The New Digisonde:

DPS-4D

B Reinisch, I Galkin, G Khmyrov, K Bibl,
I Lisysyan, A Kozlov, G Cheney, Y Luo,
D Kitrosser, R Hamel, V Paznukhov, J Grochmal

University of Massachusetts Lowell
Environmental, Earth, & Atmospheric Sciences Department
Center for Atmospheric Research

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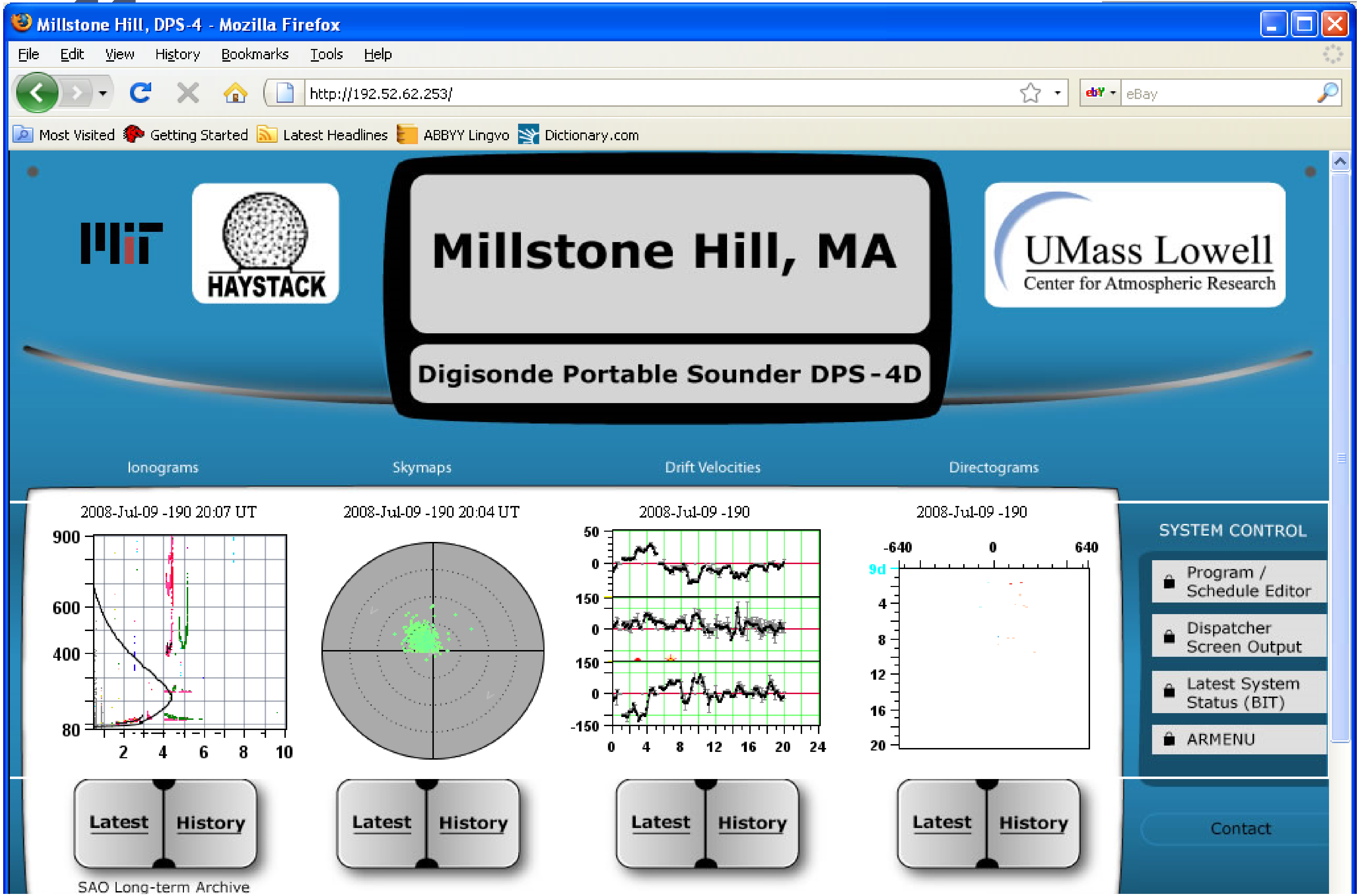
Important Issues for Ionosondes

