SuperDARN
高時間分解能二次元電場観測

A SuperDARN high temporal resolution two-dimensional electric field observation

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Scientific objectives

1) dynamics of **large scale convection**
2) dynamics of **meso-/small- scale convection**
   including FTEs/TCVs/OCB/aurora/patches etc.
3) **substorm/storm/sub-auroral** studies **SAPS**
4) FTE/**reconnection**/reconnection rates
5) **FAC**s
6) **MHD waves**
7) **Inner magnentosphere**
8) D/E/F region **irregularities (FAIs)** (radar aurora)
9) **atmospheric waves** (TIDs, tides, gravity waves)
10) **neutral winds** 11) **PMSE/MSE**
12) **Sea** surface waves 13)...

higher spatial/temporal resolution?

SDI/FDI/pulse coding/imaging/higher resolution...

- SuperDARNは元々広域･大域的観測が主目的であった為、レンジ方向の空間分解能は、15,30,45kmであり、研究目的によっては、荒すぎる場合が少なくない。
- 時間分解能も、研究目的によってはより高い方が望ましい。
- 時間分解能の向上の為には、前々項の生IQ時系列観測手法を応用することで、SN比の十分高い、またrange aliasing（cross range effect）の少ないエコーについては、積分時間を少なく、又は無にして、高い時間分解能を得ることも可能。
- 方位角(ビーム)方向の分解能の向上には、各アンテナ出力を記録して、任意のビームの形成を可能にするimaging技術で、大幅に向上することが可能な筈で、最近一部でその実現に向けた動きがある。
- 距離方向の分解能の向上の為には、ビーム方向のimagingと原理は同じである、周波数領域干渉計（FDI）やパルスを分割するphase coding、oversampling等の方法が考えられ、試験が行われている。

Required resolution

- Phenomena:
  - spatial scale : <1 km ~ >1000 km
  - temporal scale : <1 sec ~ >10 min
- Required resolution:
  - spatial scale : <~1 km
  - temporal scale : <~1 sec
- Convectional SuperDARN:
  - spatial scale : >=15km (radial)
    ⇒ <~1 km if possible…?
  - temporal scale : ~1sec(1-D) & ~1min (2-D)
    ⇒ <~1 sec (2-D) if possible…?

Semeter et al., JASTP, 2009

PolerFlar IS Radar (AMISER)

3-D Ne : ~15 sec resol.

2-D E-field - ~2min resol.

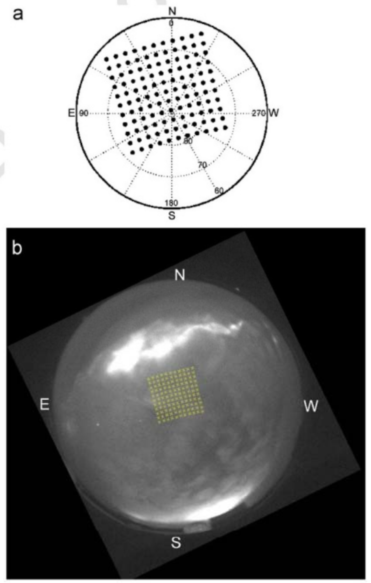


Fig. 1. (a) PFISR beam positions used in this experiment, depicted in a horizon-based polar coordinate system. (b) Beam positions superimposed on an image recorded with the collocated all-sky camera.

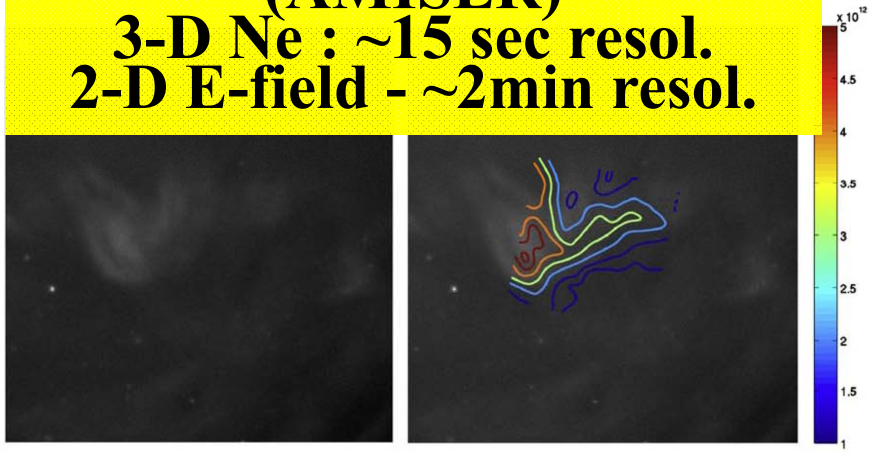


Fig. 3. (a) An average auroral image corresponding to the period shown in Fig. 2. The image is a cropped version of the all-sky image shown in Fig. 1(b). (b) Same image overlain with contours of $\int \alpha N_e^2\, dr$, computed from PFISR measurements.

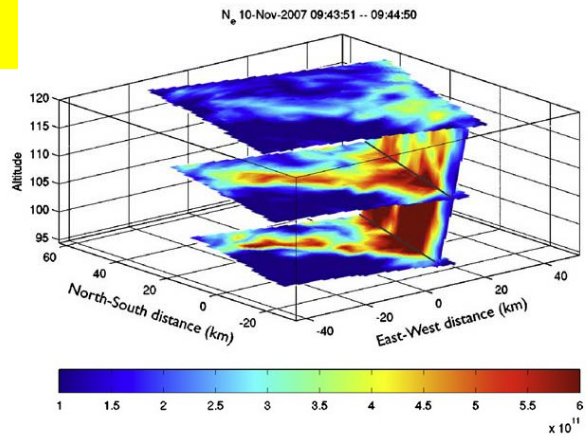
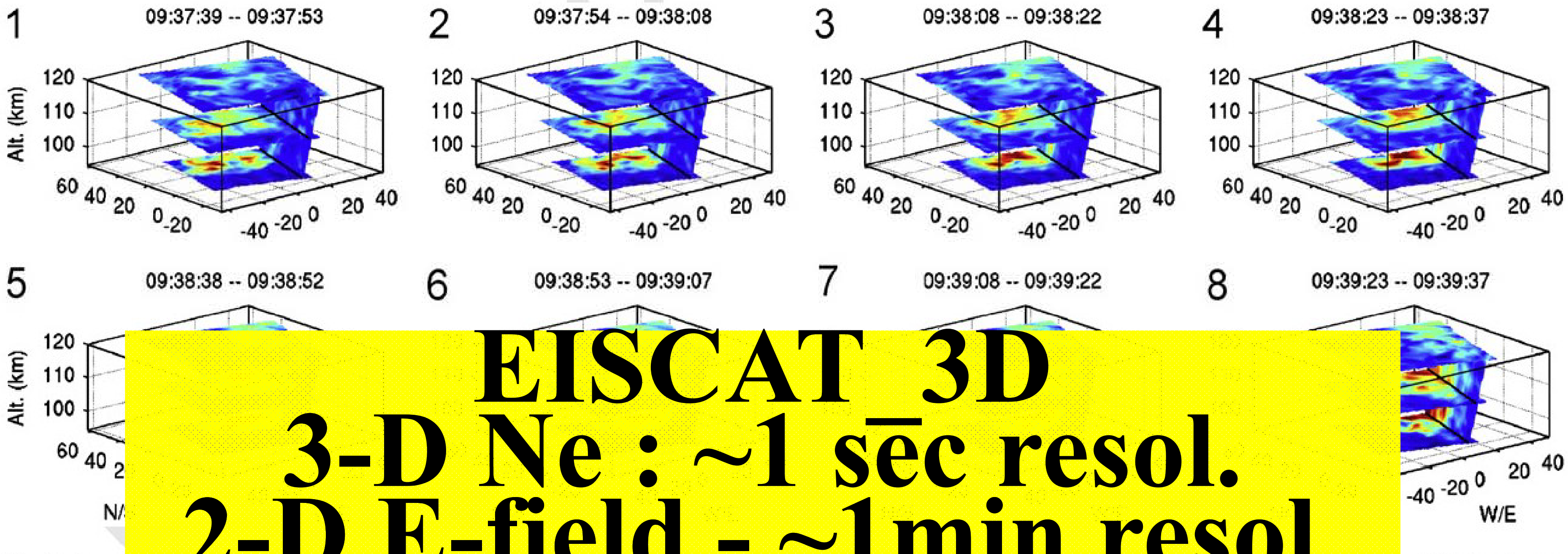


Fig. 2. Volumetric image of E-region on 10 November 2007, 09:43:51–09:44:50 UT. The image was produced by averaging 192 pulses-per-position. The horizontal cuts are at 100, 107, and 120 km. The structured density enhancement seen in the image was produced by auroral electron precipitation in the ~20 keV range.



EISCAT_3D

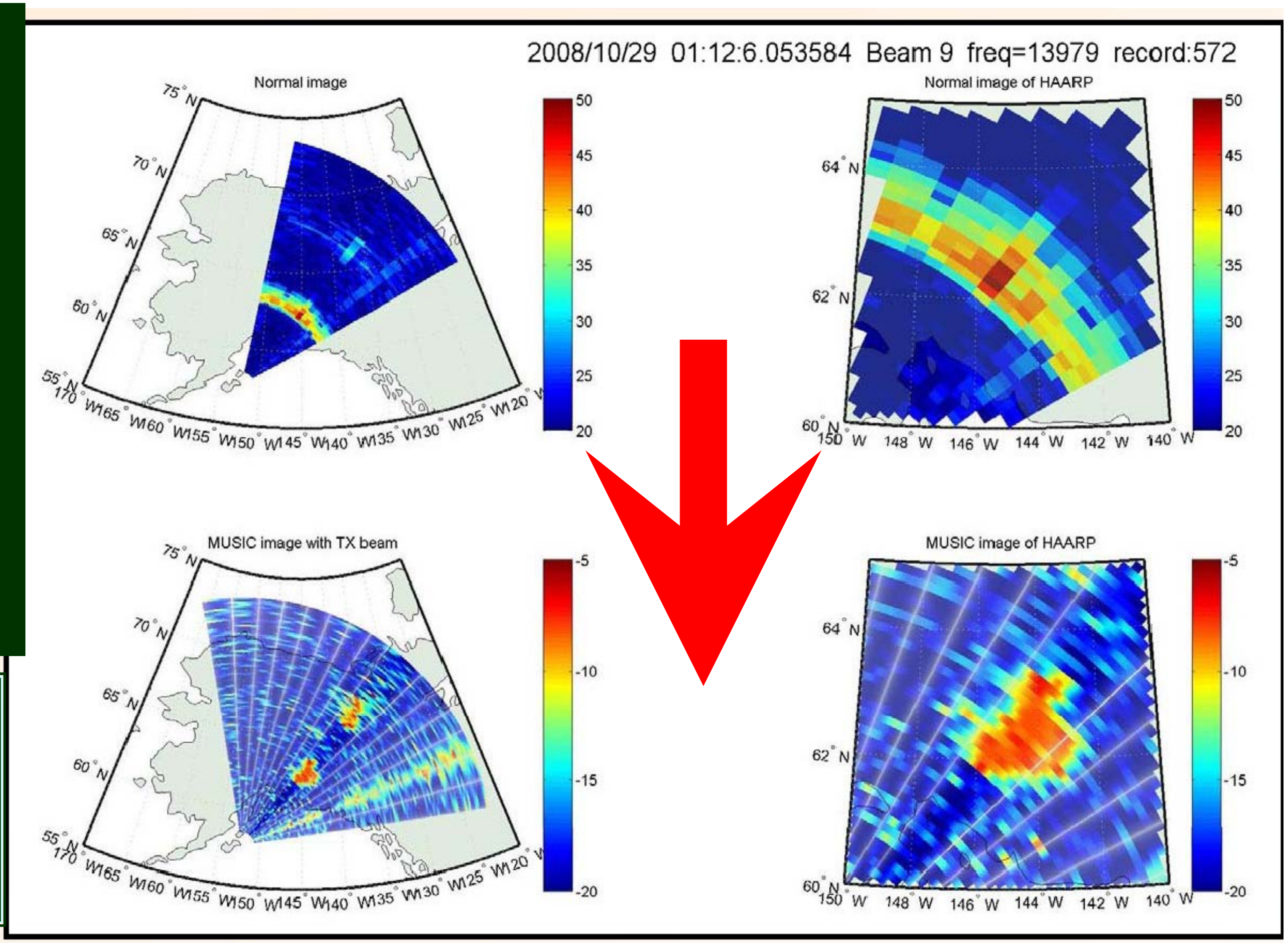
3-D Ne : ~1 sec resol.

2-D E-field - ~1min resol.

Fig. 7. Anot ... ~100-km (same color scale a...

