Correspondence to: jdb23@ion.le.ac.uk

Double Pulse Operations with SuperDARN

SuperDARN Workshop Newcastle, Australia 2008

2nd June 2008

SPEAR

Space Plasma Exploration by Active Radar

CUTLASS

Co-operative UK Twin Located Auroral Sounding System

Authors: J.D. Borderick[1], T.K. Yeoman[1], A.S. Yukimatu[2] and D.M. Wright[1]

1 Department of Physics & Astronomy, University of Leicester, University Road, Leicester, England

2 National Institute of Polar Research, 9-10, Kaga1-chome, Itabashi-ku, Tokyo, Japan

Contents of Talk

- Standard SuperDARN Mode
- Motivation for the Double Pulse Technique
- Emulated Double Pulse Technique
- TMS Raw times series Analysis
- Experimental Double Pulse Technique
- Preliminary Results
- Conclusions
- Further Work

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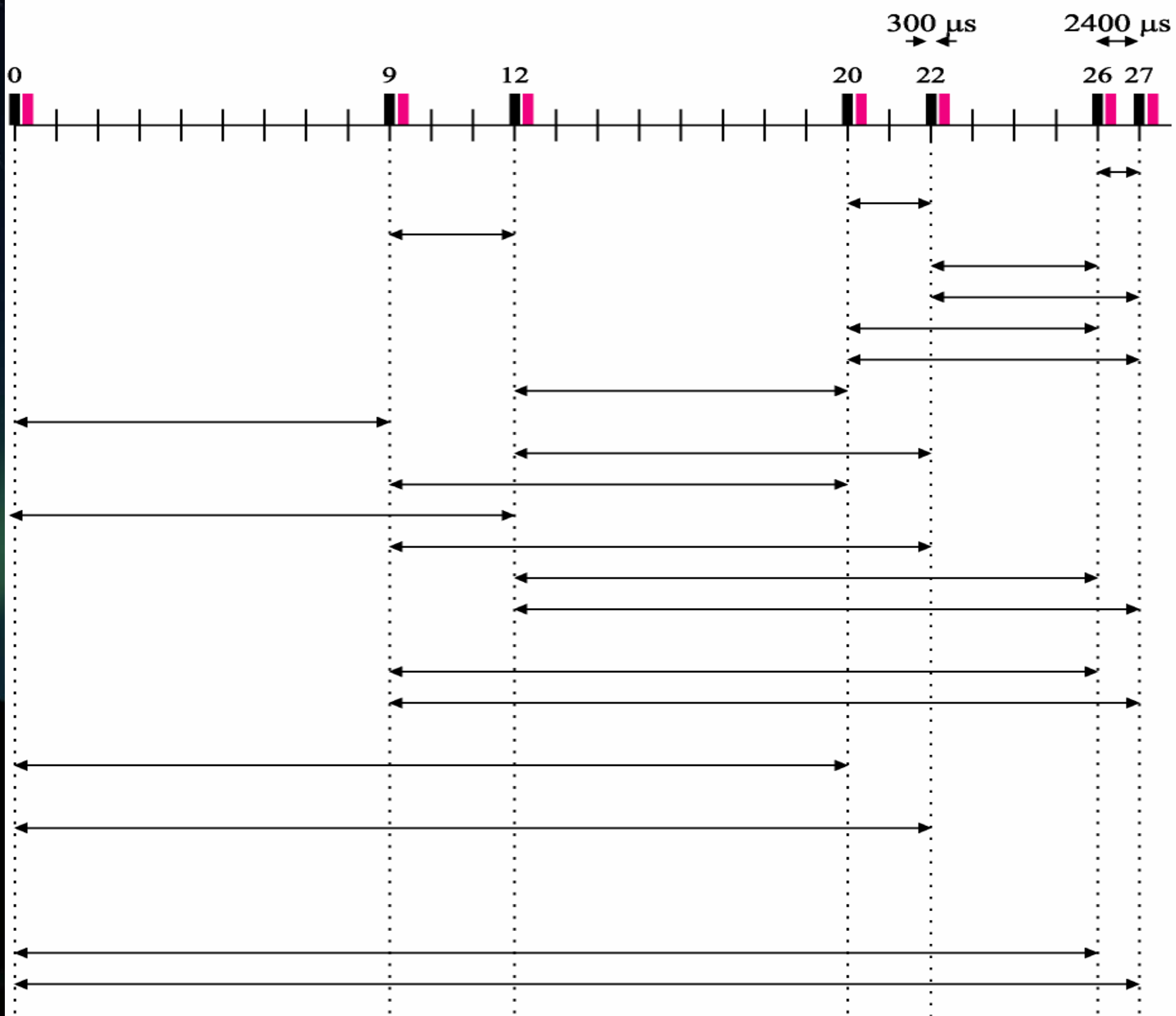
SuperDARN-Standard Radar Mode (a)

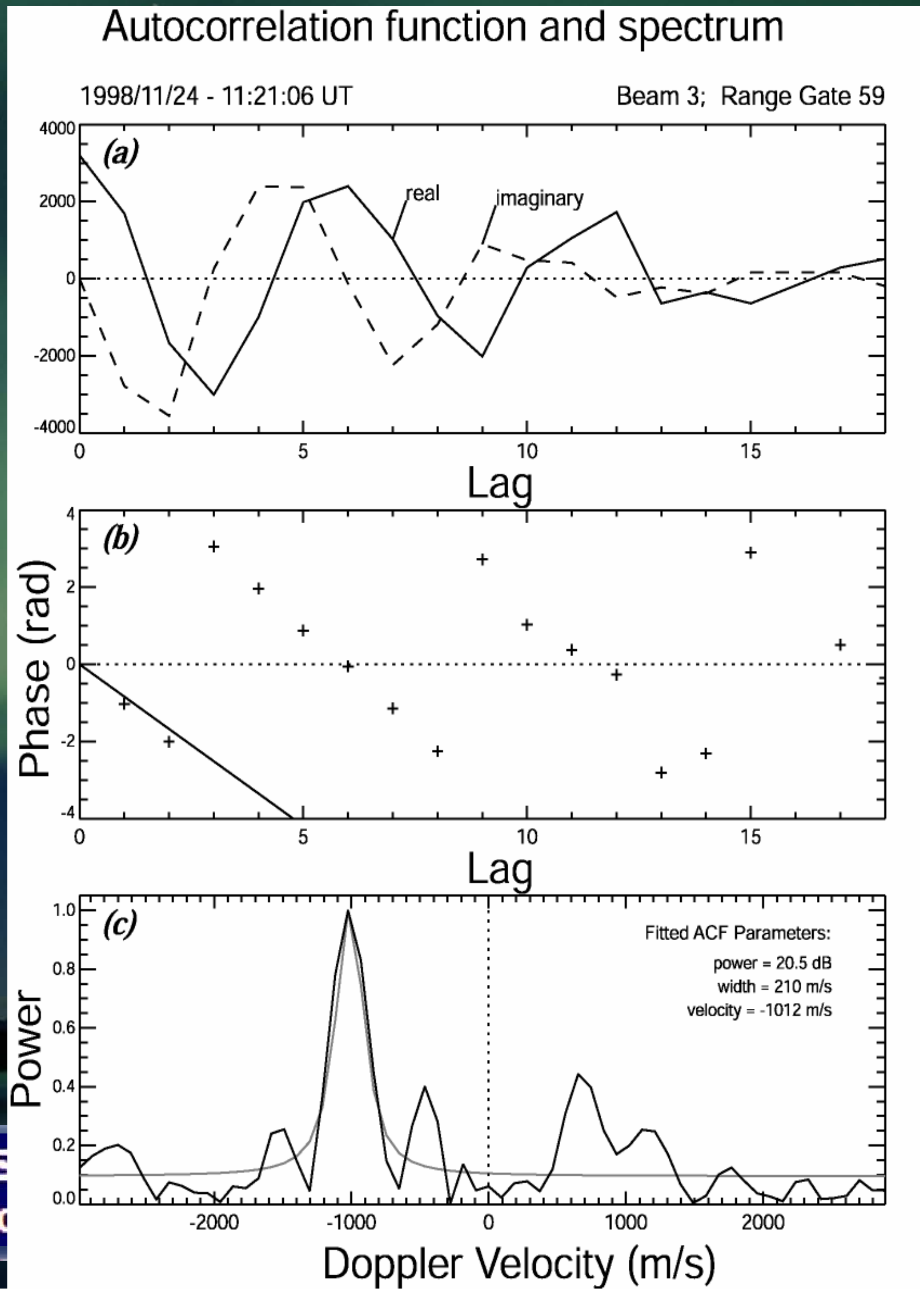
Pulse sequence and calculated lags



Lag	Pulses
0	0-0
1	26-27
2	20-22
3	9-12
4	22-26
5	22-27
6	20-26
7	20-27
8	12-20
9	0-9
10	12-22
11	9-20
12	0-12
13	9-22
14	12-26
15	12-27
16	missing
17	9-26
18	9-27
19	missing
20	0-20
21	missing
22	0-22
23	missing
24	missing
25	missing
26	0-26
27	0-27