- High quality ionograms
- Real time autoscaling and EDPs
- Standardized format of user data (SAOXML)
- Real time data dissemination
- Remote control
- Flexibility for research and campaigns
- Analysis software tools
- Low transmit power for reduced RFI
- Ease of maintenance

New Face of the DPS



History of the Digisonde Development

Starting in 1969

- Digisondes 128, 128P, 128PS
- Digisondes 256, including DISS
- DPS
- DPS-4D

Today: Majority of Digisondes report in real time data and EDPs to Data Centers like

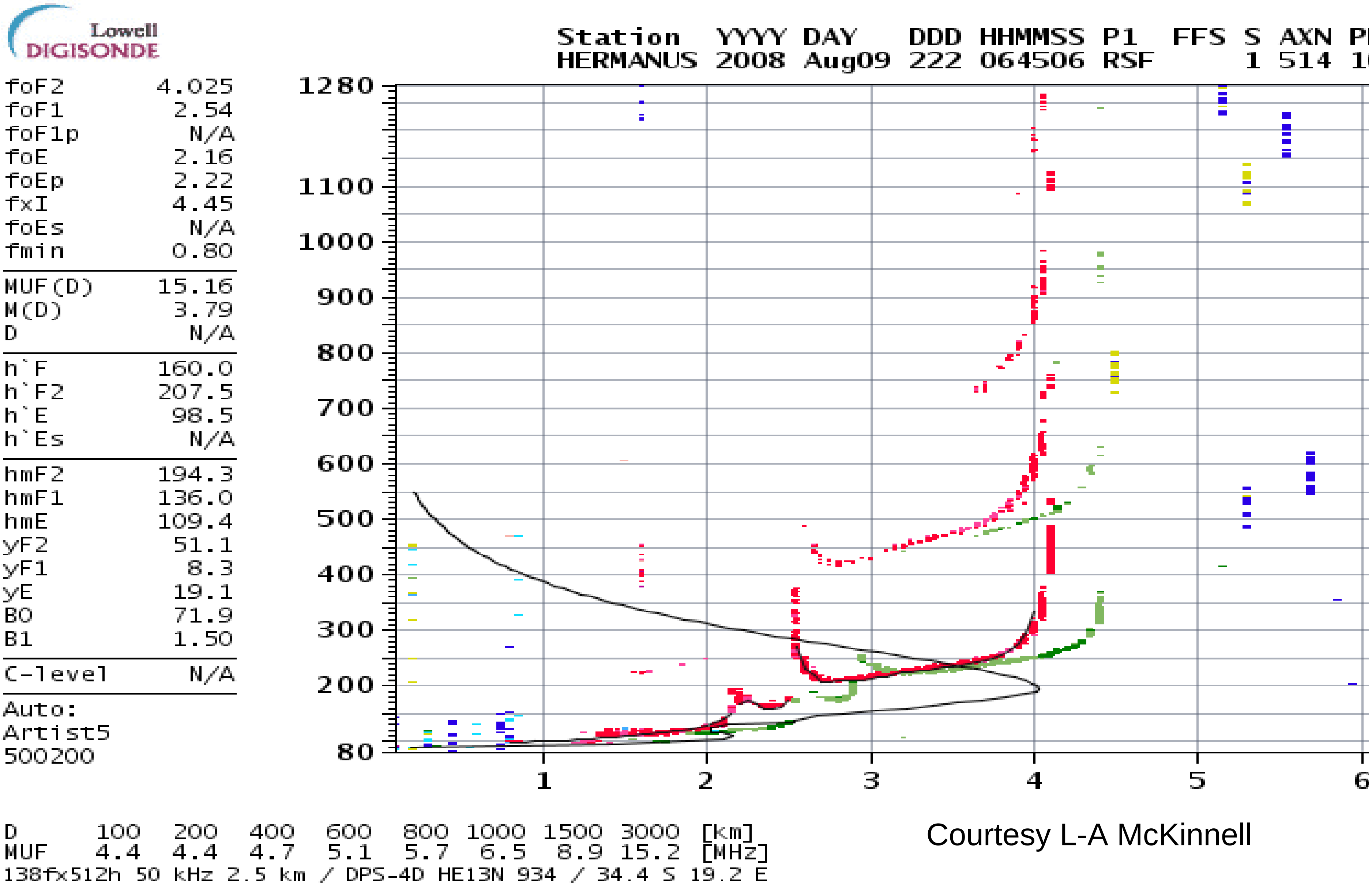
- Digital Ionogram Data Base "DIDBase" at UML
- World Data Center, Boulder → NOAA SPIDR
- World Data Center, London
- US AFWA → GAIM
- DIAS / COST
- COST 251 Vertical Incidence Sounding Database