SuperDARNレーダーのimagingレーダー化

各アンテナ出力を独立に取得し、adaptive beam formingによる方位角方向のimagingを実現。



SuperDARNのImaging radar化の効果

・1桁程度（15km⇒1km程度）高い空間分解能観測が可能に。新世代の観測が可能。
広域観測とsmall~middle scaleの同時観測が電離圏dynamics観測には不可欠。

・ステレオレーダー、及び高時間分解能生時系列取得解析手法との併用により、従来は分解が困難であった、光学オーロラ観測との比較によるオーロラ近傍の詳細な電場の時空間発展及び電磁圏ダイナミクスの研究、電離層不規則構造（FAI）の生成消滅過程の研究、PANSYレーダーとの共同研究様々な研究に応用が期待される。

SuperDARNレーダーの
時間分解能の向上

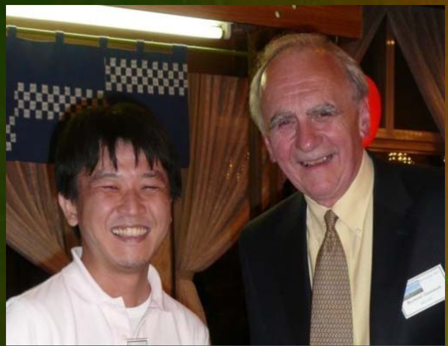
本目的:2-D電場観測の時間分解能向上

A few years ago...
K. Hosokawa showed about...

Electric Field Oscillation behind Pulsating Aurora

Simultaneous observations

with all-sky TV camera and SuperDARN in Iceland



○ K. Hosokawa[1] , A. Kadokura[2] , N. Sato[2]

S. E. Milan[3] , M. Lester[3] , G. Bjornsson[4] and T. Saemundsson[4]

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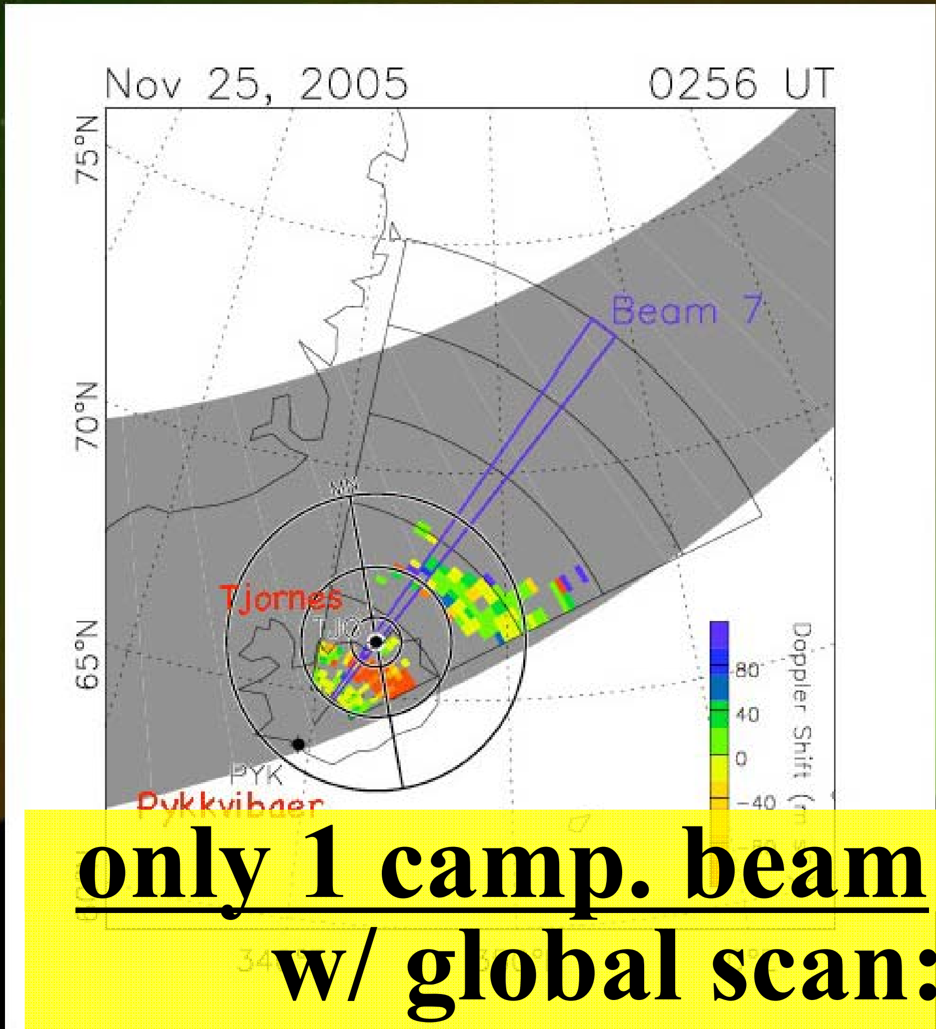
[4] Science Institute, University of Iceland

stereo myopic mode w/ NIPR ASC

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:

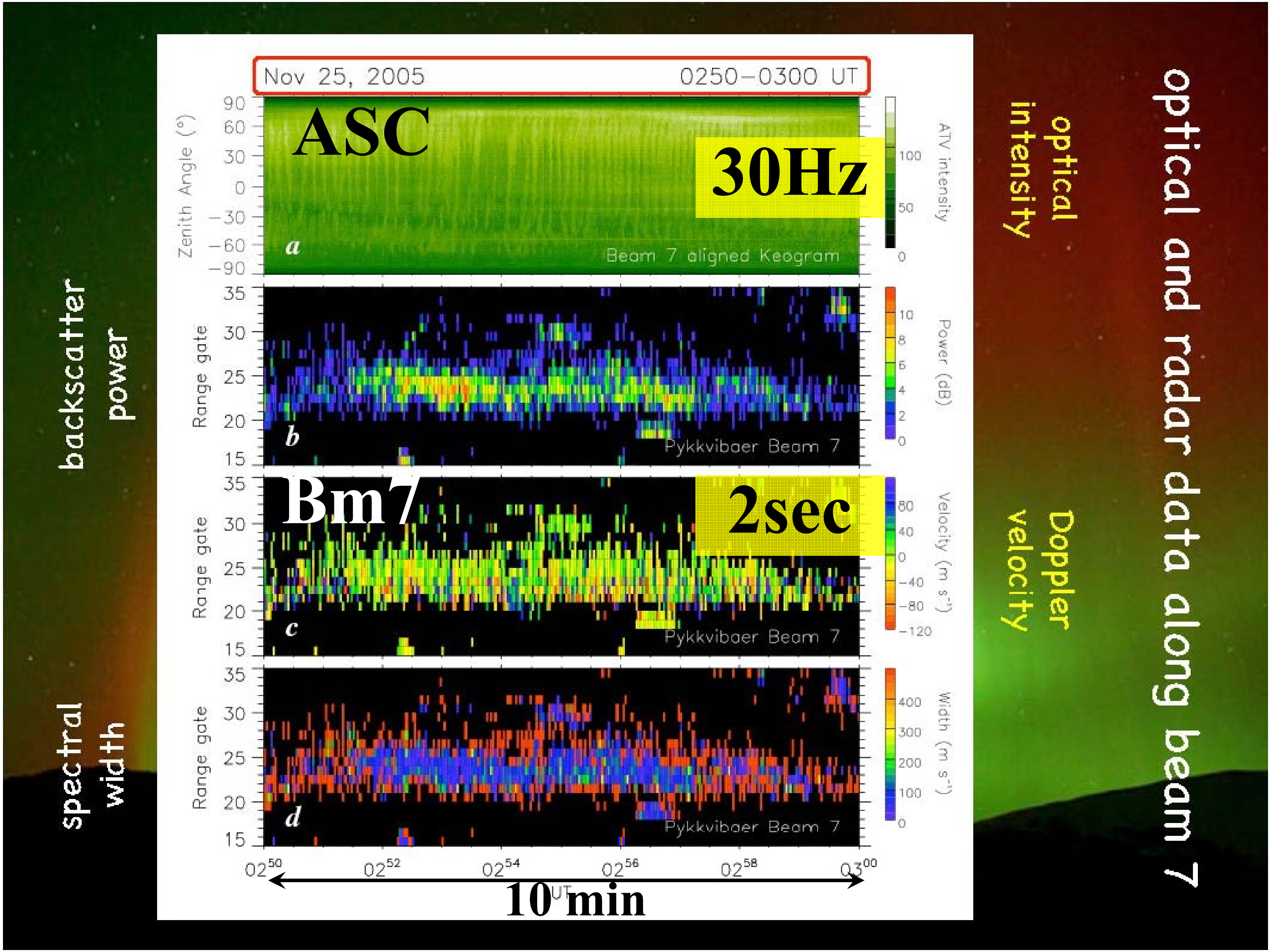
Tjornes (66.19 N, 17.93 W)

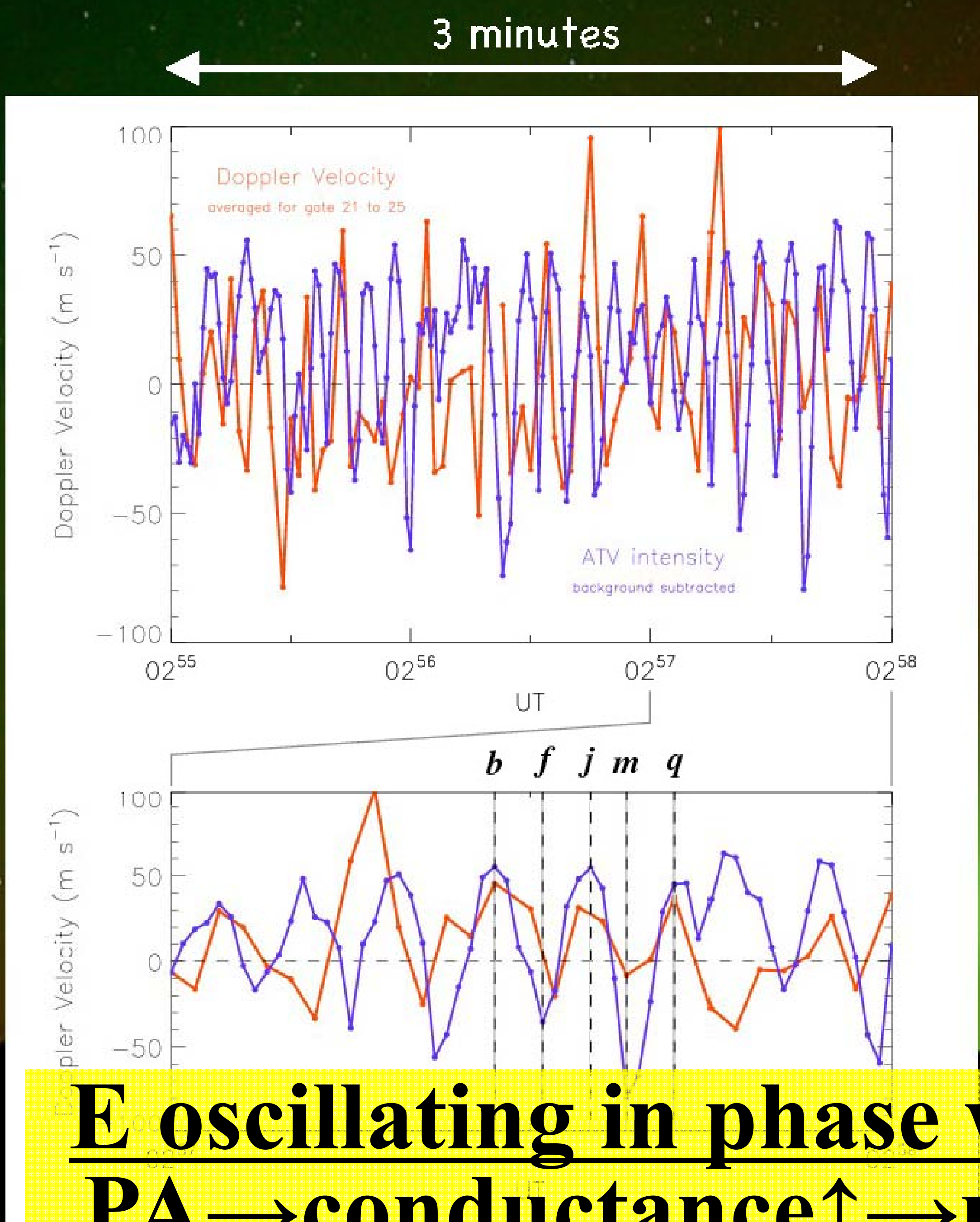
All-sky TV camera with I.I.

temporal resolution: 30 Hz

<u>only 1 camp. beam</u>: 2-sec temp. resol.

w/ global scan: ~30-sec resol.


optical and radar data along beam 7
Nov 25, 2005
0250–0300 UT
ASC
30Hz
Bm7
2sec
10 min
optical intensity
Doppler velocity
backscatter power
spectral width
Zenith Angle (°)
Beam 7 aligned Keogram
ATV intensity
Range gate
Pykkvibaer Beam 7
Power (dB)
Velocity (m s⁻¹)
Width (m s⁻¹)
UT