SuperDARN-Standard Radar Mode (b)

- The top panel shows the complex ACF measured along beam 3 at range gate 59 at 11:21:06 UT on 24th November 1998 by the SuperDARN radar at Pykkvibaer Iceland
- The middle panel shows the phase of the ACF
- The lower panel shows the normalised power spectrum (black line) obtained from the FFT of the ACF



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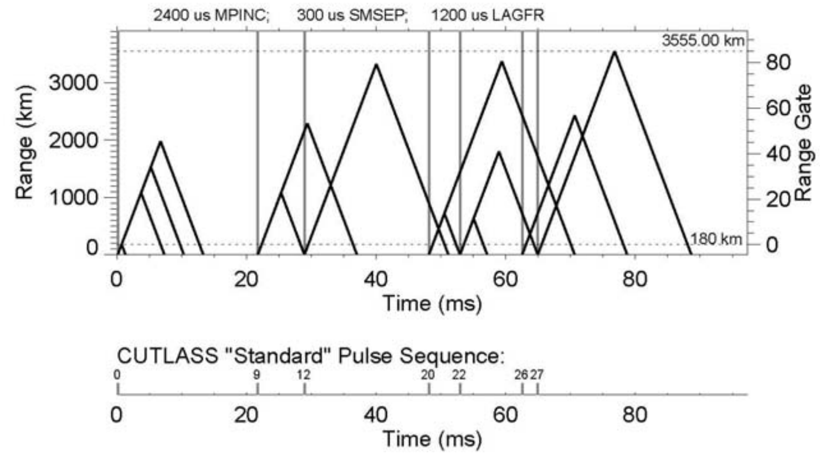
The two modes…

- The SuperDARN 7 Pulse Scheme
- Each pulse is 300μs long and are separated by the multi pulse increment of 2400μs.

SUPERDARN PARAMETER PLOT

CUTLASS: STANDARD AND A THREE DOUBLE PULSE SEQUENCE



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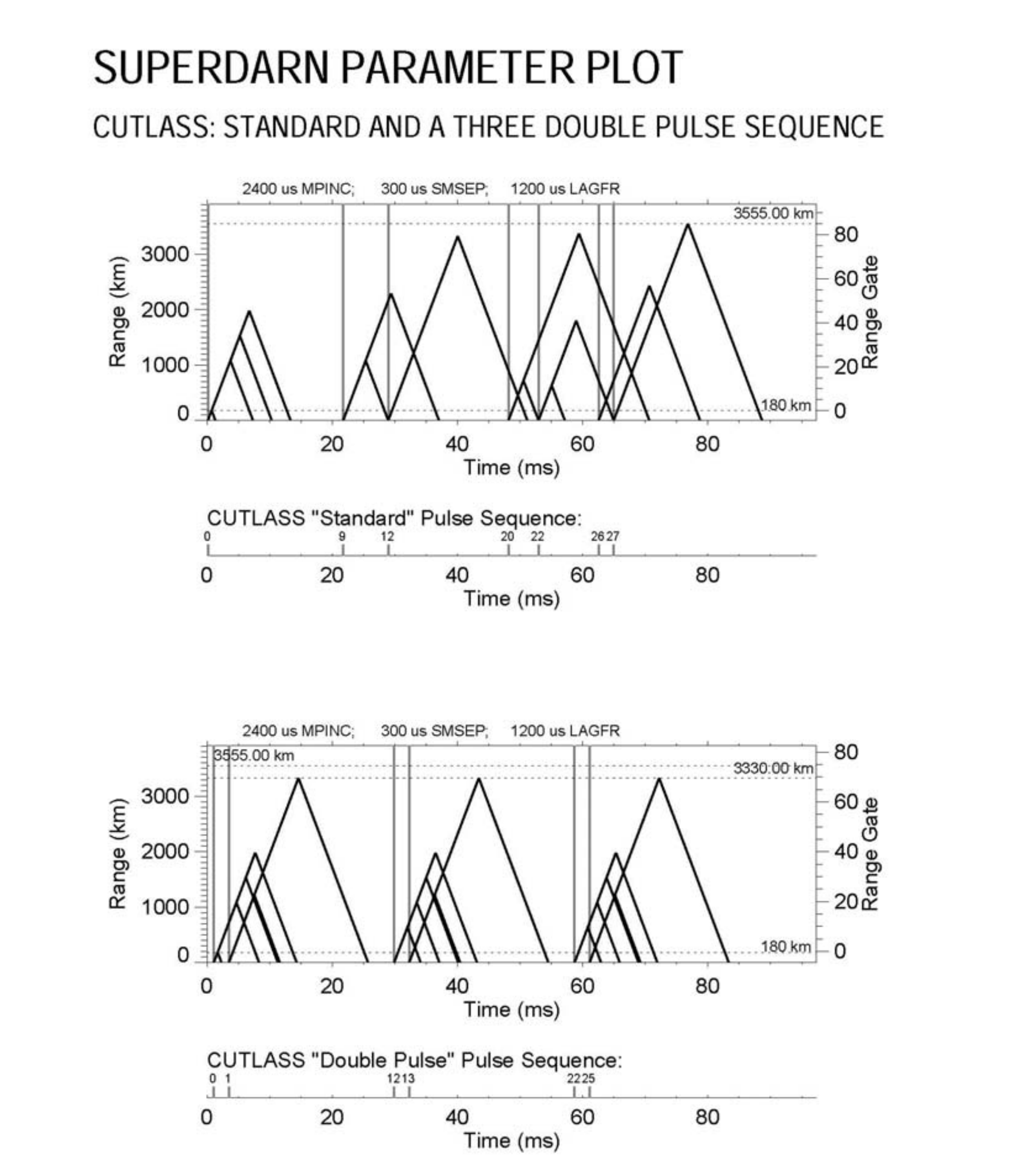
The two modes…

- The SuperDARN 7 Pulse Scheme
- Each pulse is 300μs long and are separated by the multi pulse increment of 2400μs.
- Lower panel shows the Double Pulse scheme
- We can effectively increase the temporal resolution by 3x and still maintain the same range resolution
- No definitive lag zero power



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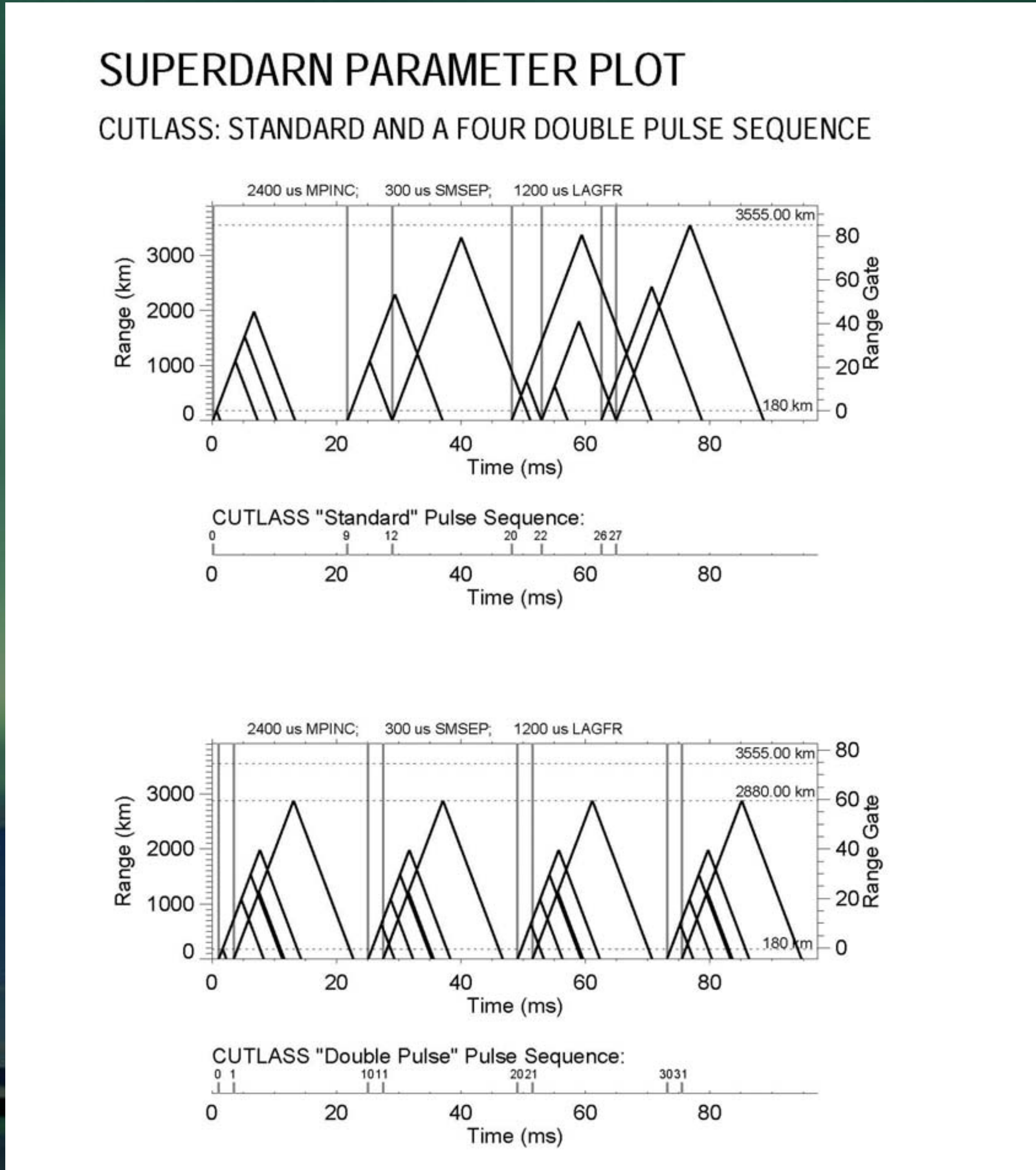
- Each pulse is 300μs long and are separated by the multi pulse increment of 2400μs.
- Lower panel shows the Double Pulse scheme
- We can effectively increase the temporal resolution by 3x and still maintain the same range resolution
- No definitive lag zero power
- We could increase the temporal resolution by a factor of 4 but we would lose some range gates at the higher end