Digisonde Network

4D installations in 2008:

http://ulcar.uml.edu/DIDBase/

Hermanus, South Africa, 9 Aug 2008



Courtesy L-A McKinnell

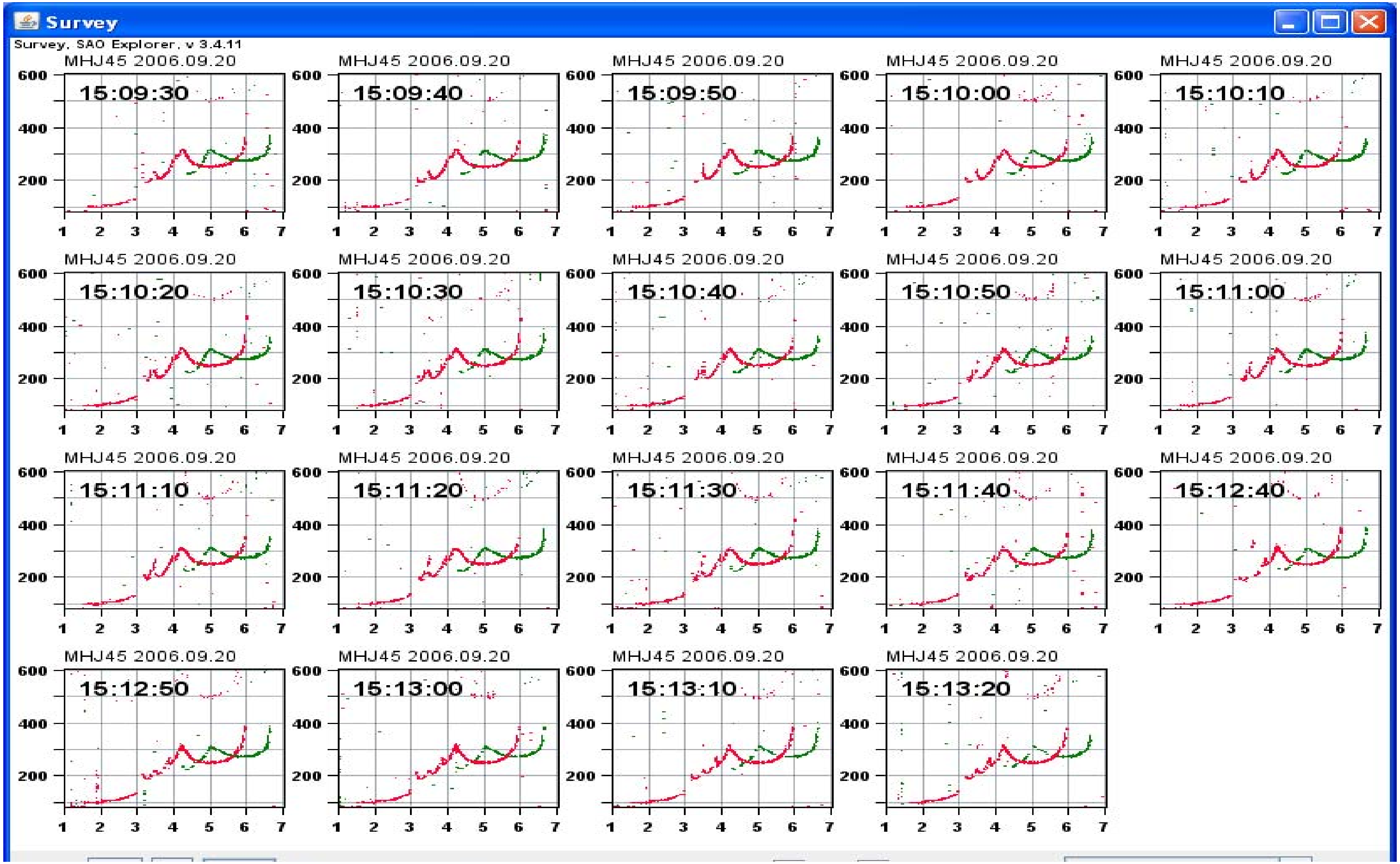
Summary of DPS Key Features

- 2x150 W low-power solid-state transmitters with half octave filters reduce RFI
- Circular polarized transmission/reception identify O and X echoes
- Four-element receiving antenna array identifies angles of arrival
- Multiple levels of DSP:
  - Spread spectrum transmission
  - Phase-coded waveform for pulse compression
  - Doppler spectrum analysis (2, 4, …, 128 pulse sequence)
  - Precise radar range measurements with bi-frequency transmission
- Remote commanding & real time data dissemination
- Remote diagnostic with Built-In-Test (BIT)
- ARTIST autoscaling and EDPs

DPS-4D Innovations (1)

- **Digital transceiver technology**
  - Superior accuracy, precision, and resolution of amplitude and phase measurements
    - **16 bit ADCs and receivers**
    - **Improved angle of arrival processing**
    - **High resolution h'(f) in routine operation**
- **High speed interfaces between embedded processors**
  - **Time domain raw-data output for user processing**
  - **New RFI Mitigation technique improves SNR by up to 40 dB**
  - **Passive mode for monitoring transmitters-of-opportunity**
  - **Faster measurements (2-second ionograms)**