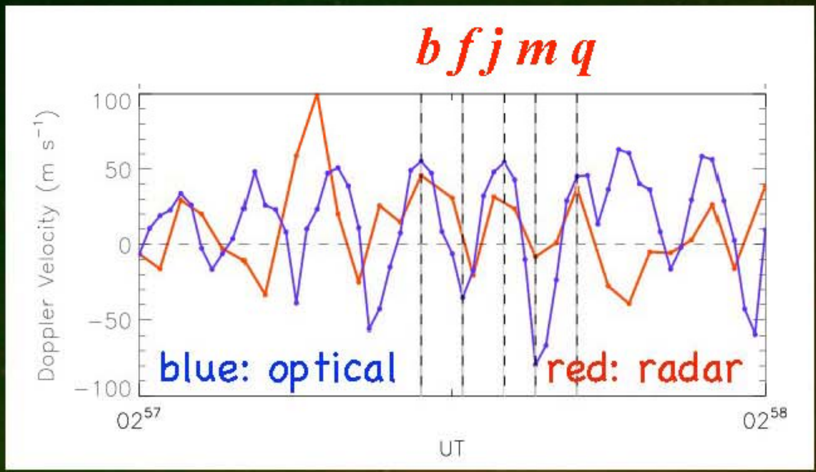


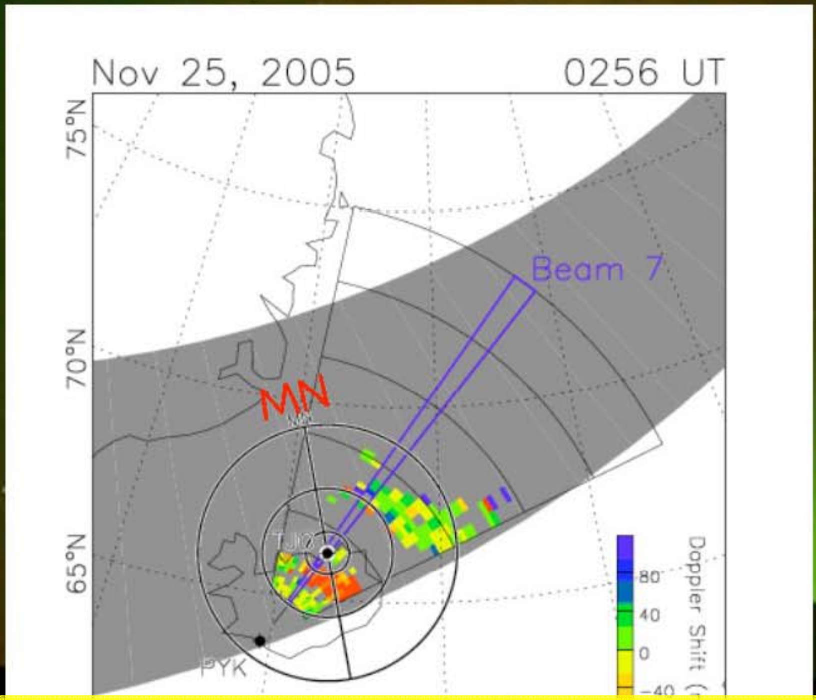
blue: optical pulsation
pulsating period: 8 s

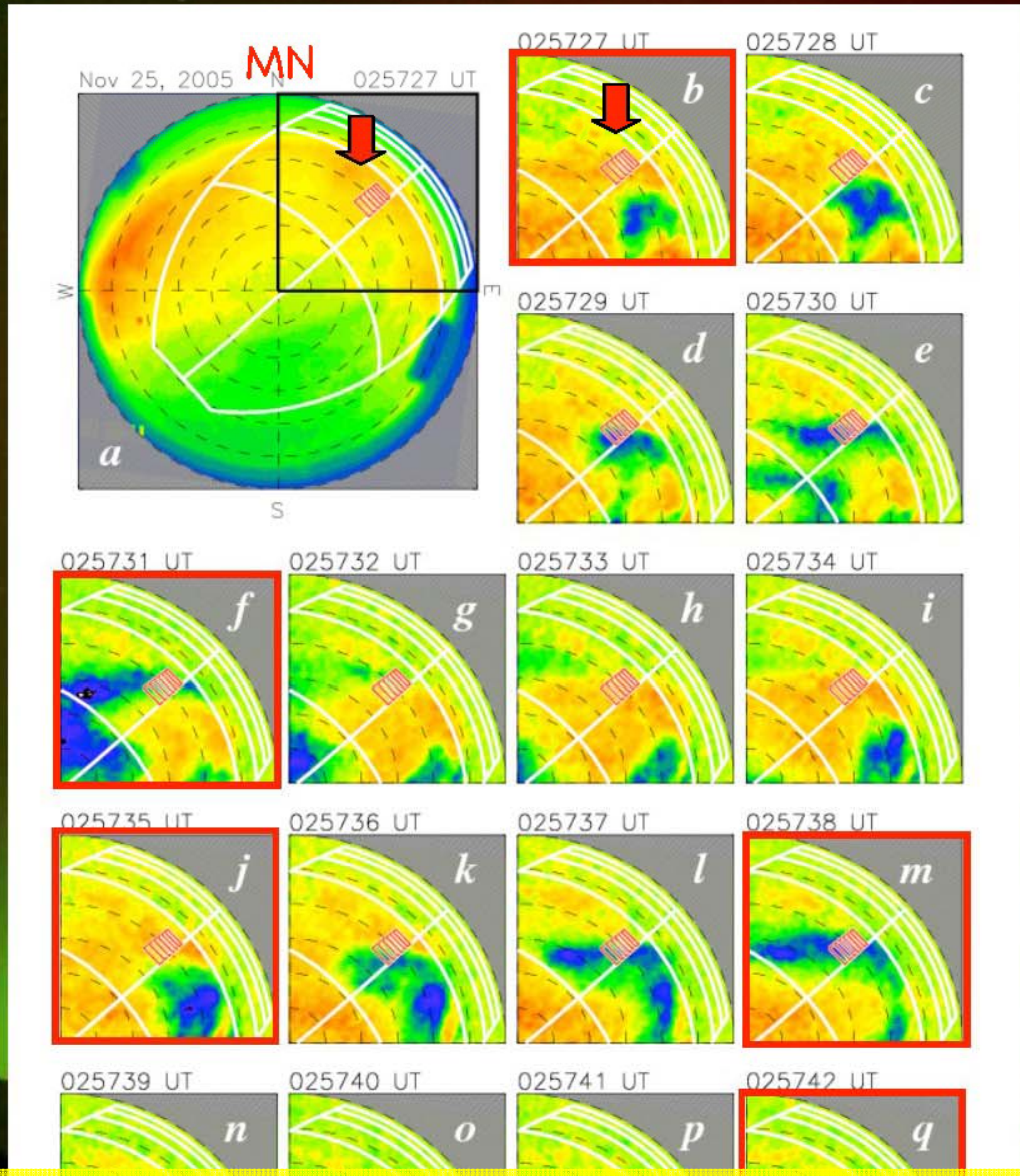
red: radar pulsation
pulsating period: 8 s
(amplitude 100 m s^{-1})

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

<u>E oscillating in phase w/ Puls. Aurora</u>
PA→conductance↑→polarization E?







only 1-D high temp. resol. obs. along a beam

→ 2-D Vel/E field variation unknown

Last year, Keisuke Hosokawa showed about...

Small-scale converging electric field structure

in the vicinity of breakup auroral arcs

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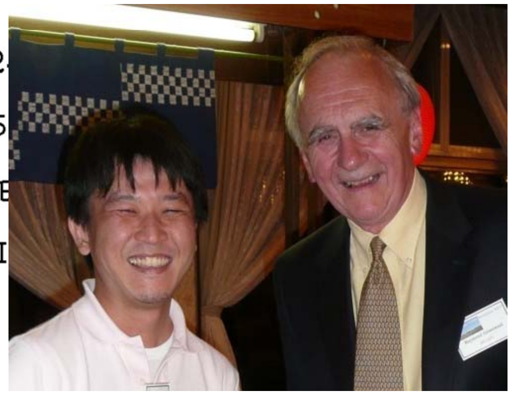
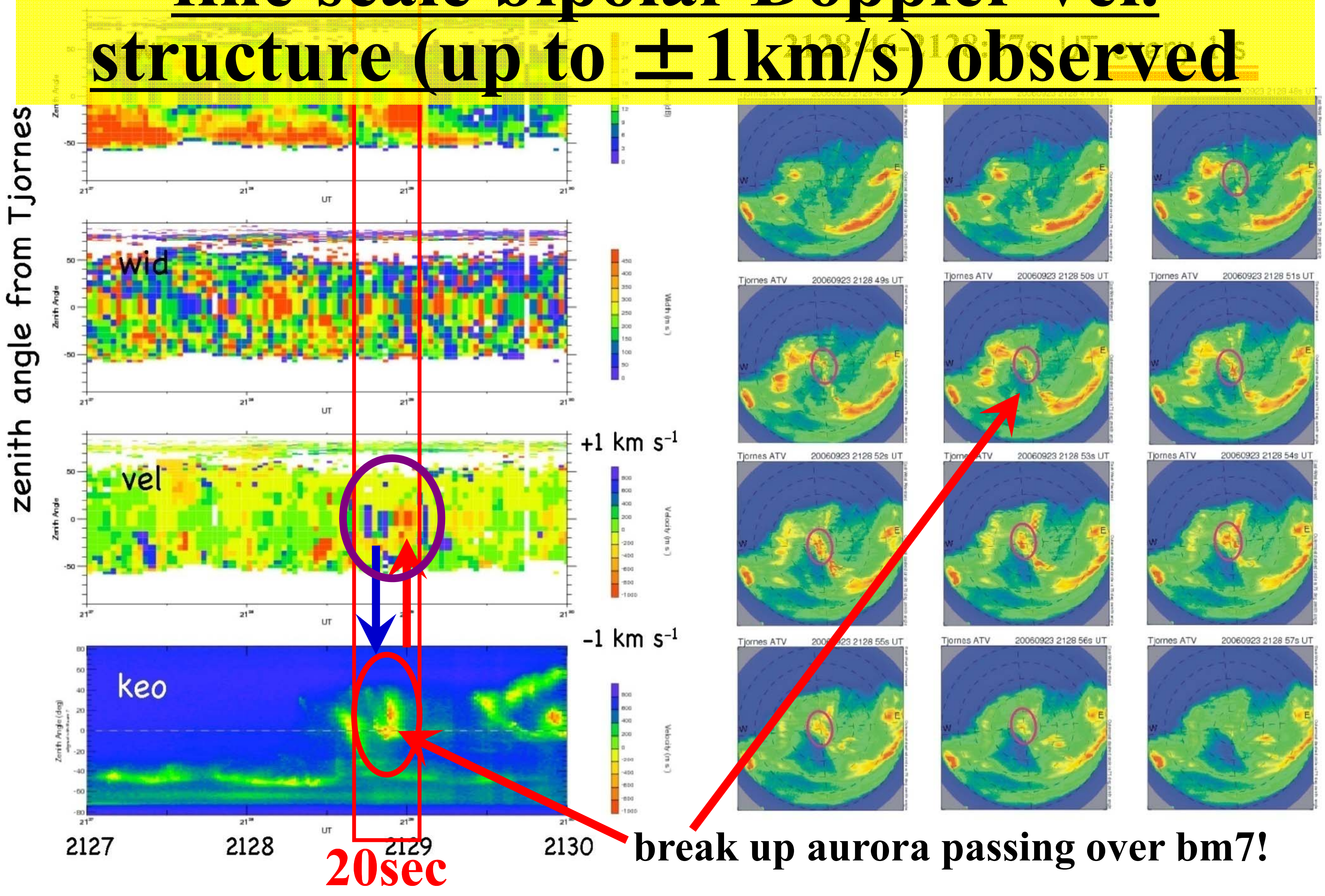
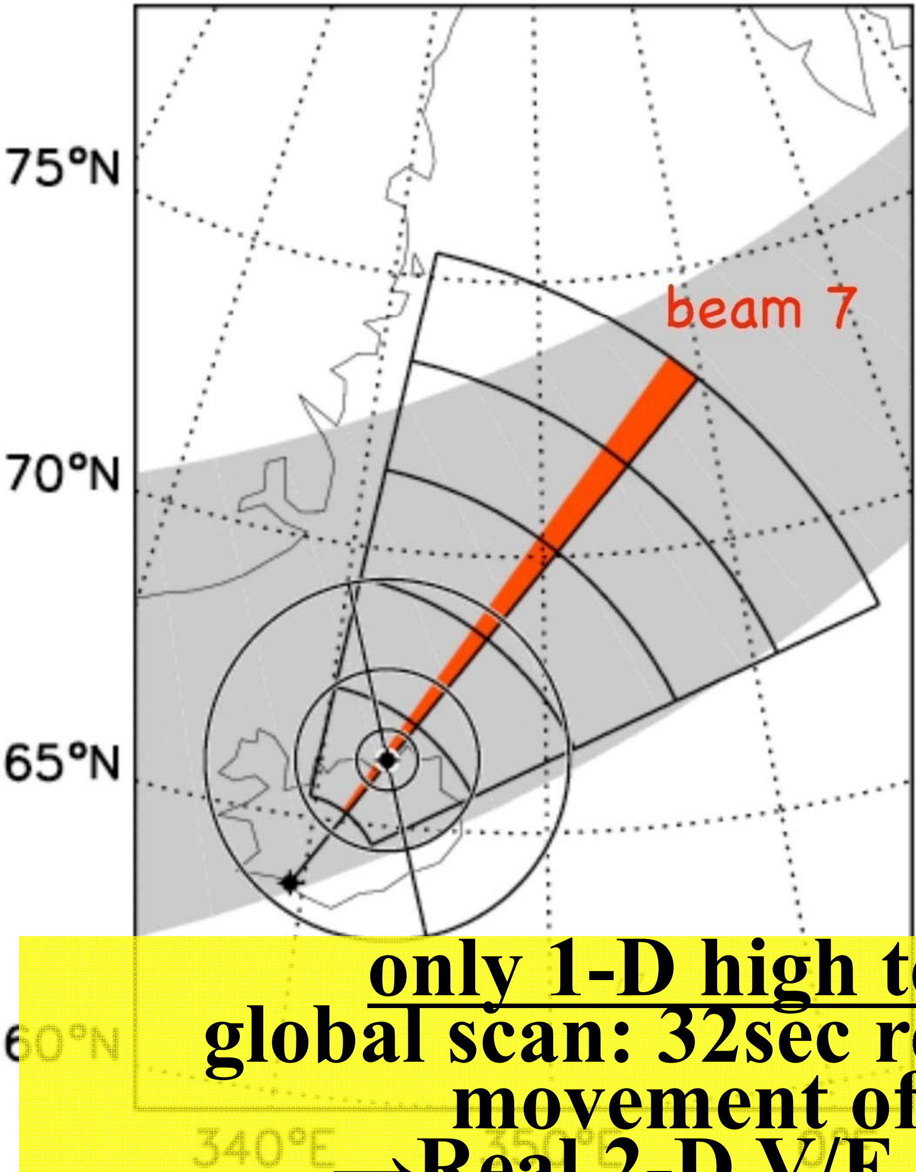