Double Pulse Mode Formula

- The Doppler Velocity

$$V_{doppler} = \frac{C}{4\pi f_{rad}} \frac{d\phi}{dt} \quad (1)$$

$$V_{DoublePulse} = \frac{C}{4\pi f_{rad}} \frac{\phi_2 - \phi_1}{t_2 - t_1} \quad (2)$$

Where the phase is

$$\phi = \tan^{-1}\left(\frac{\text{Im}}{\text{Re}}\right) \quad (3)$$

- With only two lags points…

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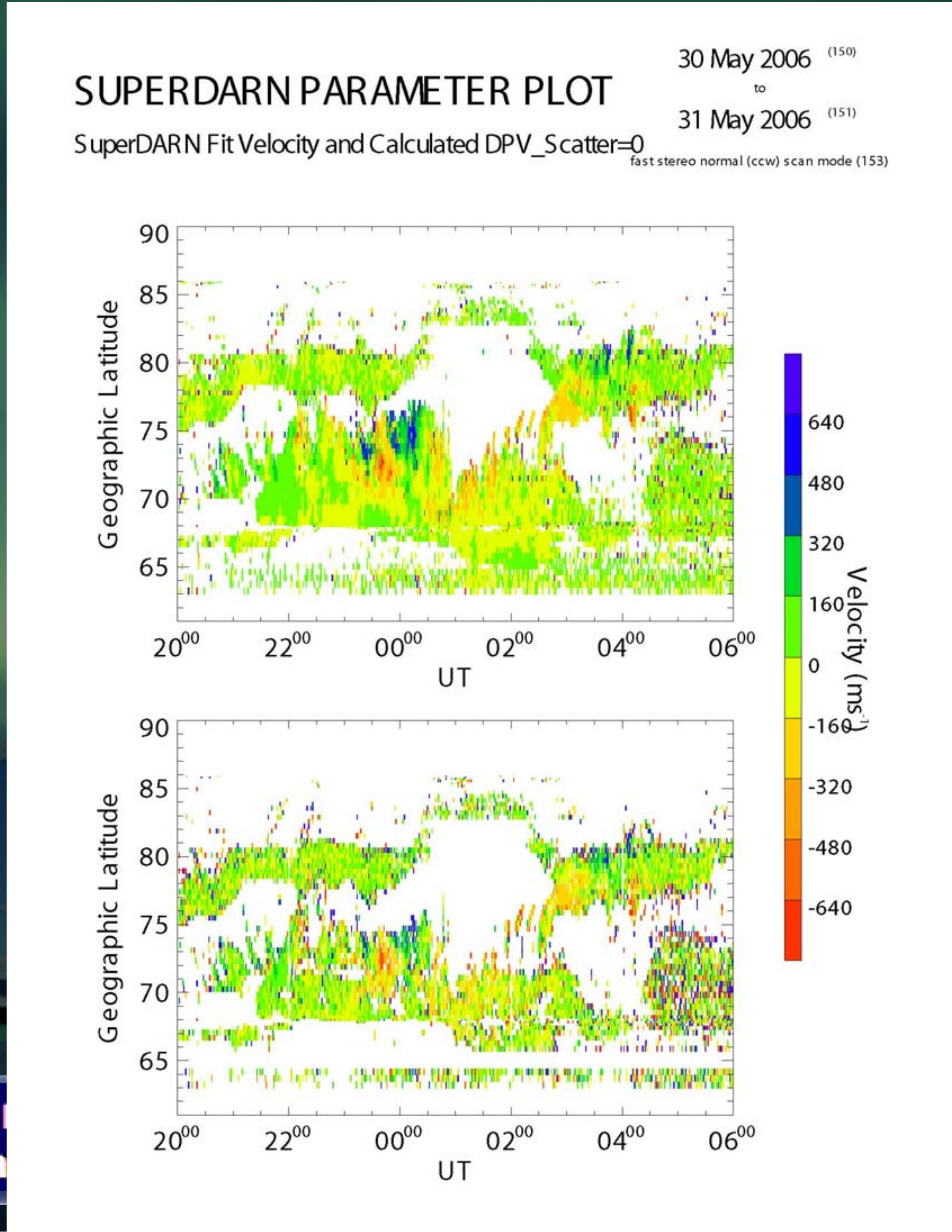
Standard Radar Mode Double Pulse Emulation