Millstone Hill: 2-second ionograms,10 sec cadence

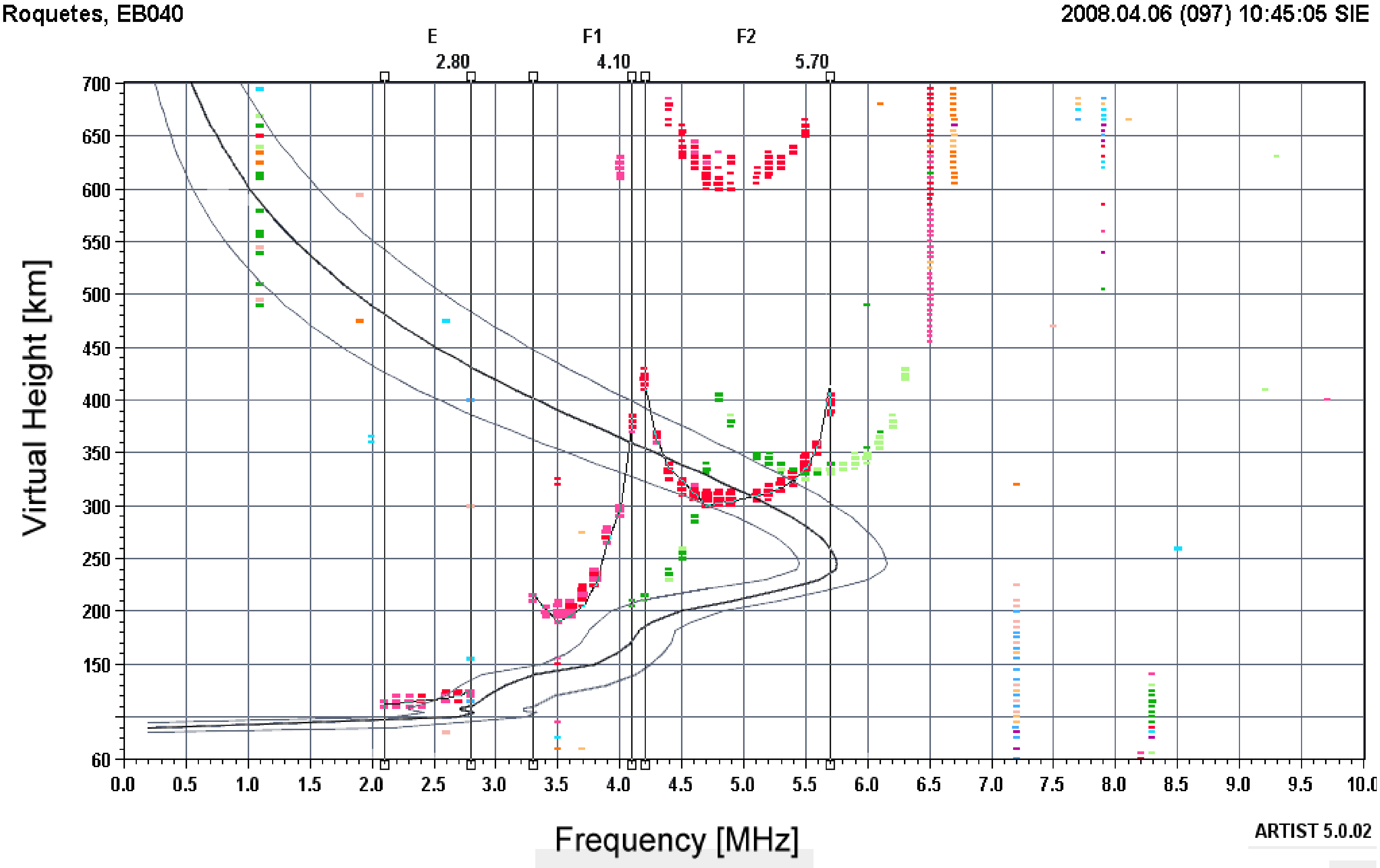


DPS-4D Innovations (2)

New embedded software

- Real-time operating system RTEMS
  - Superior clarity, reliability, scalability, quality control, and technical support of the code
- Java environment for online data processing
  - Superior development tools and graphics libraries
  - Reusable code from and for other projects
    - **SAO and Drift Explorers,**
    - **ARTIST- 5 with profile error bars,**
    - **DIDBase and Drift-Base**
  - Superior visualization, control, and debugging environment for DPS operations
    - Data capture, replay for processing, interim data
    - Stepping through processing stages
    - Operational logs for troubleshooting

