6sec (intt=3s)
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  if CRN are negligible and S/N is high enough

Summary

- Twin radar operation – more flexible operation in hand! Tx sync. will possibly improve quality
- Interferometer reliability – important to be checked
- I-M mapping – P.P. detection using wider FOV data..
- ERG modes (inc. trigger method…)? – needs more debate and final decision...
- Higher temporal resolution mode?
  Depending on scientific target
  EMIC detection can be possible
  (but not continuous monitoring…)