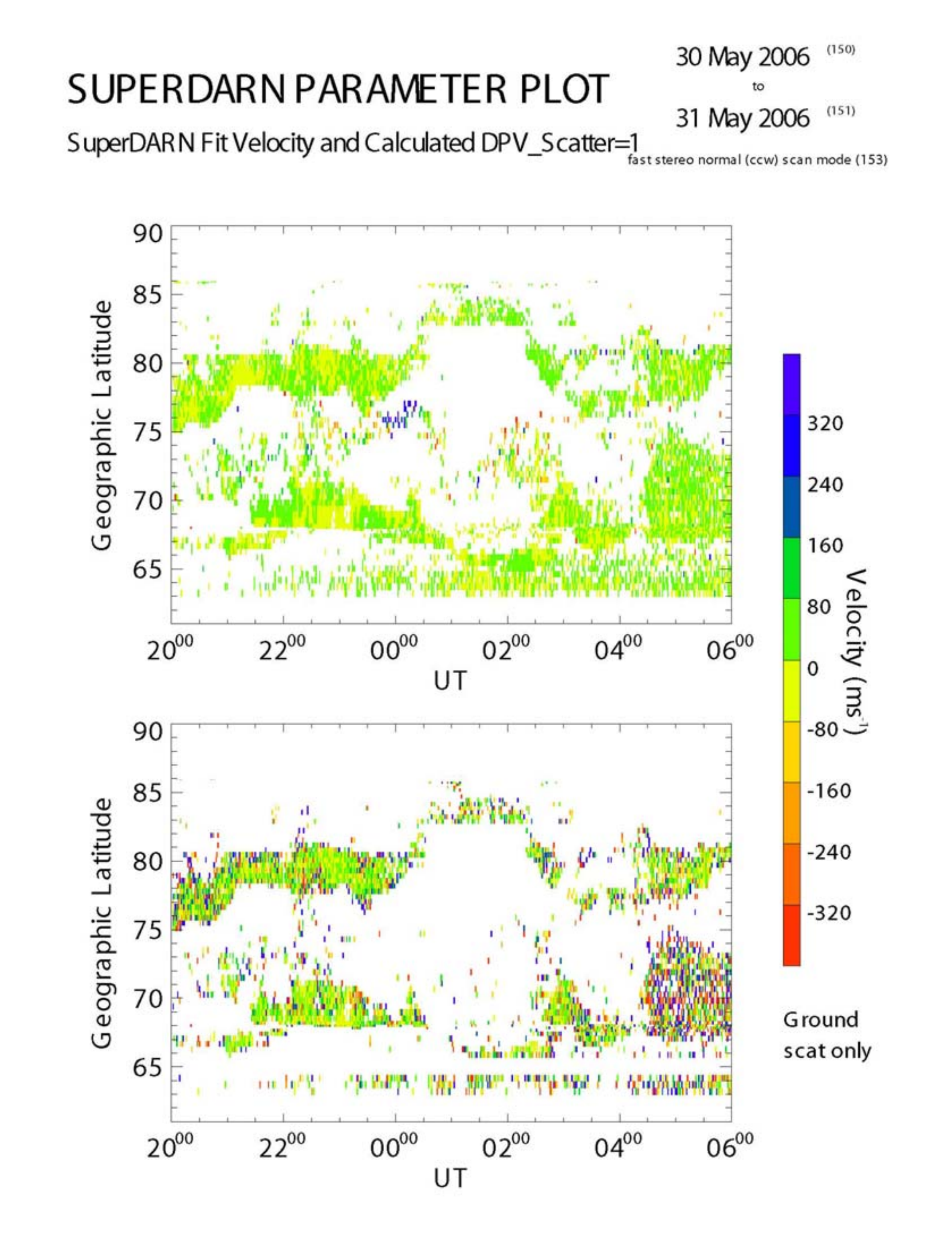
- We can see here

The DPV plotted vs. SuperDARN fit Velocity



Standard Radar Mode Double Pulse Emulation

- We can see here The DPV plotted vs. SuperDARN fit Velocity



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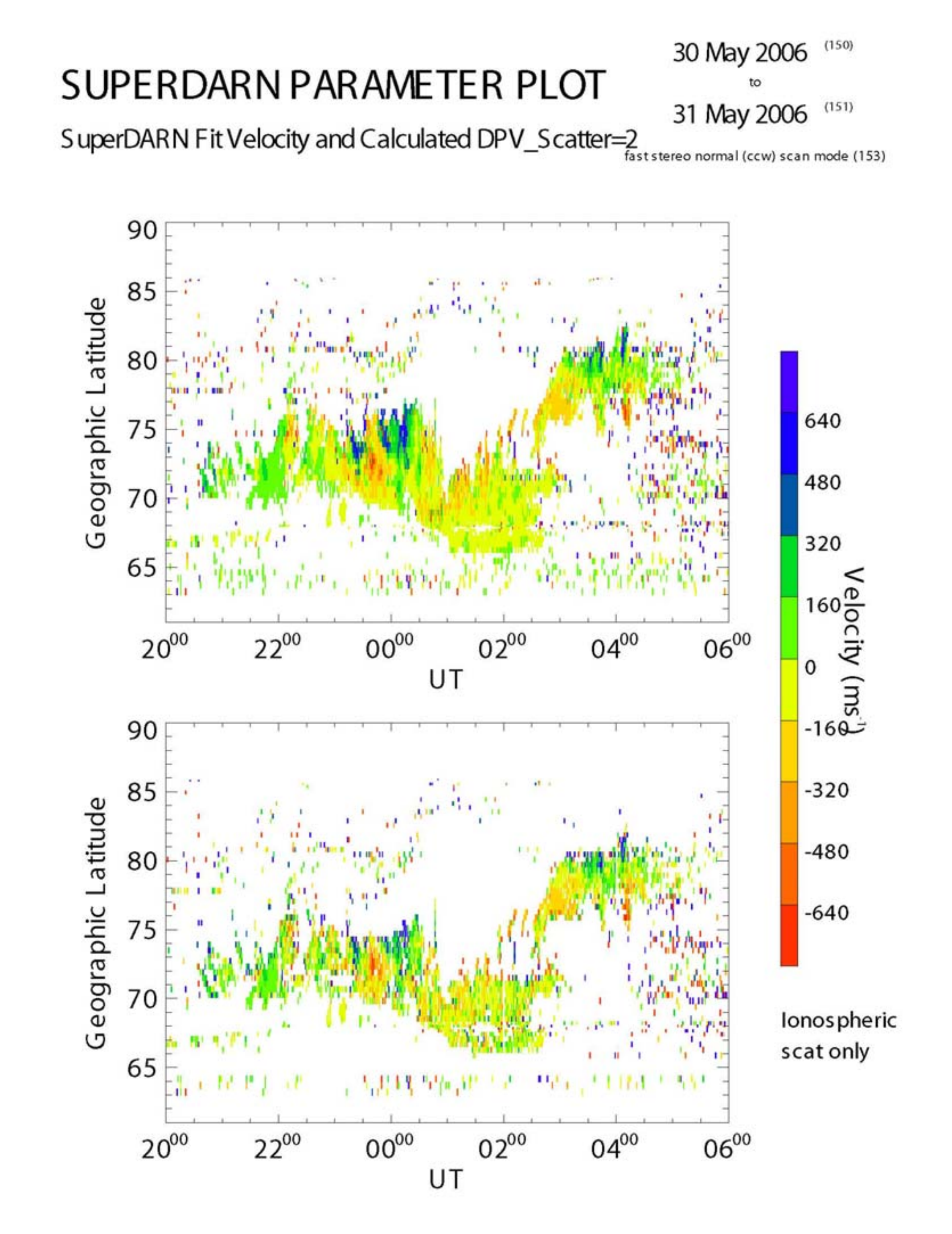
Standard Radar Mode Double Pulse Emulation

- We can see here The DPV plotted vs. SuperDARN fit Velocity
- Notice the good correlation for the Ionospheric scatter



Standard Radar Mode Double Pulse Emulation

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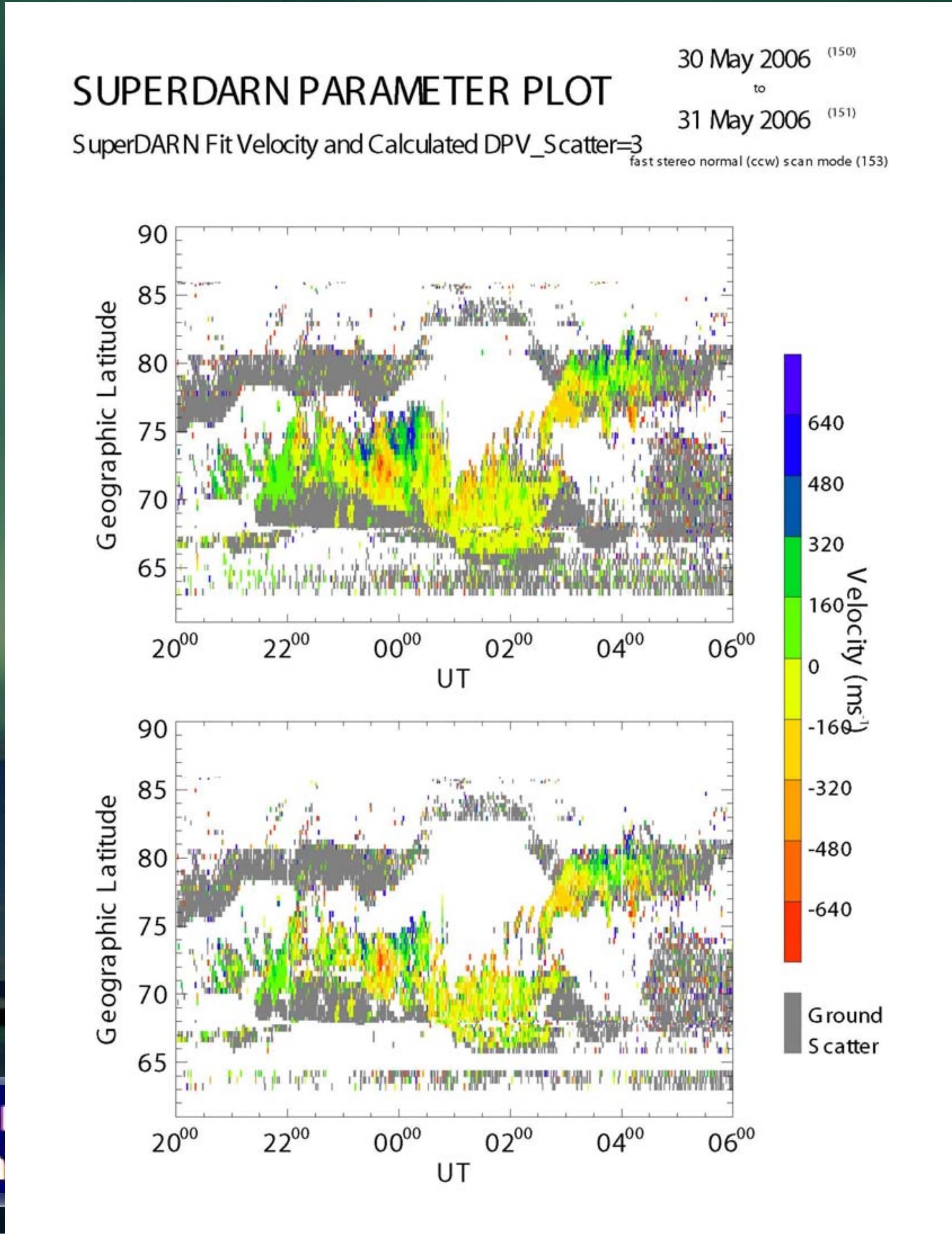