Profile Error Bounds



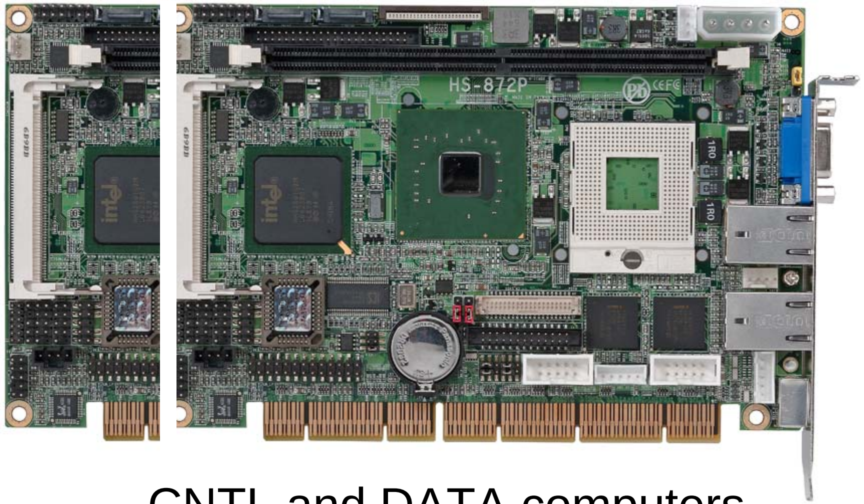
New Hardware

Transmitter/Timing

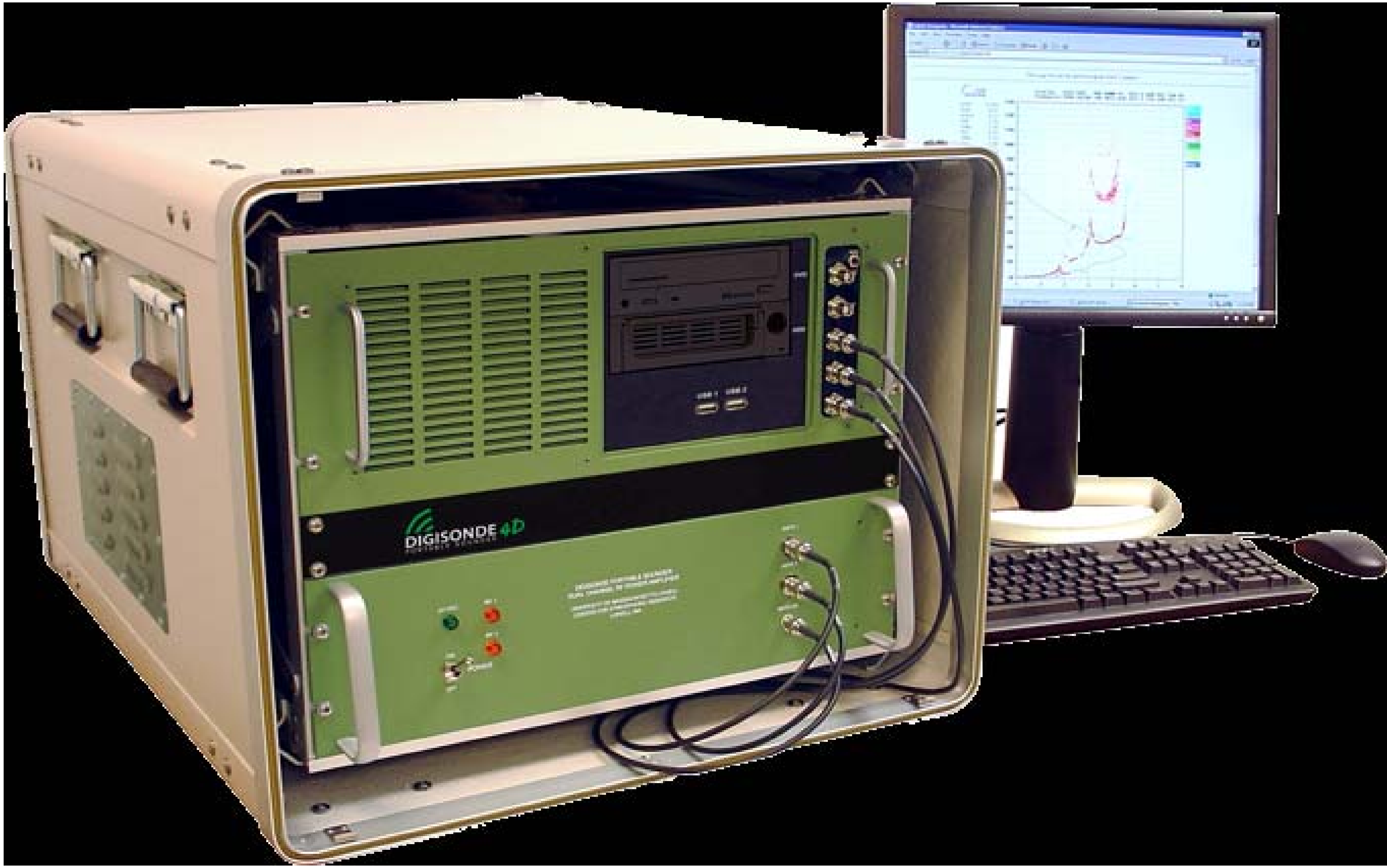
8-Channel Receiver

Preprocessor

Four tracking bandpass filters



CNTL and DATA computers