When break-up arc passed over bm7 fine scale bipolar Doppler Vel. structure (up to ±1km/s) observed

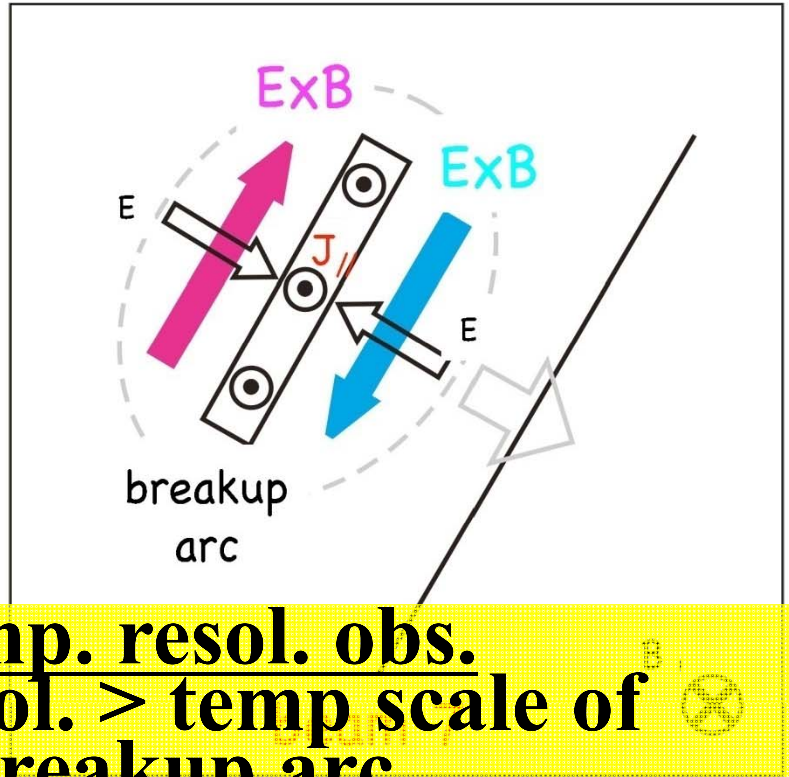


Bipolar signature in the plasma drift

Hosokawa tried to infer the 2-D structure



Bipolar signature in the plasma velocity should be observed in the vicinity of any auroral arcs including breakup arc. The magnitude of the shear could be proportional to the luminocity of arc.

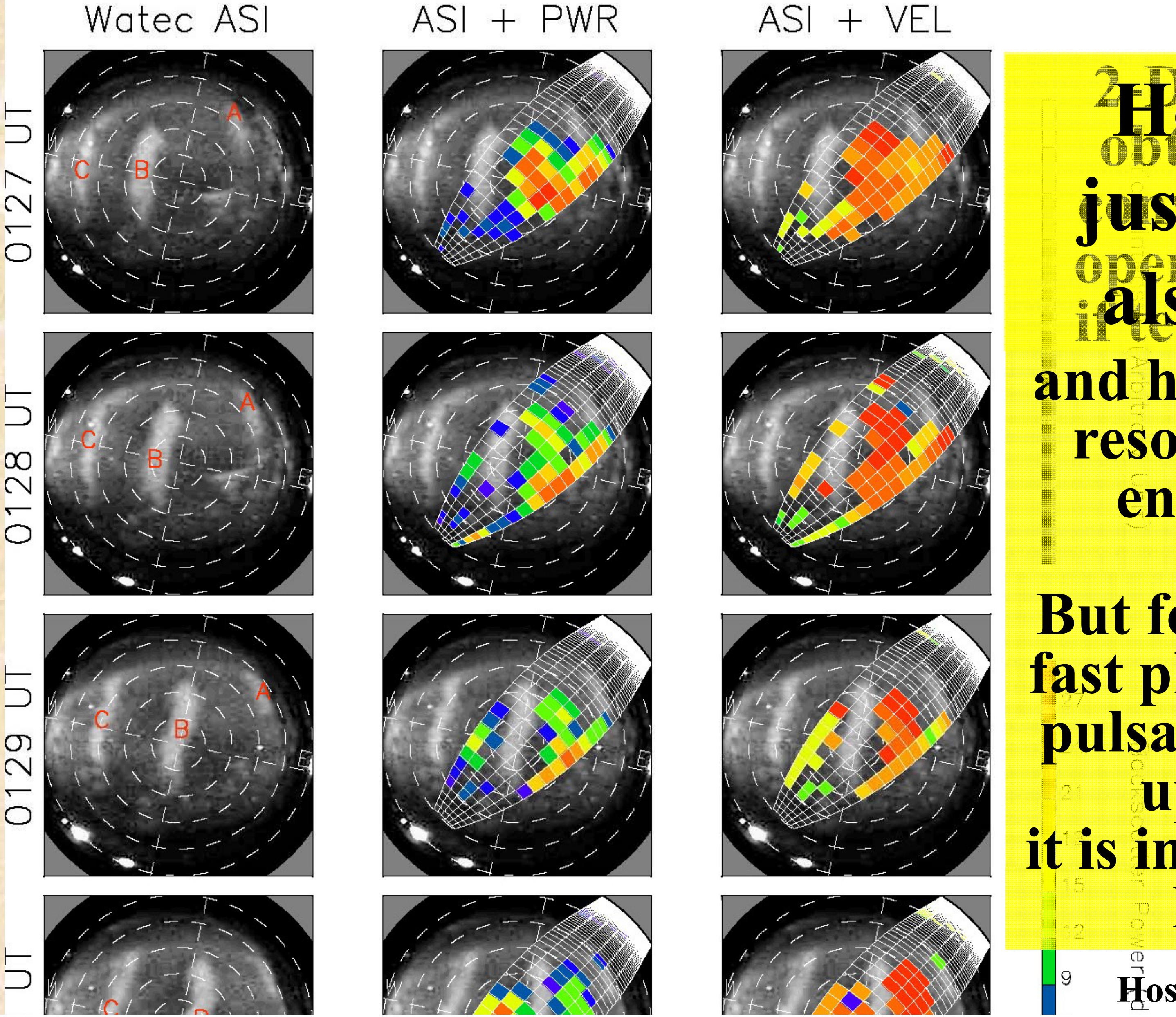


<u>only 1-D high temp. resol. obs.</u>

global scan: 32sec resol. > temp scale of movement of breakup arc

→Real 2-D V/E field unknown...

1-min resol. 2-D SD observation compared with optical intensity and evolution of patches in diffuse aurora



2-D V/E can be obtained using conventional SD operation modes if temporal scale and hence temporal resol. required is enough long..

Hosokawa just recently also tried...

But for transient or fast phenomena like pulsating or break-up auroras, it is impossible to do like this..

Hosokawa et al., JGR, 2010

What we need or what Keisuke is eager to have is...

In order to study
transient phenomena,
to obtain...
higher temporal resolution
2-D Vlos/E field data
with a temporal resolution of
at most a few seconds
or even less...

to overcome the problems, why not....?

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.

just do it!

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:

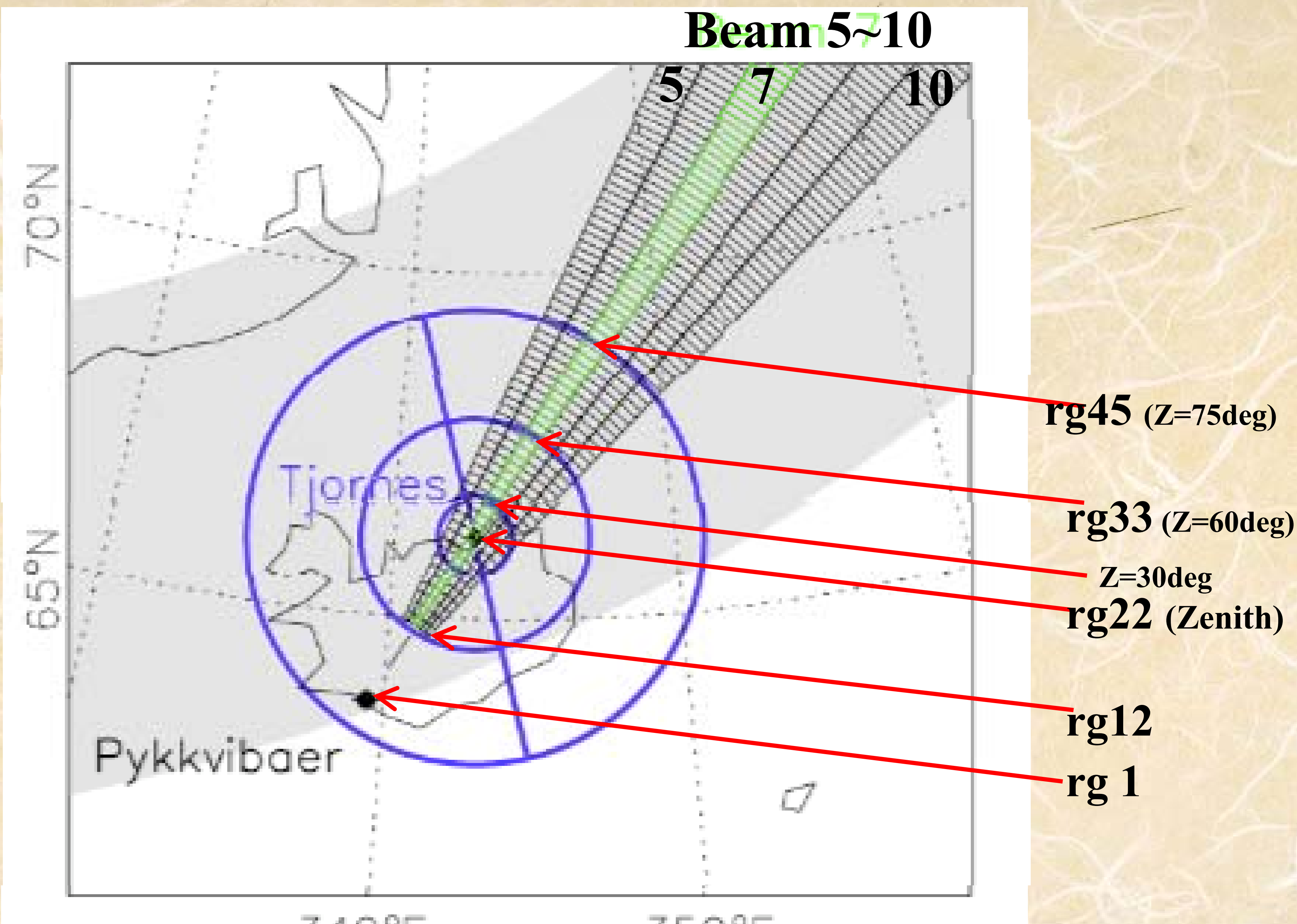
chA: conventional camping beam mode (mono myopic):

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)