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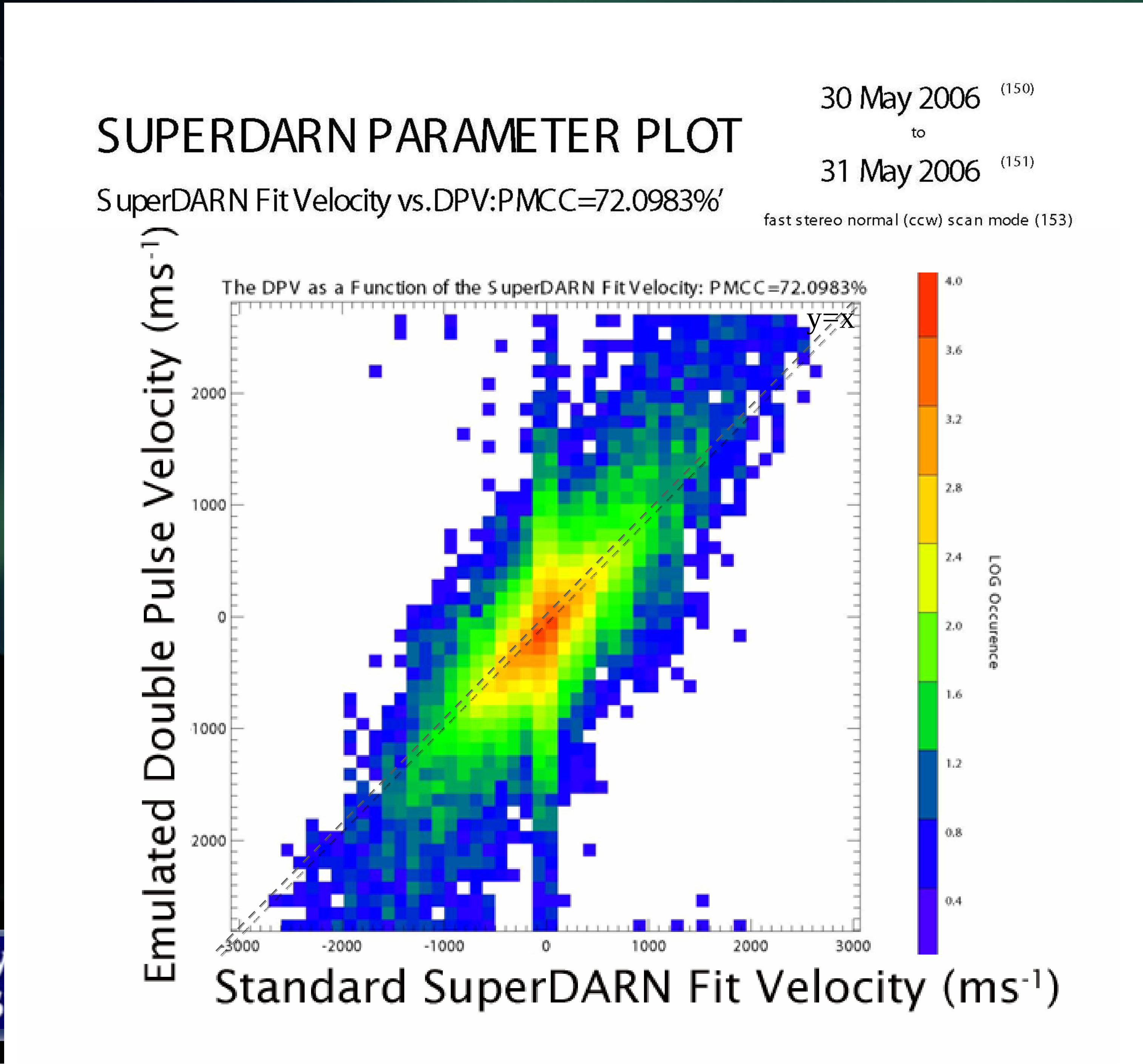
Emulated Double Pulse Velocity for Ionospheric Scatter



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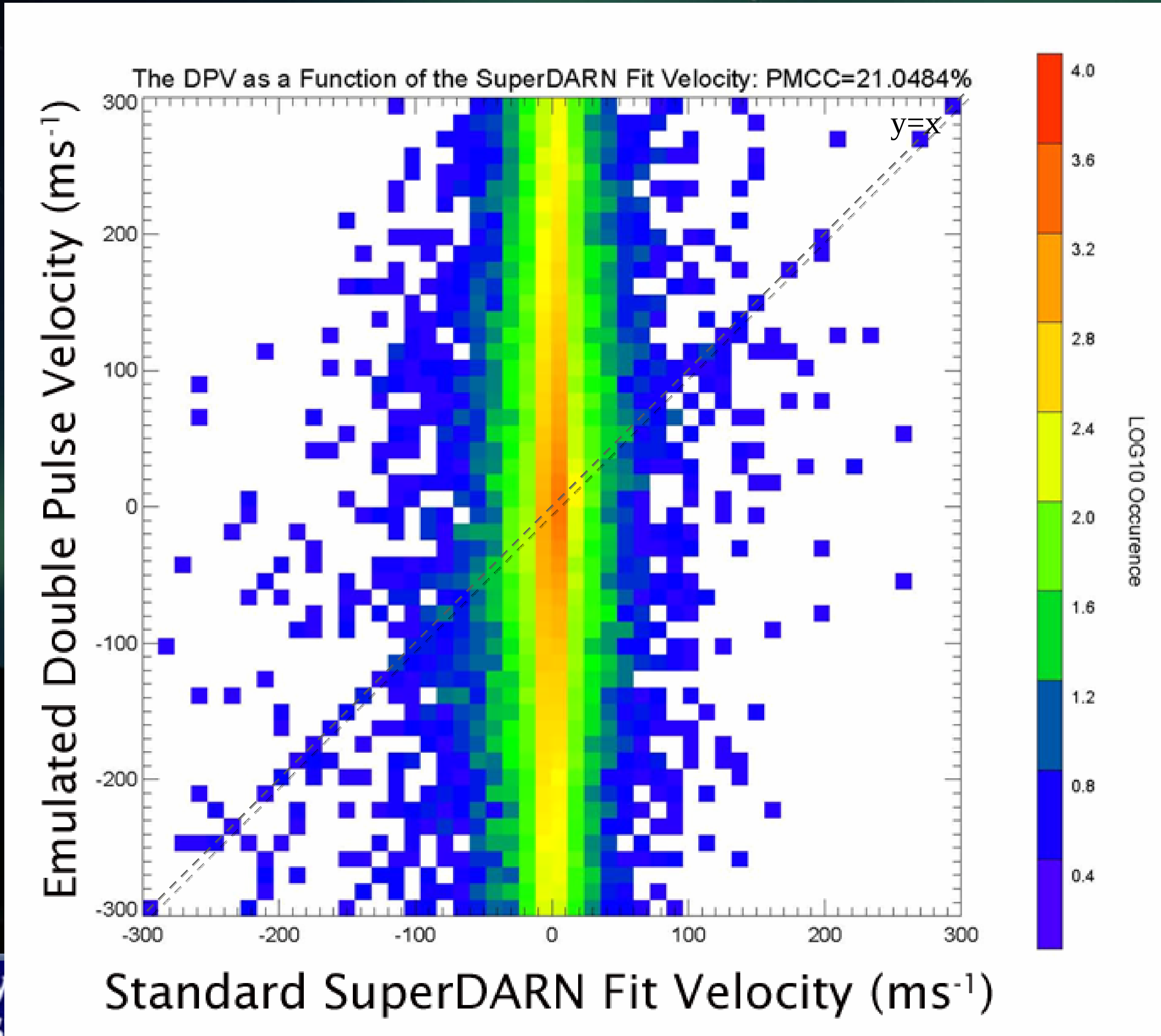
Emulated Double Pulse Velocity for Ground Scatter



University of Leicester

Physics Group

TMS Motivation

- Clearly, fitacf will not work for our double pulse experiment
- To develop a "double pulse" technique we require all the I&Q sample returns.
- Hence, we utilise, TMS (Yukimatu et al., 2002) data
- Adapt the raw time series analysis for study of our system
- Does not degrade the normal SuperDARN ACF observations
- We may want to understand high time resolution phenomena…

Experimental Double Pulse

- A double pulse operational campaign with CUTLASS observing Tromsø heater scatter on 6th March 2008.
- Narrow width
- Single region of powerful backscatter