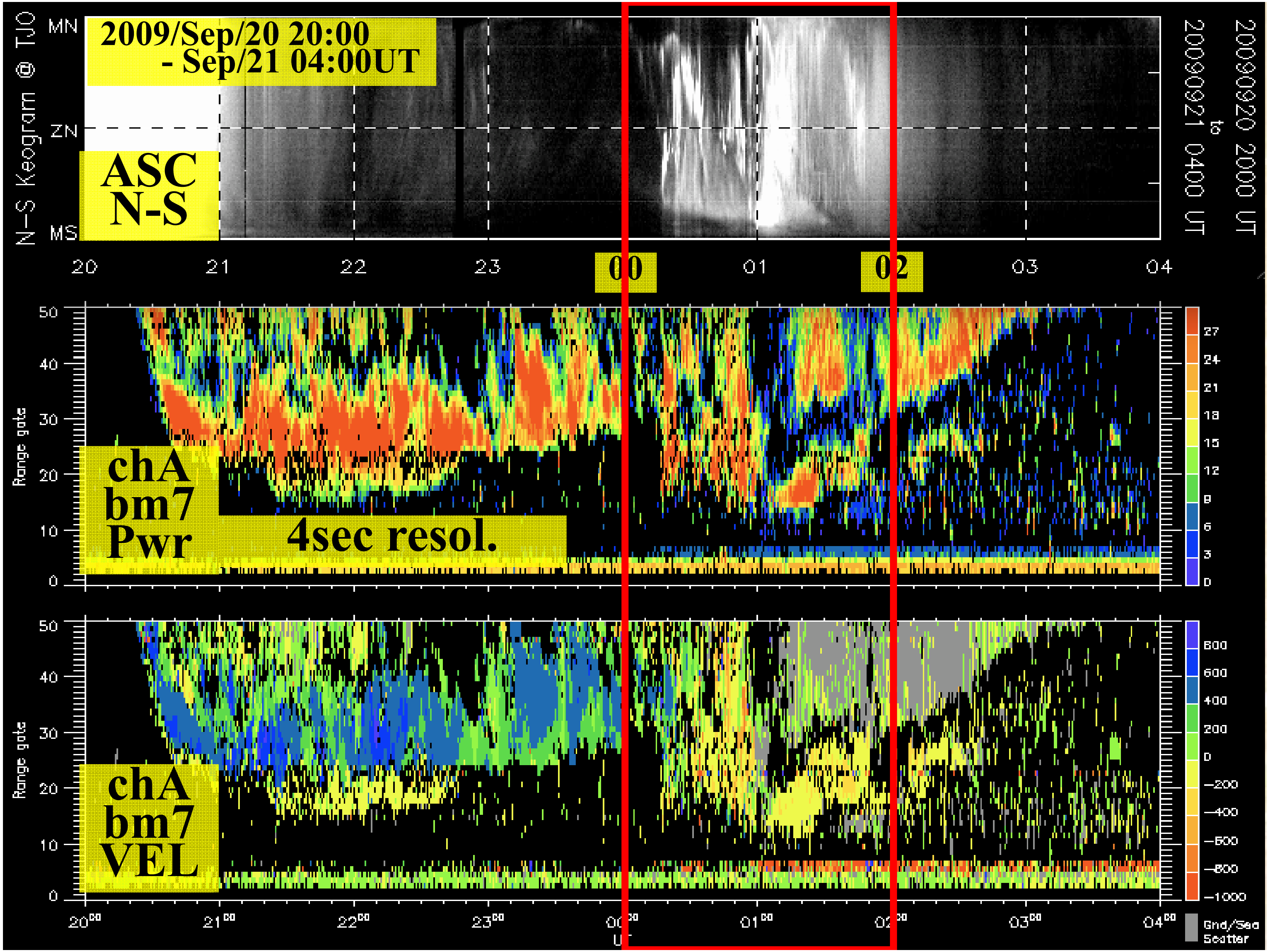
chB: new operation mode ("BeamScanInIntt")

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...

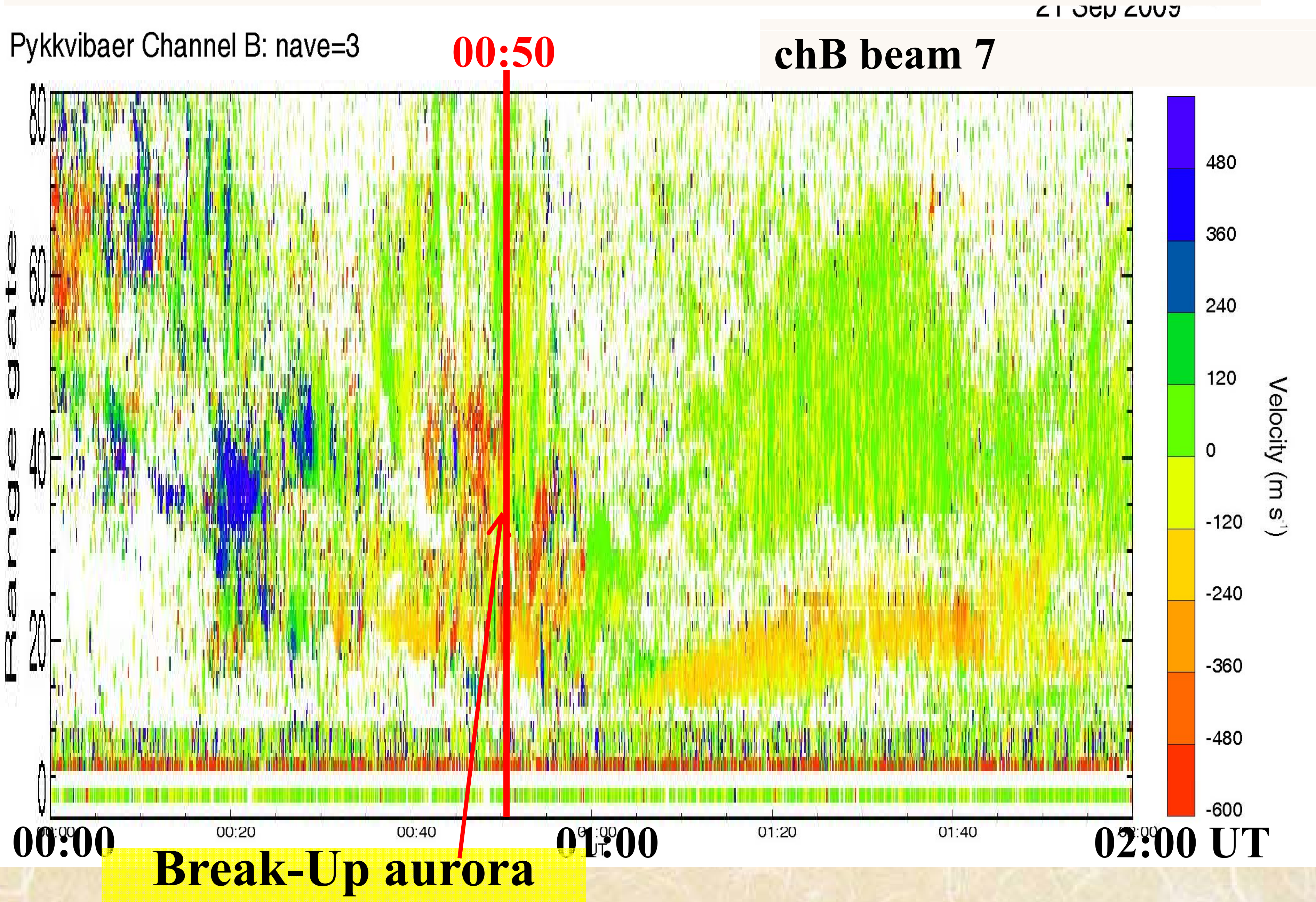


Tjornes ASC FOV and Iceland East FOV

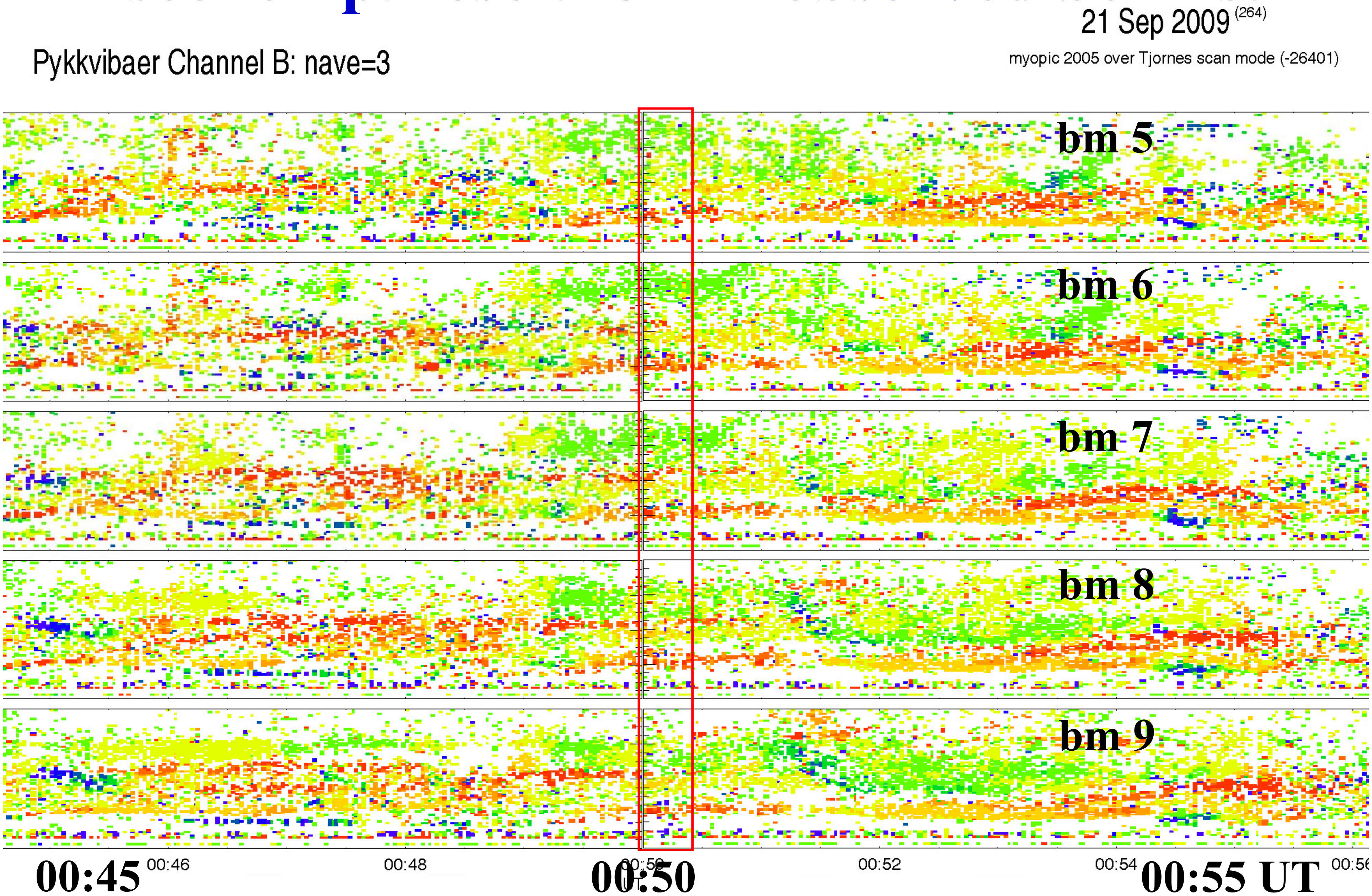


2009/Sep/20 20:00
- Sep/21 04:00UT
ASC
N-S
N-S Keogram @ TJO
MN
ZN
MS
20090920 2000 UT
to
20090921 0400 UT
20
21
22
23
00
01
02
03
04
chA
bm7
Pwr
4sec resol.
Range gate
chA
bm7
VEL
Gnd/Sea Scatter
UT

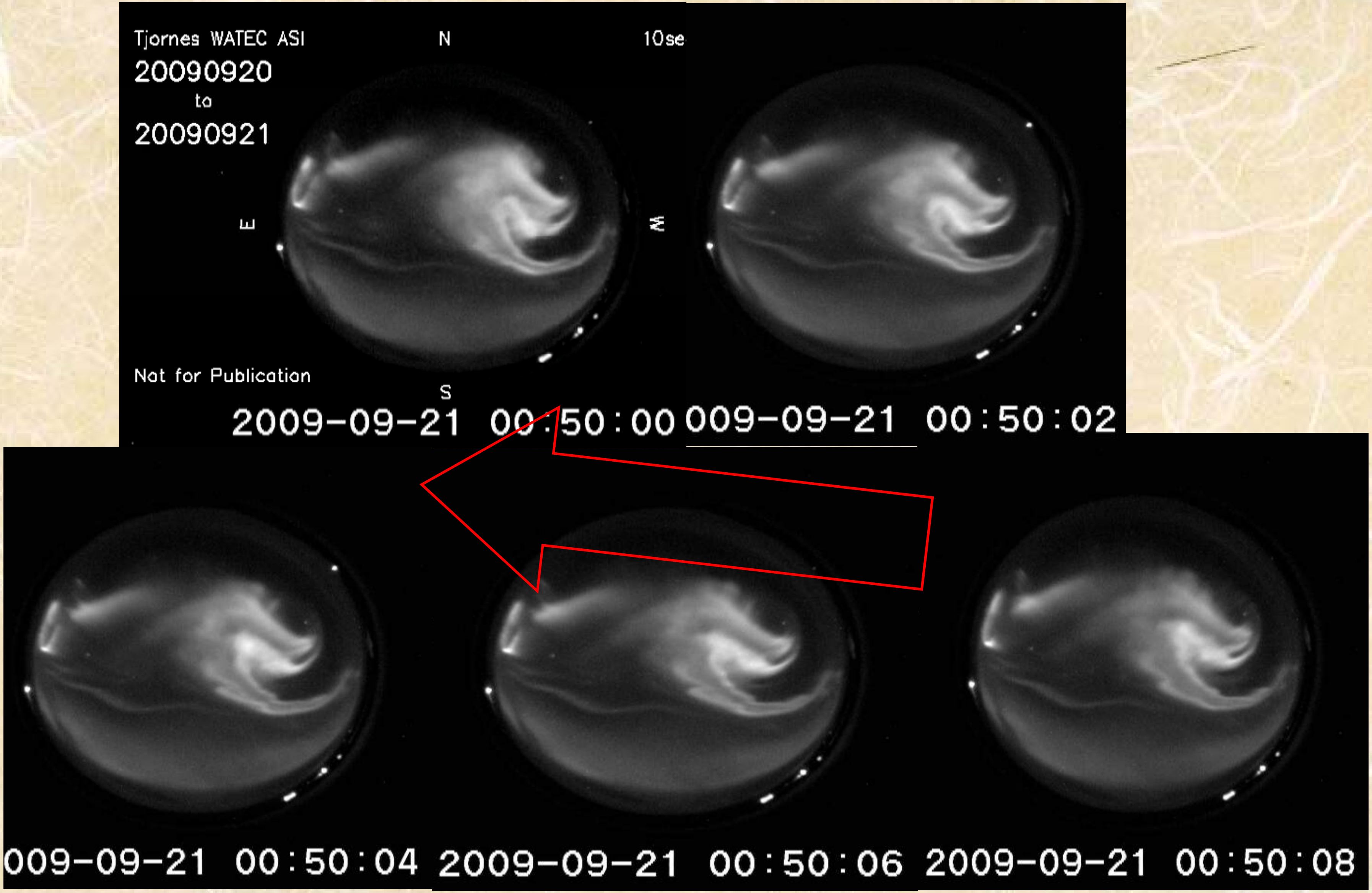
~2 sec temp. resol. for a single beam 7



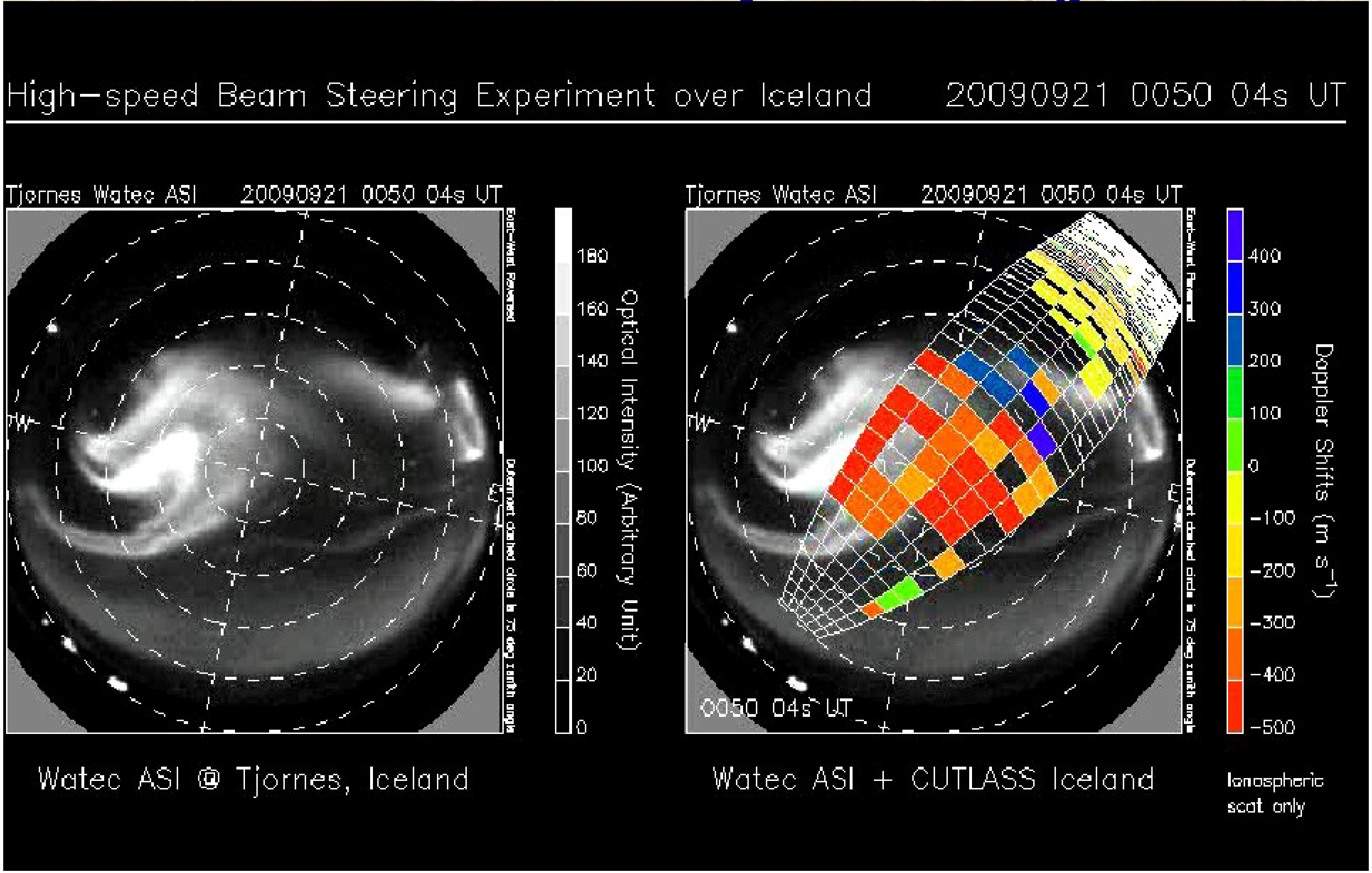
~2 sec temp. resol. for all observed beams!



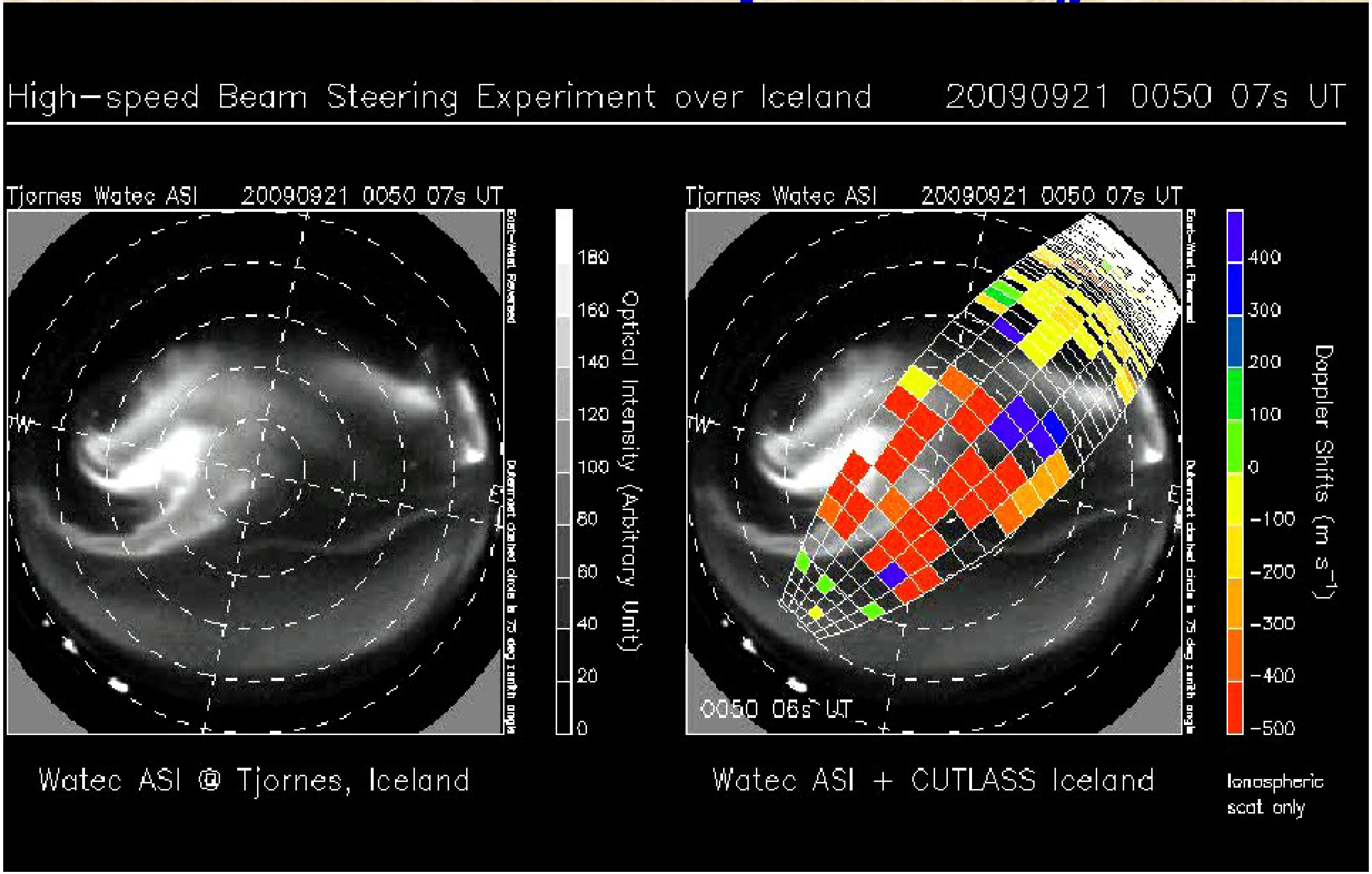
Active aurora assoc. with substorm breakup over Tjornes



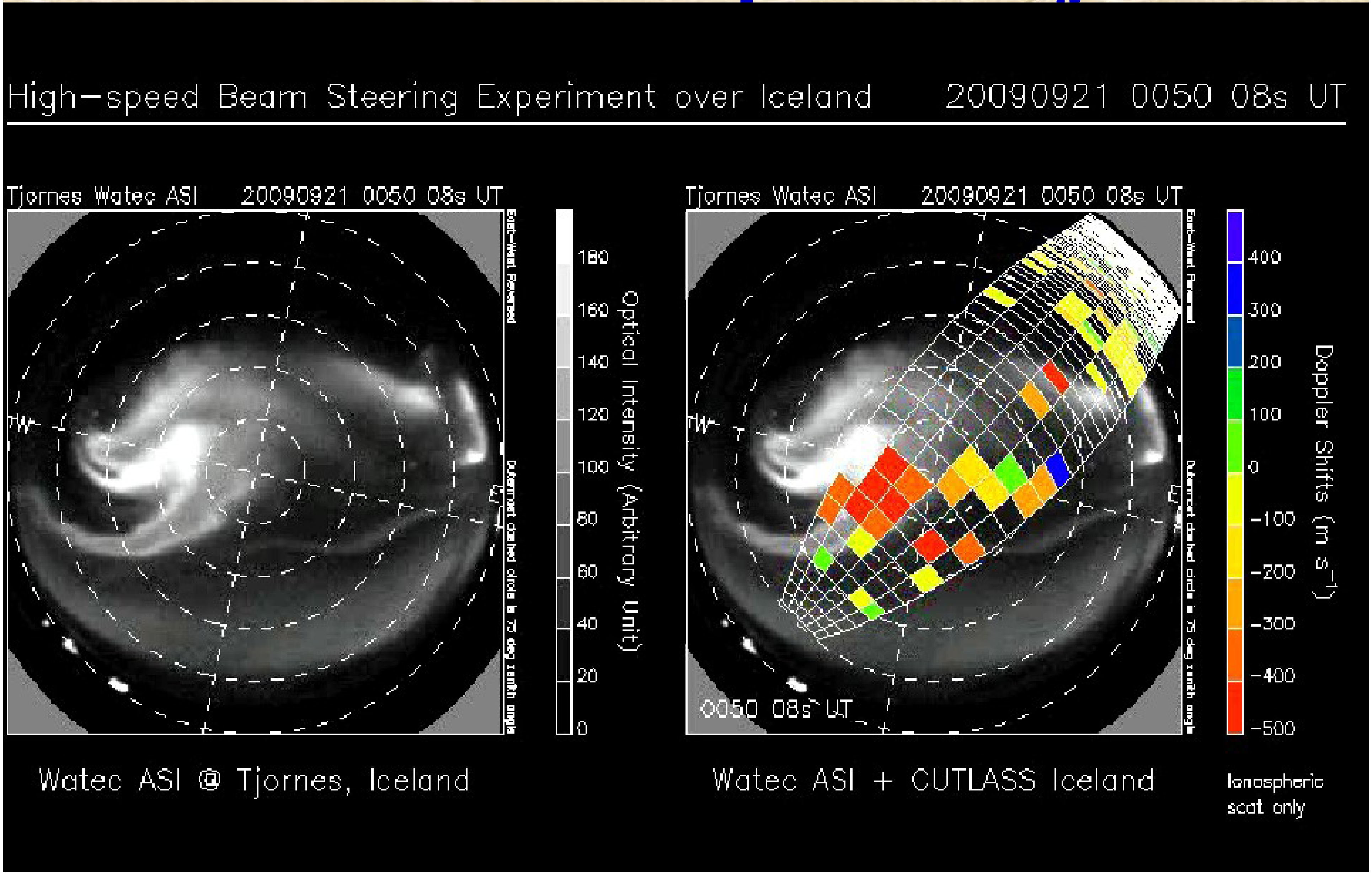
Active aurora assoc. with substorm breakup over Tjornes