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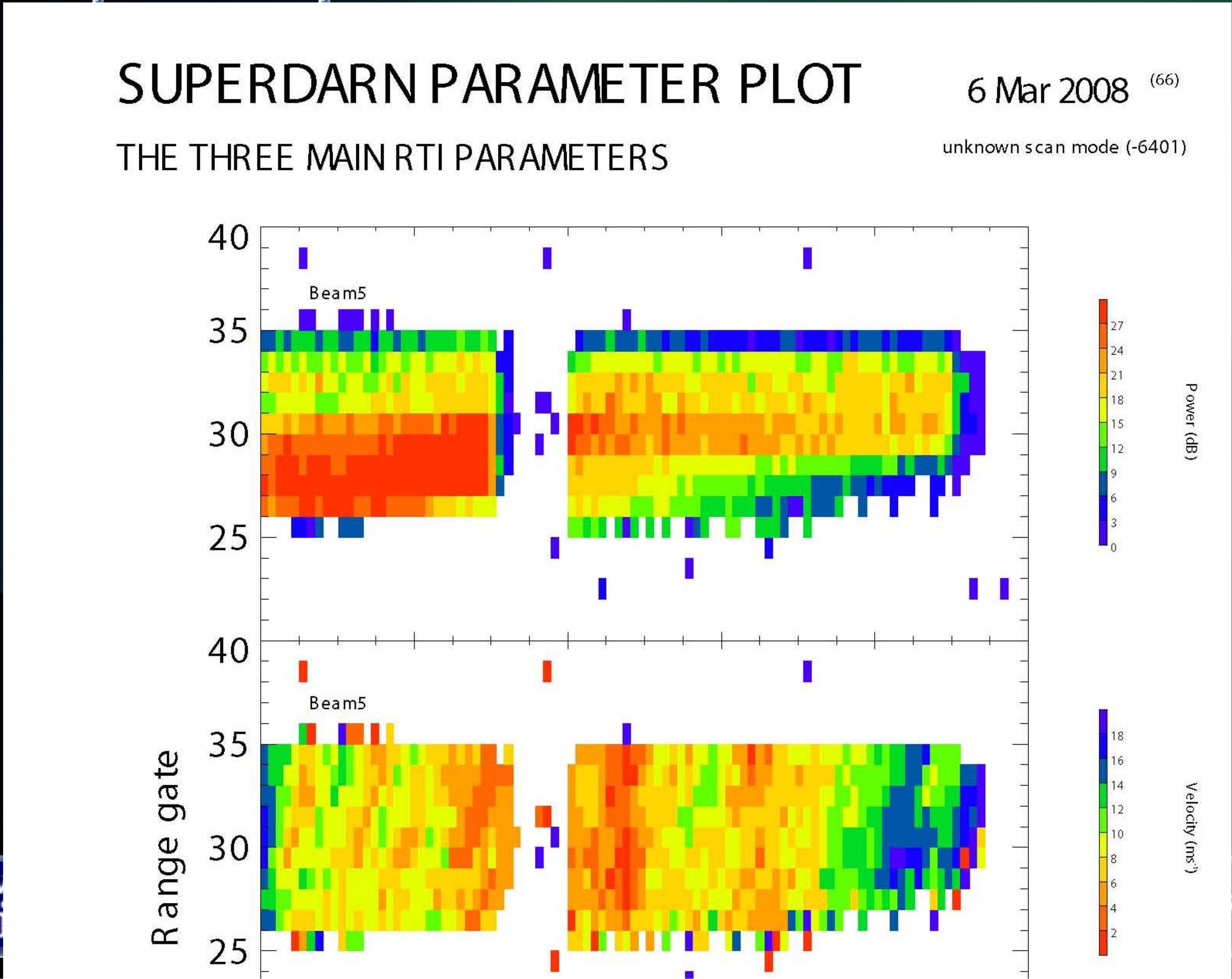
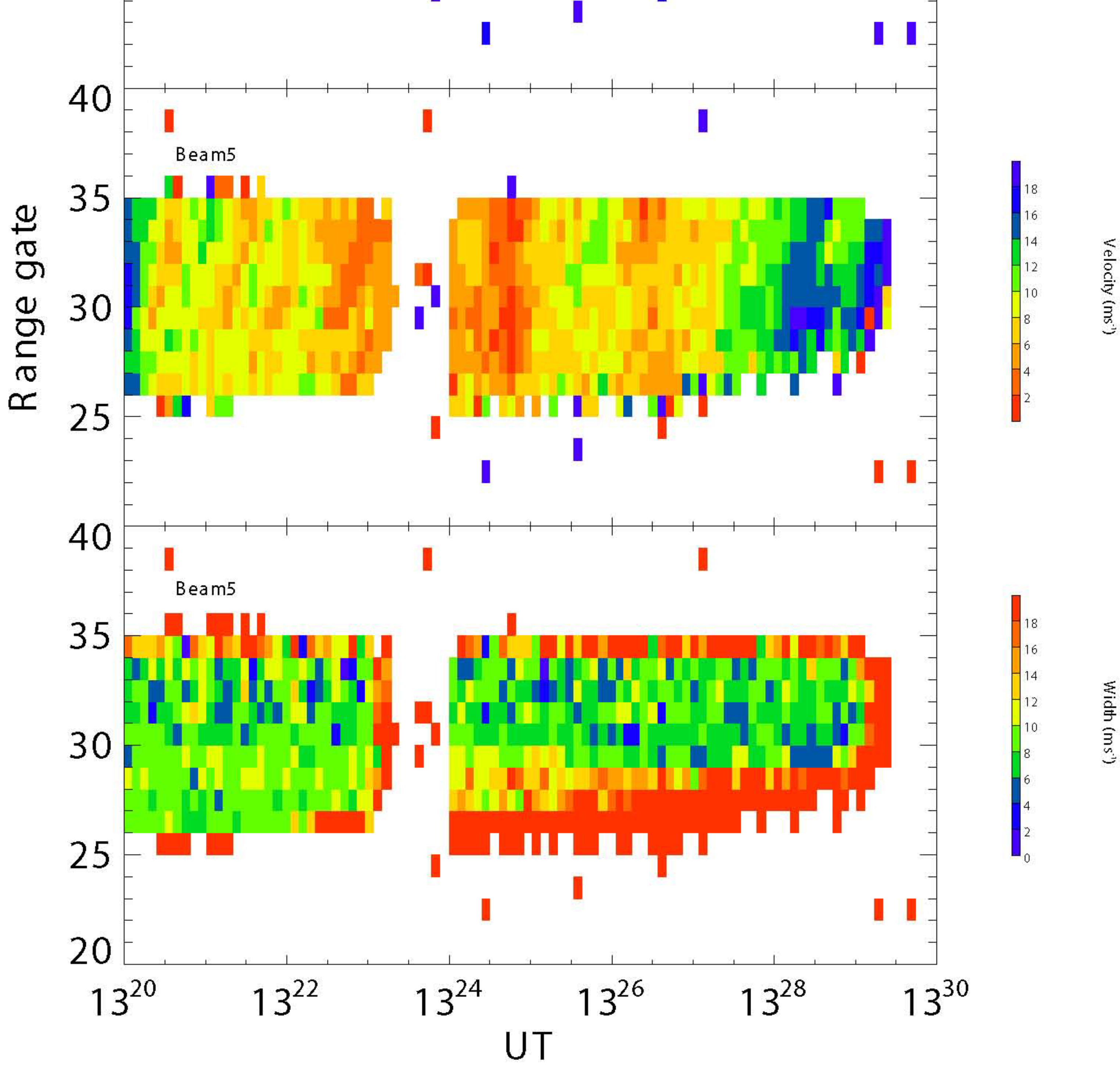
Example SuperDARN Standard Fit Data



Exa ata


Beam5
Beam5
Range gate
40
35
30
25
40
35
30
25
20
13^20
13^22
13^24
13^26
13^28
13^30
UT
Velocity (ms⁻¹)
18
16
14
12
10
8
6
4
2
Width (ms⁻¹)
18
16
14
12
10
8
6
4
2
0