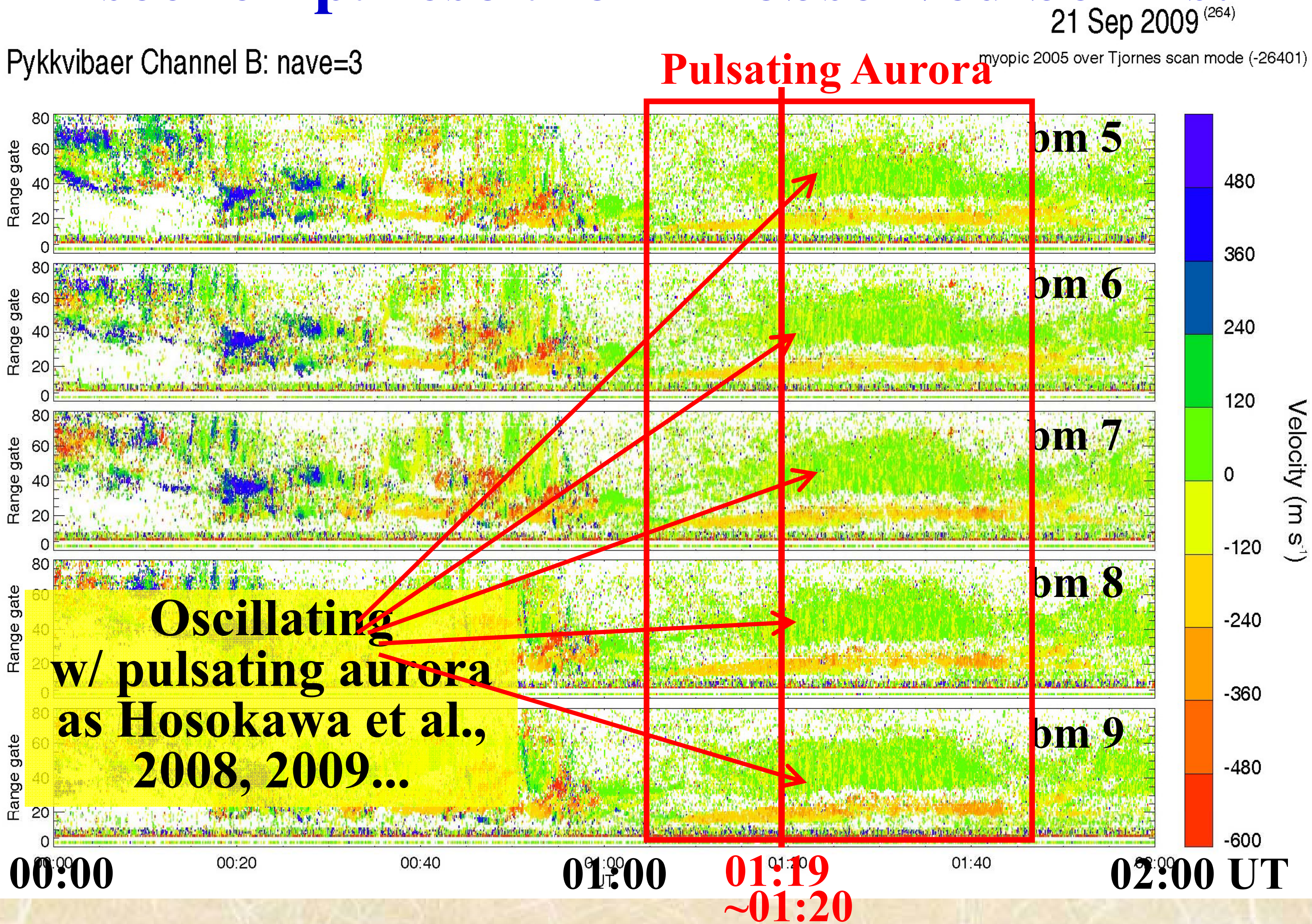
Active aurora assoc. with substorm breakup over Tjornes



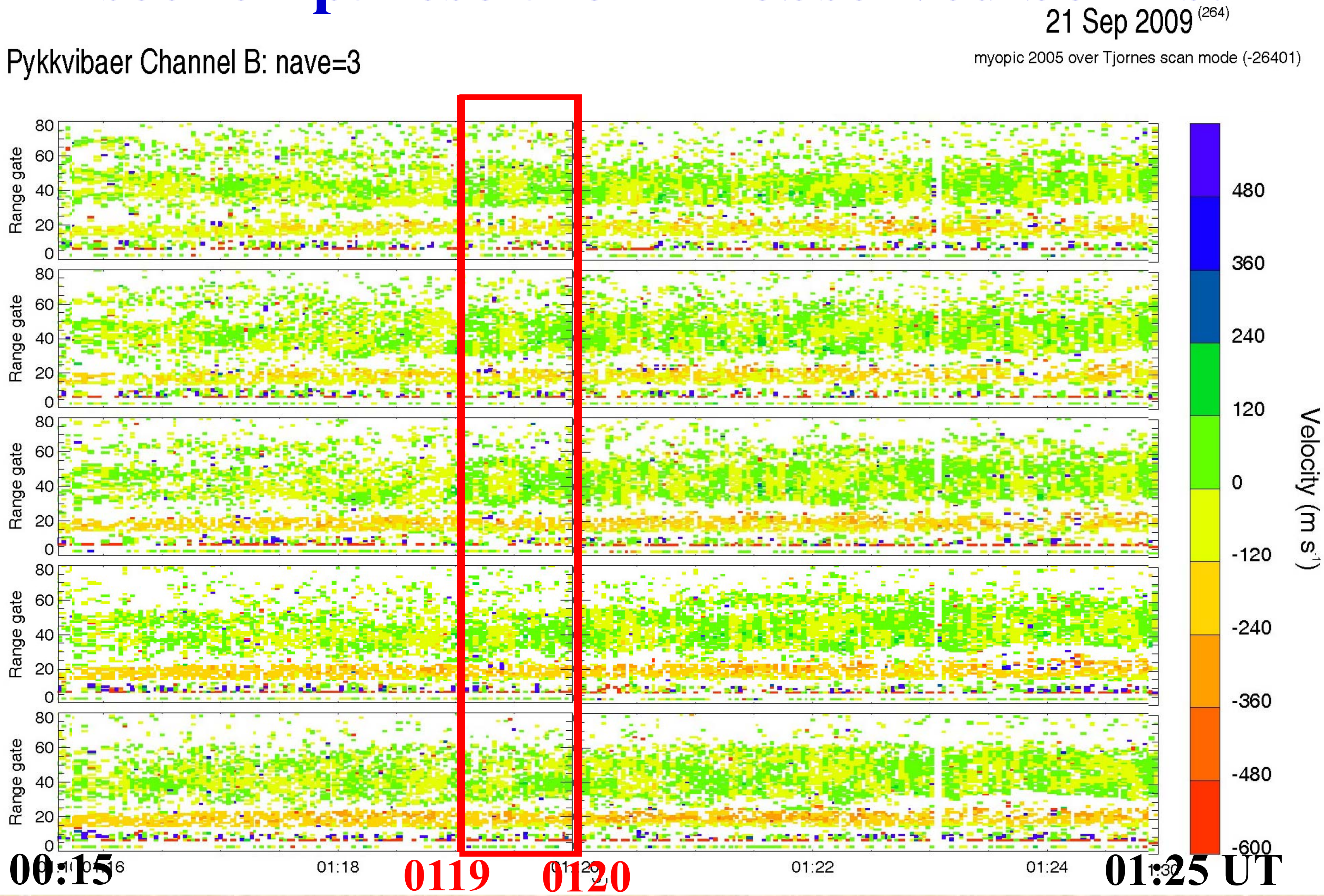
Active aurora assoc. with substorm breakup over Tjornes



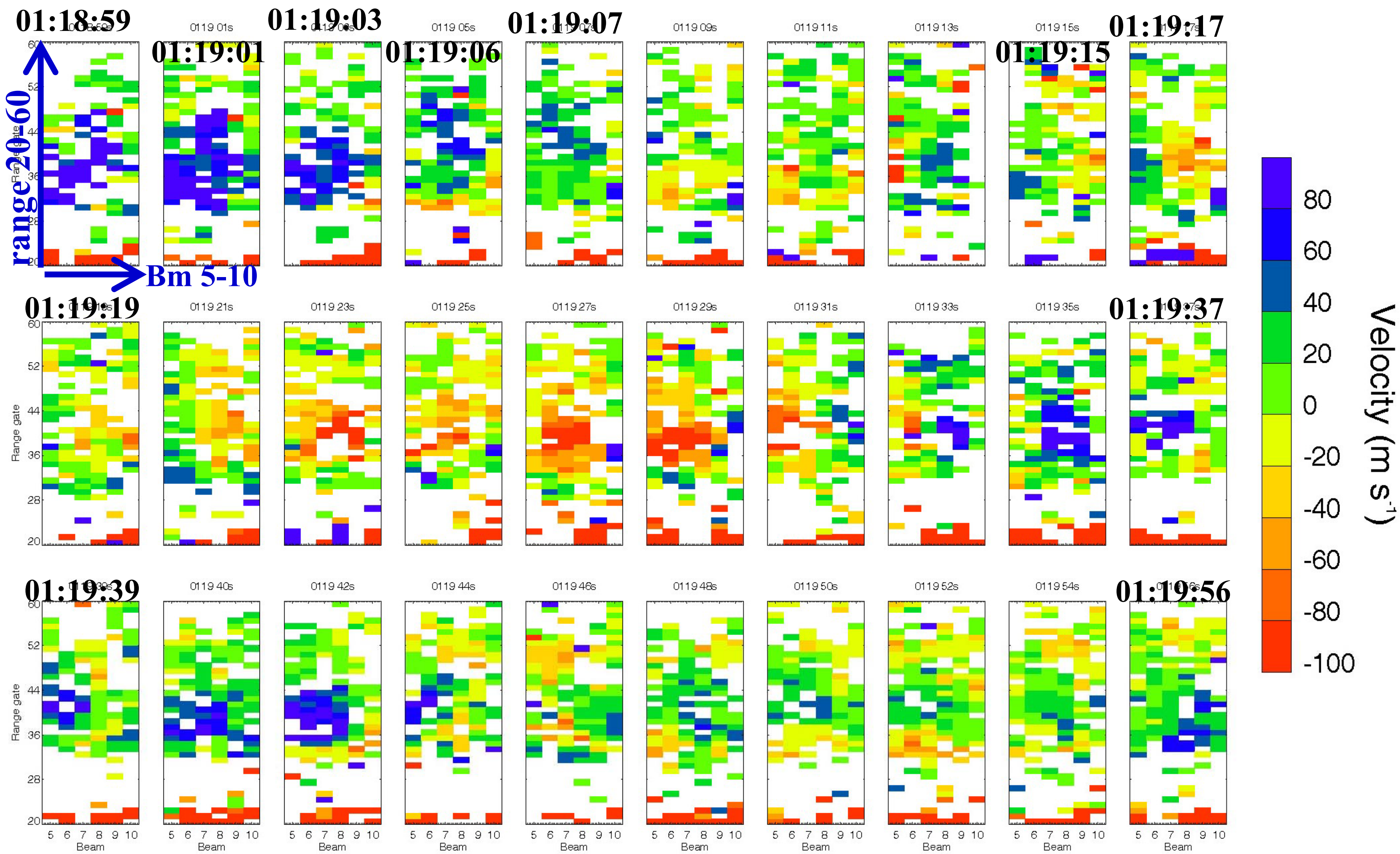
~2 sec temp. resol. for all observed beams!



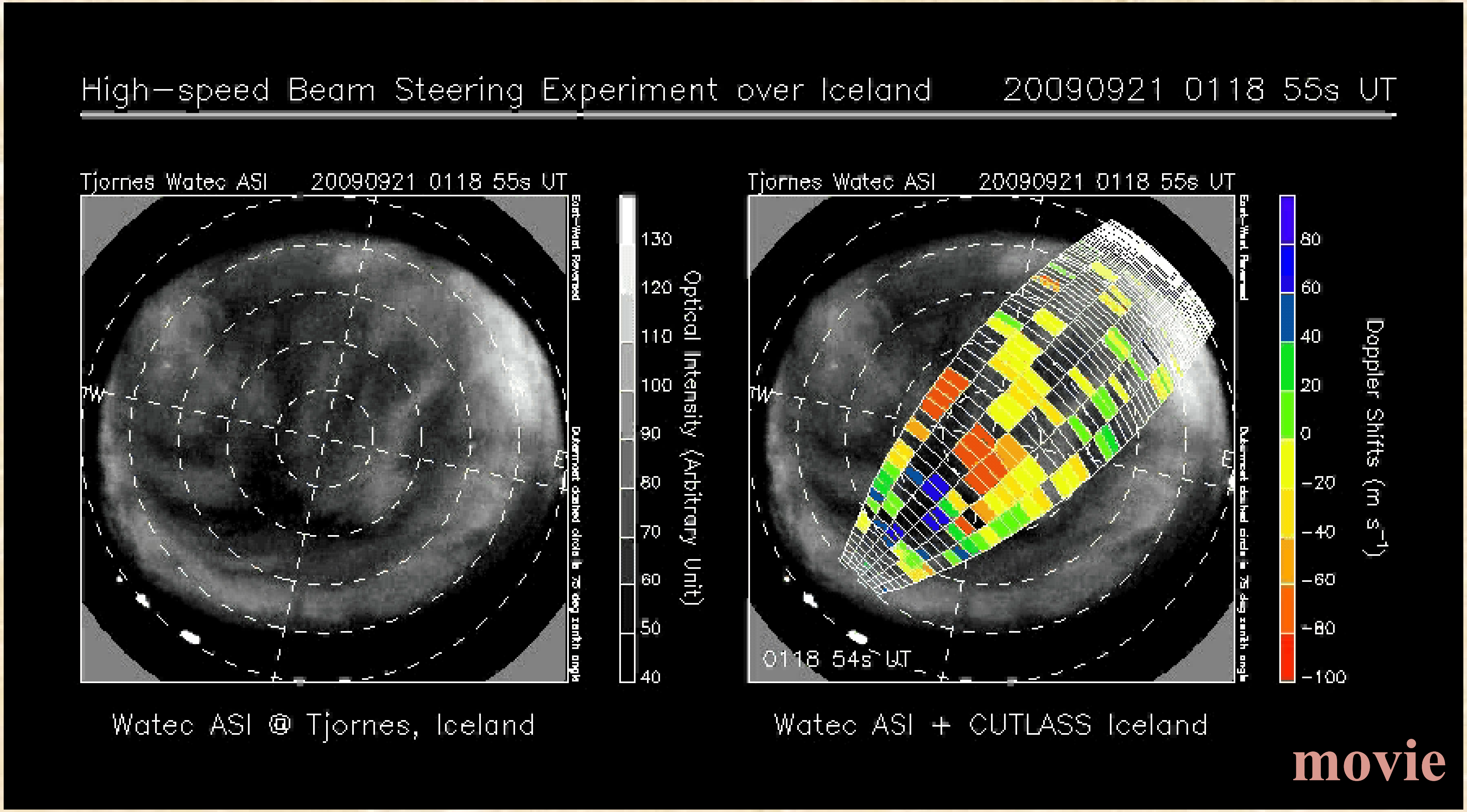
~2 sec temp. resol. for all observed beams!



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



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



not getting into the details in this talk, but careful comparisons btw ASC & H.T.SD data and detailed analysis will be made soon...

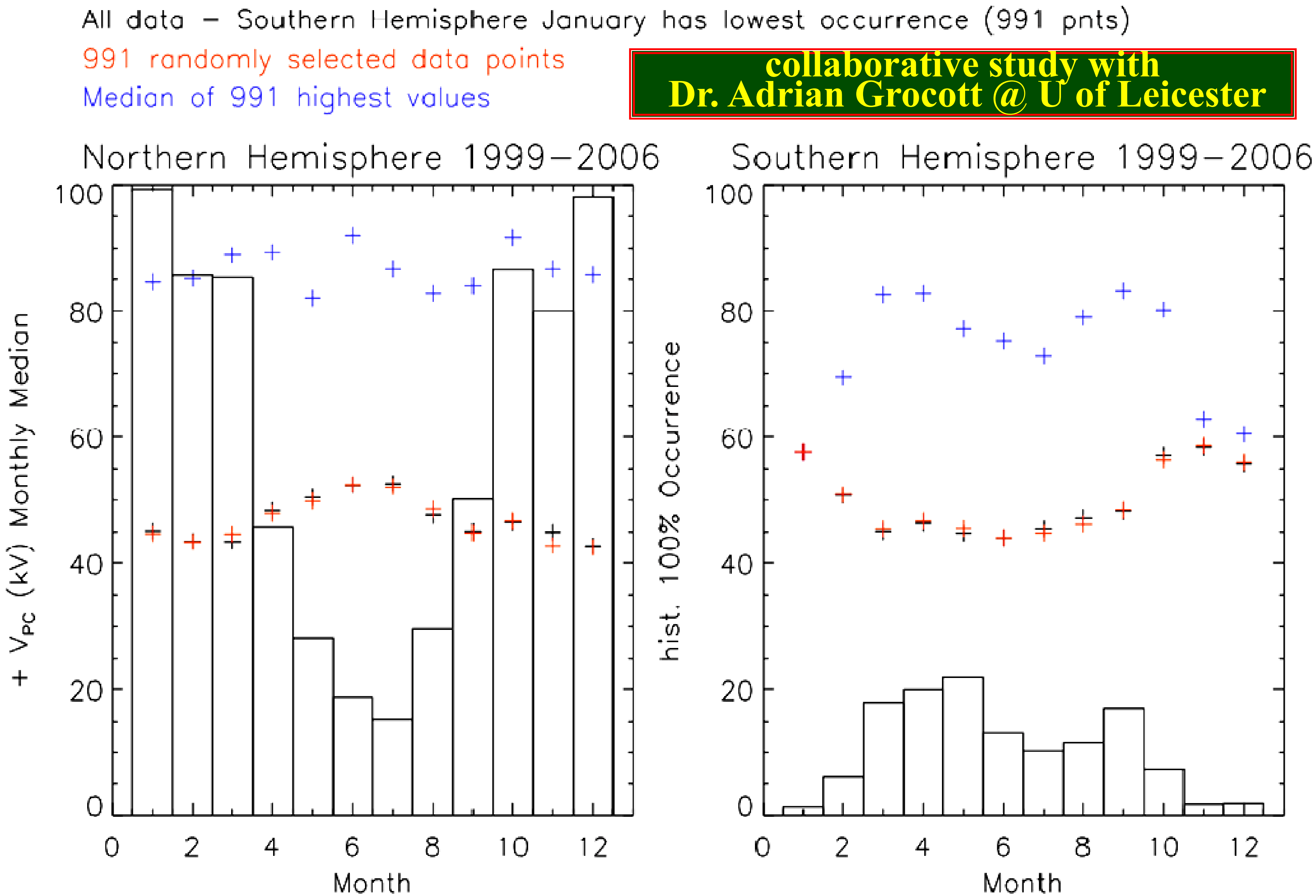
Conclusion

- A new radar operation mode to obtain 2-D high temporal resolution velocity (or electric) field has been developed and was tested using CUTLASS Iceland East radar with NIPR optical imager under the radar FOV over Iceland in success.
- If S/N ratio or echo power is enough high (with less CRI), at least 2-sec resolution of 2-D velocity/electric field can be obtained, which have probably never been obtained in other instruments.
- This new ability enables us to study a variety of transient phenomena, e.g., pulsating aurora and break-up arcs, etc – whose time scale >4sec.
- So far, we could obtain 1-D high temp. res. data and could only "infer" the 2-D transient electric field, but we can now directly measure it if cond. meets!
- SuperDARN now has a new capability!

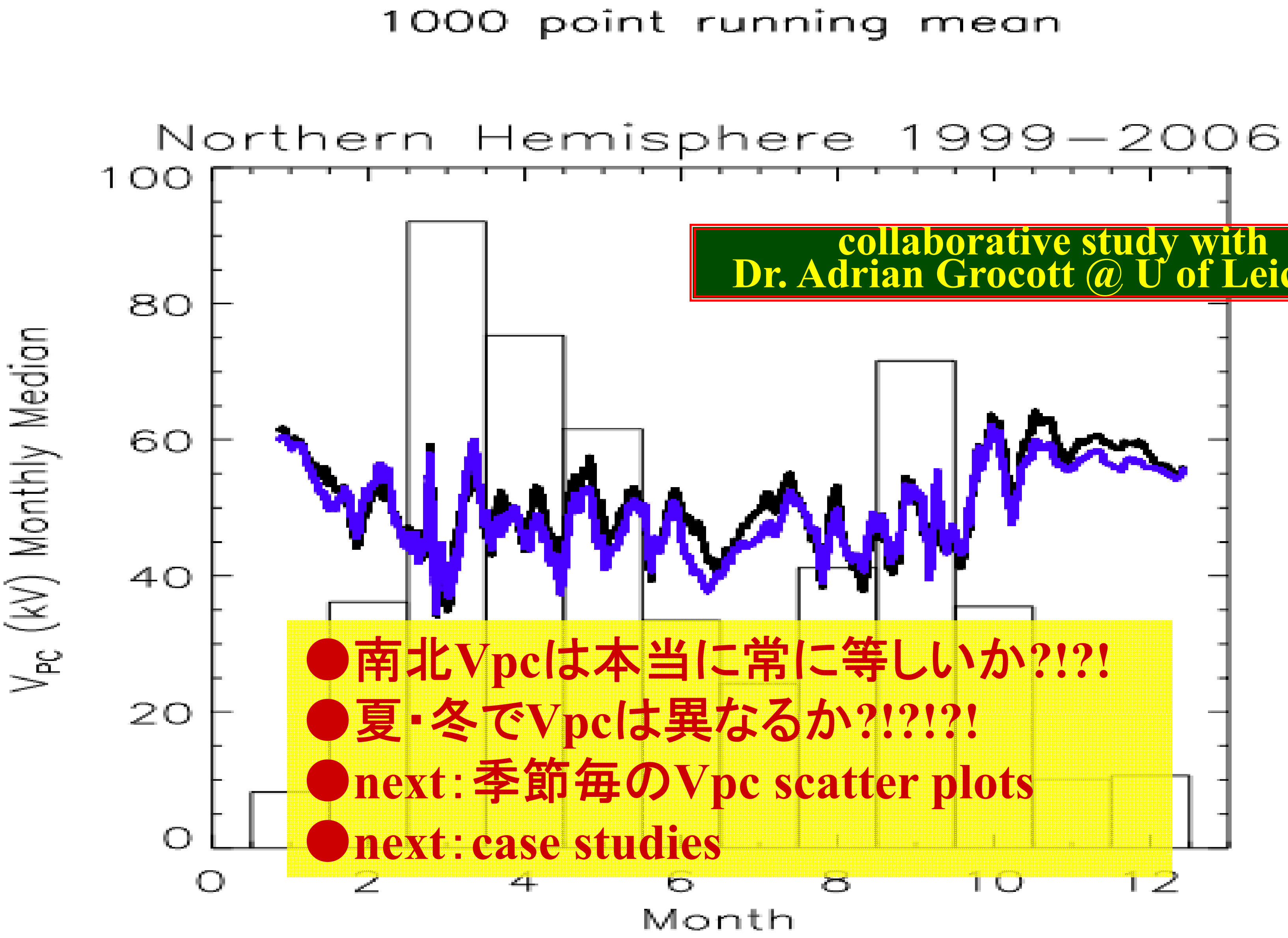
Future

- **Echoes detectable with the new technique seem relatively/considerably smaller amount than those with conventional technique (i.e., by continuous integration on each beam). This might suggest some important aspects of FAI characteristics responsible for echoes related to transient aurora, e.g., its correlation time.**
- **Echoes seem to tend to appear adjacent to aurora but not collocated with aurora as reported by Hosokawa et al., 2008-10, but it is not always true. This might be related to the issue above.**
- **More experiments for event analysis for a variety of transient and steady state aurora and comparisons among them will be important and should be done.**
- **More applications – e.g., 2-D transient FTE studies, artificial FAI observation with higher spatial resolution imaging technique**

potential collaboration w/ simulation groups



potential collaboration w/ simulation groups



collaborative study with
Dr. Adrian Grocott @ U of Leicester

- 南北Vpcは本当に常に等しいか?!?!
- 夏・冬でVpcは異なるか?!?!?!
- next：季節毎のVpc scatter plots
- next：case studies

2010年度NIPR研究集会

3/16(水) SuperDARN研究集会
3/17(木) 大学間連携IUGONET
データ解析講習会
3/18(金) EISCAT研究集会

どうぞご参集ください。

3/16(水) SuperDARN研究集会

SuperDARNによる極域超高層大気研究集会 ～今後取り組むべき重要課題の戦略～

SuperDARN(国際短波レーダー観測網)プロジェクトは、1995年の発足以来、参加研究機関、レーダー数、研究者層の増加と共に、電離圏・磁気圏のみならずMLT領域へ、極域から中緯度へもその研究領域を拡大し、日本は3機関(国立極地研究所、情報通信研究機構、名古屋大学太陽地球環境研究所)がPIとして参加し、その研究発展に大きな寄与をしてきた。SuperDARN発足15年を迎え、これ迄に解明できた事、未解決の課題を俯瞰し、地上・衛星・ロケット等観測や理論研究の動向も踏まえ、現在・今後、SuperDARNで貢献できることや、日本グループとして取組み牽引すべきテーマ、国内外の共同研究のあり方等について、情報交換や議論を中心に行い、今後の超高層大気研究の発展に資する事を目的として、本研究集会を開催します。

どうぞご参集ください。

Thanks...