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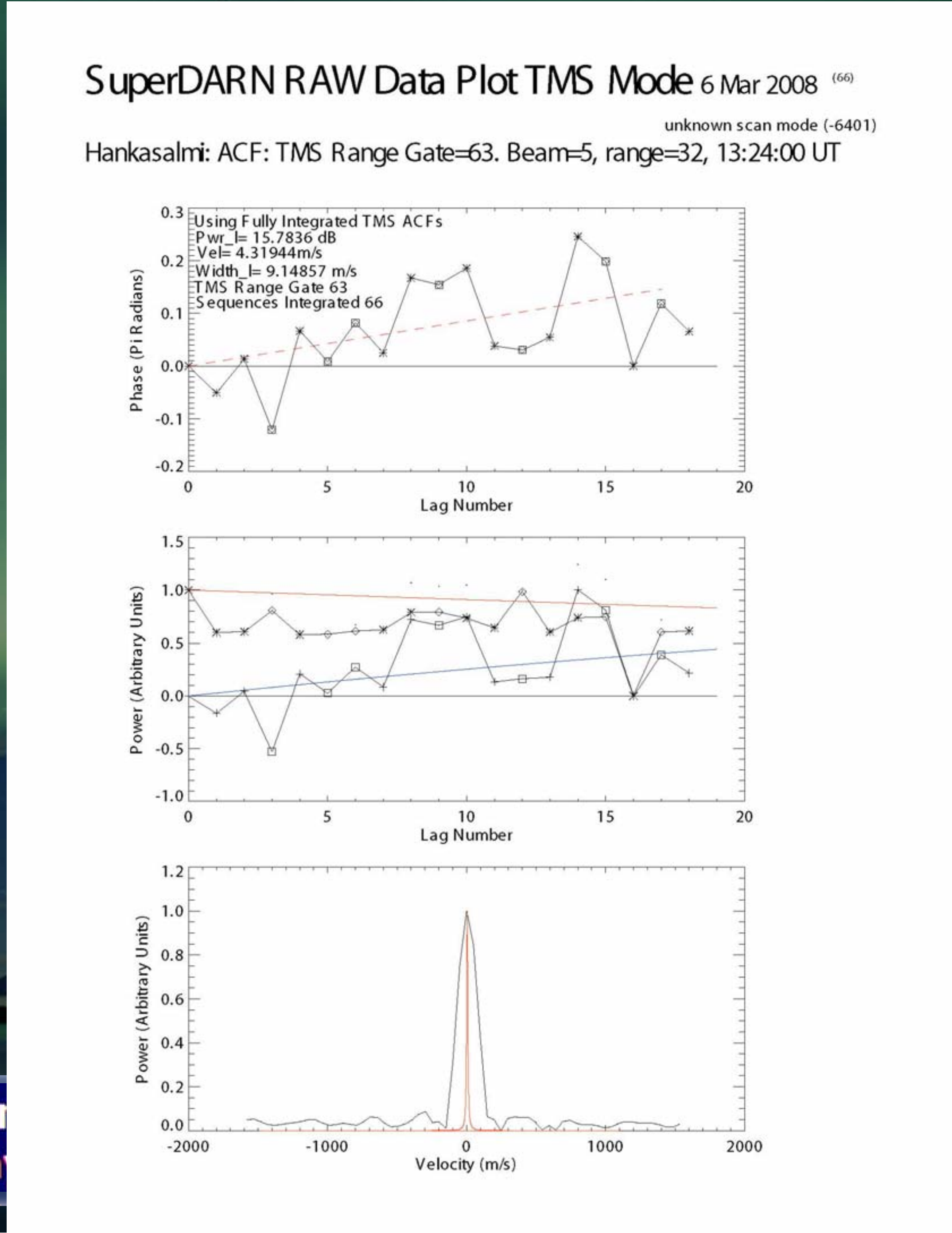
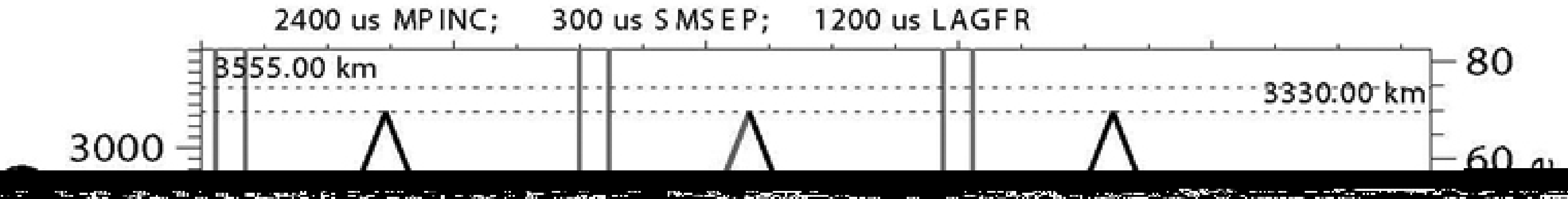
TMS Comparison with fitacf

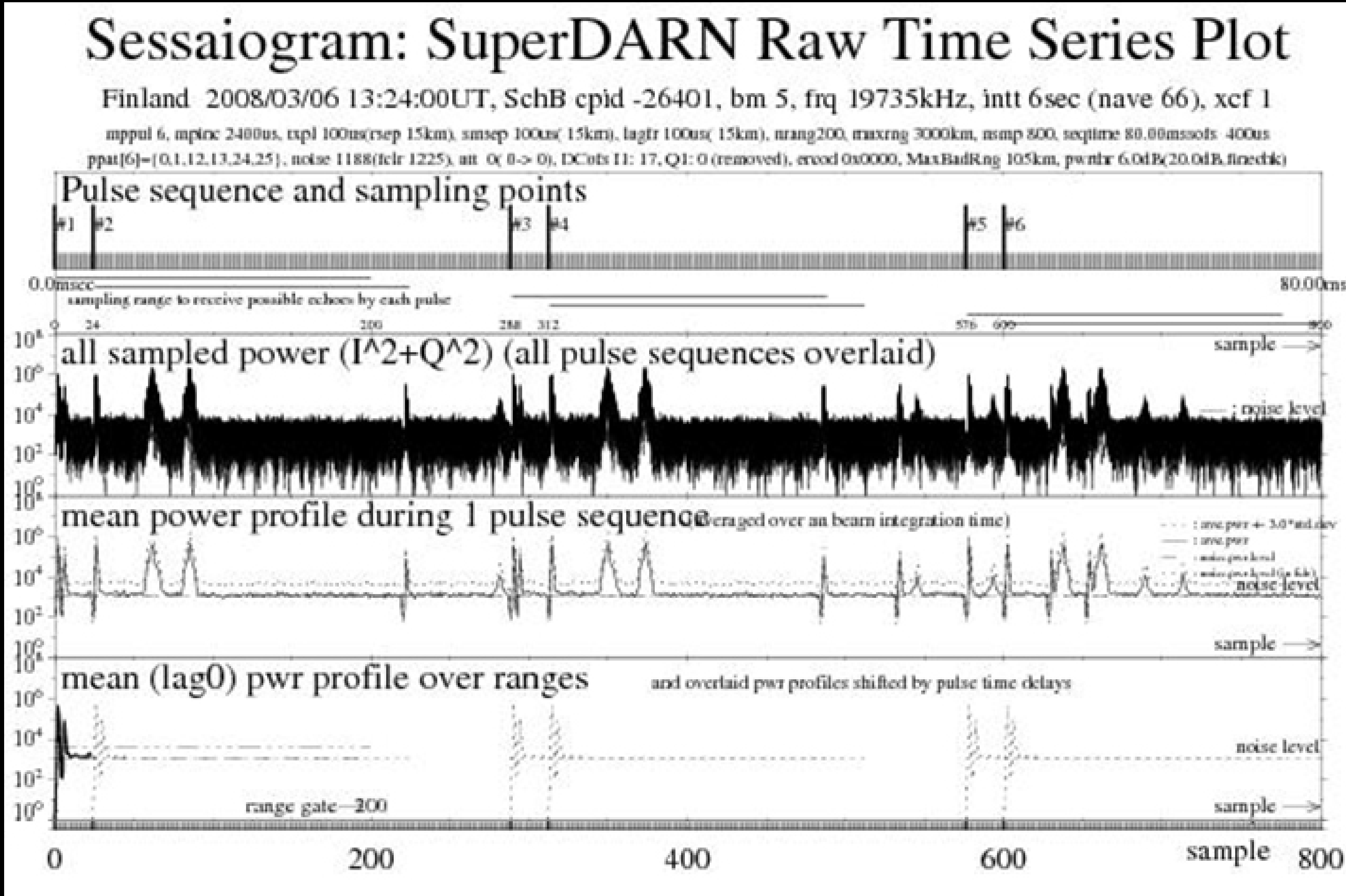
- We see that 66 integrated TMS ACFs (in this case) yield a result that is almost identical to the Fitacf routine.
- Integrating removes noise BUT does this process remove interesting data?
- Ideally, with good data we can use non-integrated TMS double pulse data.



SUPERDARN PARAMETER PLOT

A THREE DOUBLE PULSE SEQUENCE

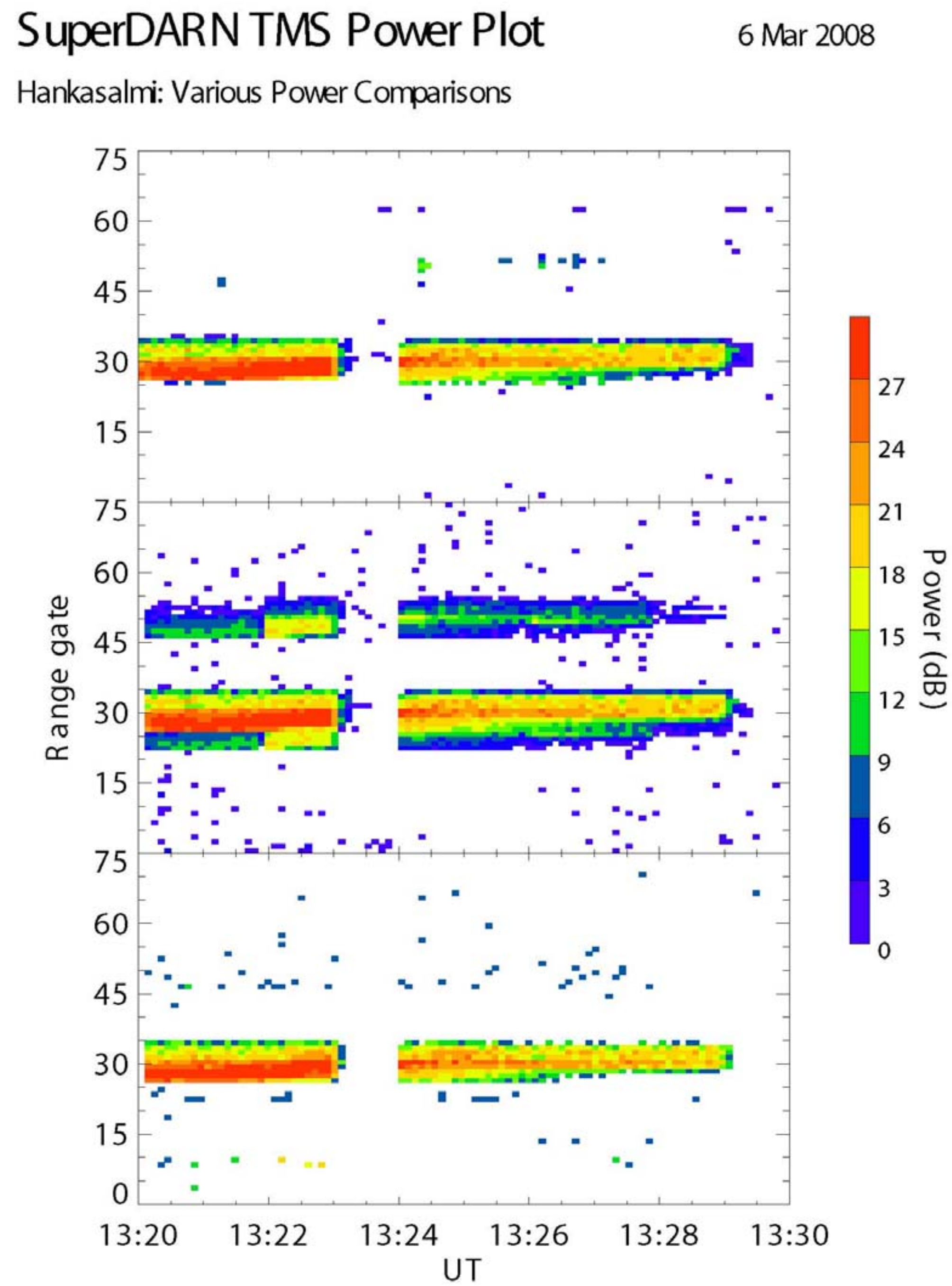



Sessaiogram: SuperDARN Raw Time Series Plot
Finland 2008/03/06 13:24:00UT, SchB cpid -26401, bm 5, frq 19735kHz, intt 6sec (nave 66), xcf 1
mppul 6, mpinc 2400us, txpl 100us(rsep 15km), smsep 100us(15km), lagfr 100us(15km), nrang200, maxrng 3000km, nsmp 800, seqtime 80.00mssofs 400us
ppat[6]={0,1,12,13,24,25}, noise 1188(fclr 1225), att 0(0-> 0), DCofs I1: 17, Q1: 0 (removed), ercod 0x0000, MaxBadRng 105km, pwrthr 6.0dB(20.0dB,firechk)
Pulse sequence and sampling points
#1
#2
#3
#4
#5
#6
0.0msec
80.00ms
sampling range to receive possible echoes by each pulse
all sampled power (I^2+Q^2) (all pulse sequences overlaid)
sample →
: noise level
mean power profile during 1 pulse sequence (averaged over an beam integration time)
noise level
sample →
mean (lag0) pwr profile over ranges
and overlaid pwr profiles shifted by pulse time delays
noise level
range gate→200
sample →
0
200
400
600
800
sample

ChA Standard Fitdata

Integrated TMS Data
Unconvolved

ChB with Power
Deconvolution Applied
(Double Pulse)



ChA Standard Radar Mode Fitdata

ChA Standard Radar Mode dat data

ChA Integrated TMS data

ChA Emulated Double Pulse (dat data)

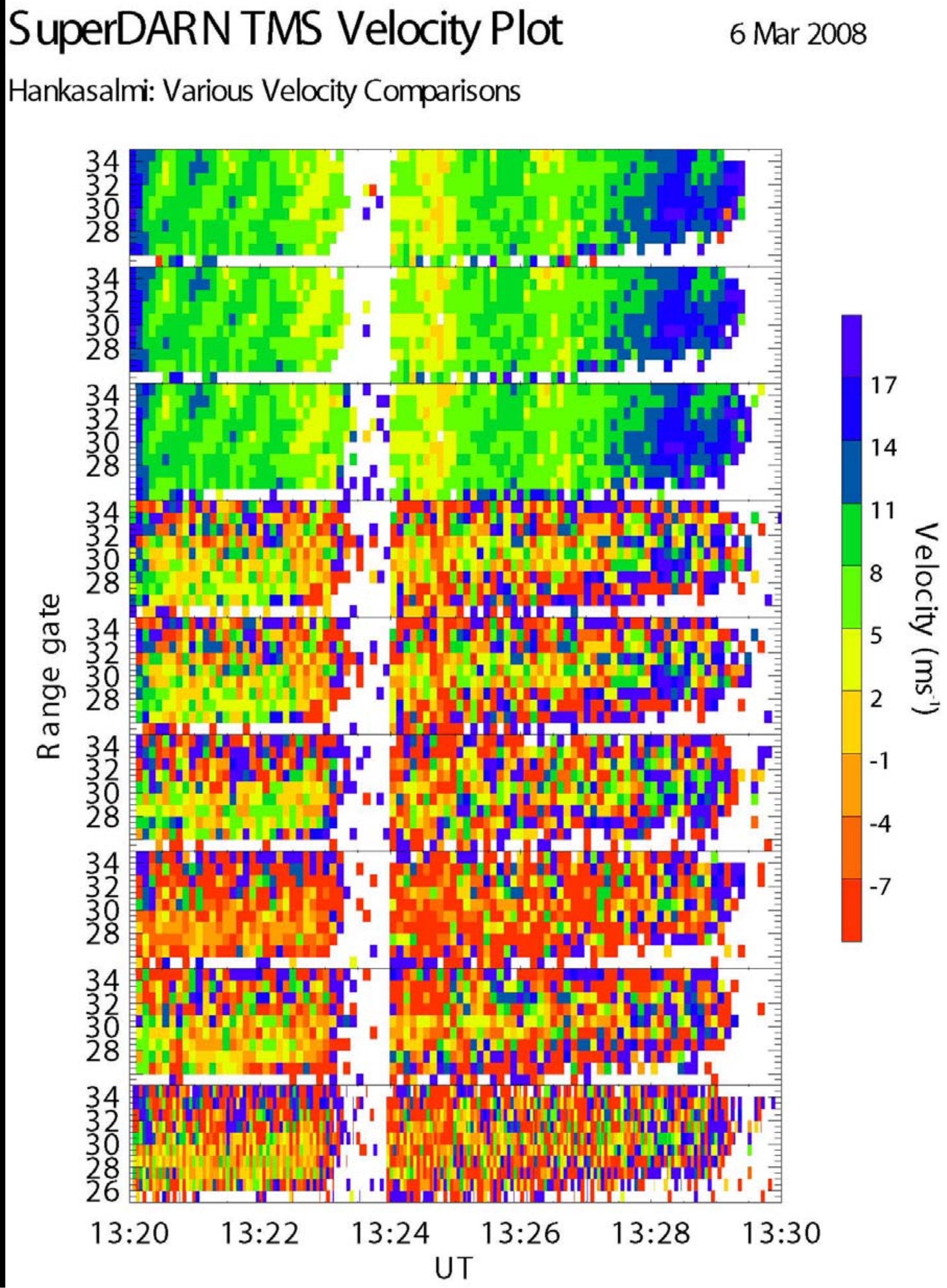
ChA Emulated Double Pulse (TMS data)

ChB Double Pulse P1&2 data

ChB Double Pulse P3&4 data

ChB Double Pulse P5&6 data

ChB 3x Temporal Resolution



Conclusions- Emulation Double Pulse

- Firstly, we investigated a comparison between the standard SuperDARN fit velocity and the calculated DPV
- We demonstrated that while the DPV can yield results similar to the SuperDARN Fit velocity, it really has to be run in conjunction with the standard mode
- The DPV method yields an impressive data set for the ionospheric scatter, however, the DPV method struggles with ground scatter due to a noise issue. (i.e. Slow plasma convection velocities)

Conclusions- Experimental Double Pulse

- We have also conducted a preliminary investigation into the workings of TMS data from SuperDARN
- We have shown that a direct integration of individual ACFs (each 100ms pulses) yields a result almost identical to the standard ACF from fitacf
- Our results of the double pulse technique demonstrate that double pulse requires high ionospheric convection velocities to be an effective measurement tool.
- However, we have shown a proof of concept that the general method works and we can, to a certain degree, increase our temporal resolution by a factor of three.
- And we can deconvolve the power returns such that we can form a reasonable lag zero power…

Future Work

- Perform analysis of other TMS Double pulse intervals using the raw time series analysis technique.