DIGISONDE 4D

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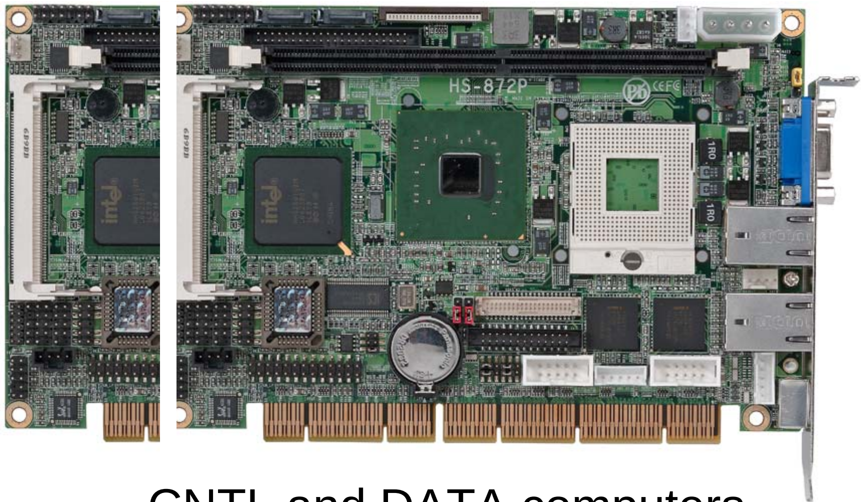
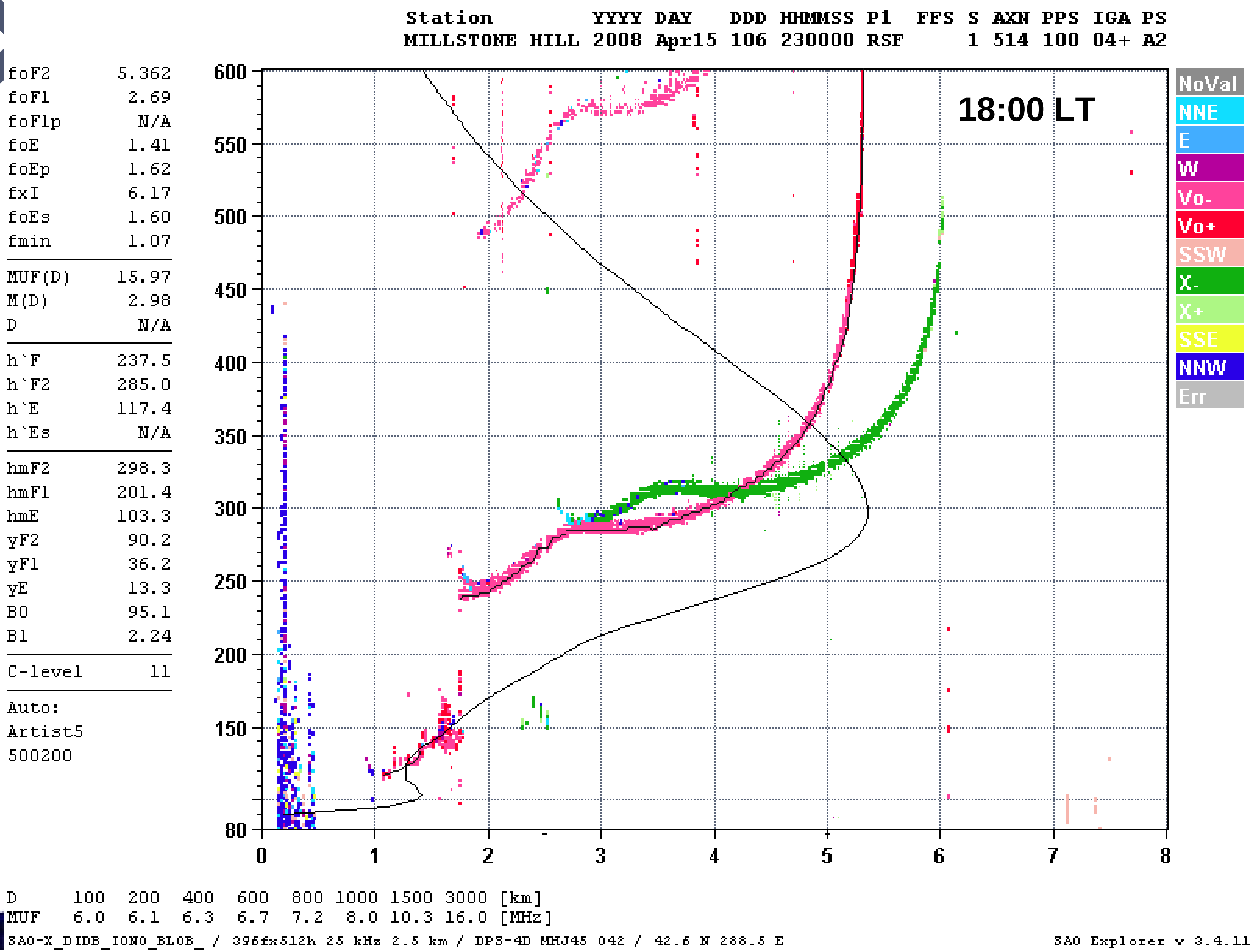
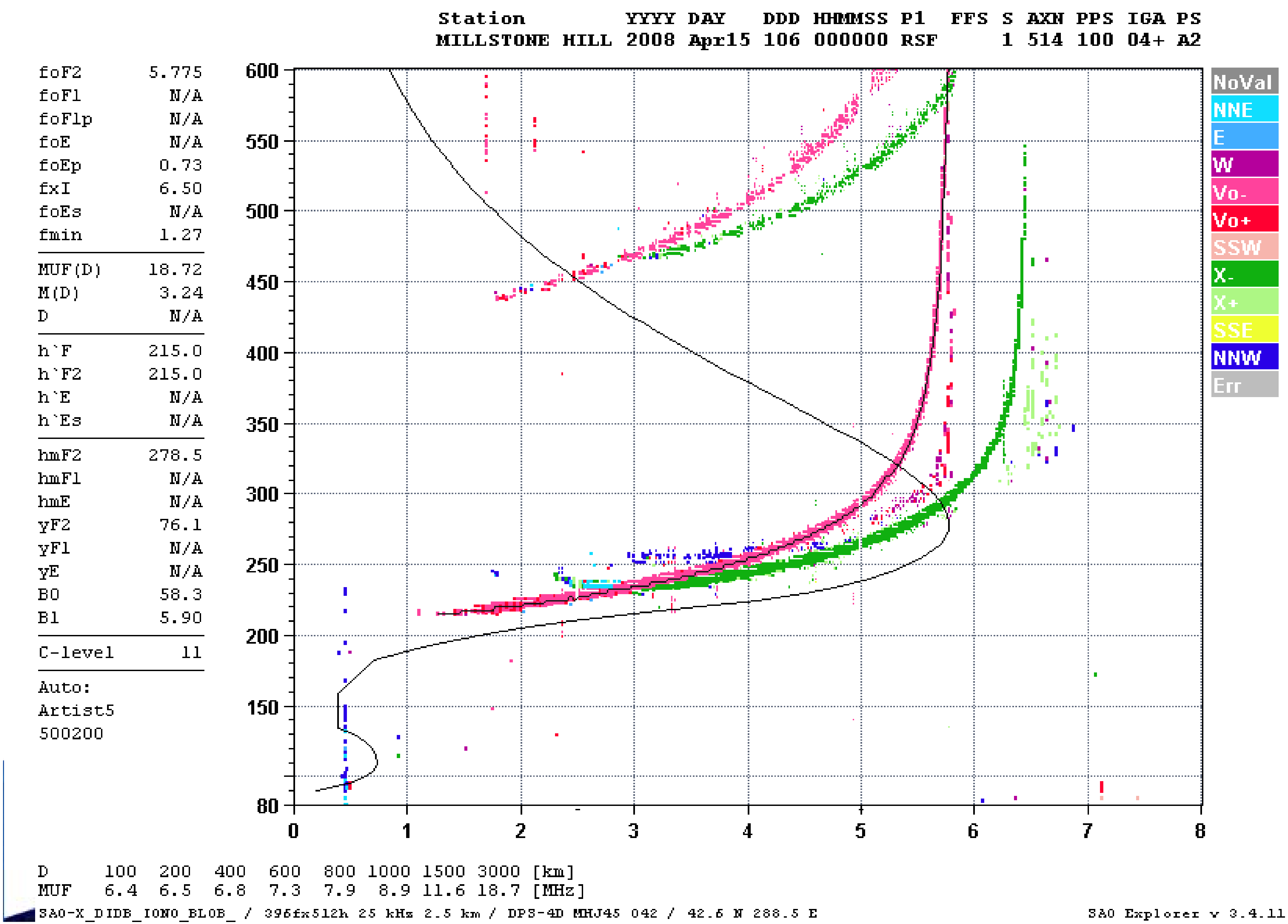


CNTL and DATA computers


Station YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
MILLSTONE HILL 2008 Apr15 106 230000 RSF 1 514 100 04+ A2
18:00 LT
foF2 5.362
foF1 2.69
foF1p N/A
foE 1.41
foEp 1.62
fxI 6.17
foEs 1.60
fmin 1.07
MUF(D) 15.97
M(D) 2.98
D N/A
h`F 237.5
h`F2 285.0
h`E 117.4
h`Es N/A
hmF2 298.3
hmF1 201.4
hmE 103.3
yF2 90.2
yF1 36.2
yE 13.3
B0 95.1
B1 2.24
C-level 11
Auto:
Artist5
500200
600
550
500
450
400
350
300
250
200
150
80
0 1 2 3 4 5 6 7 8
NoVal
NNE
E
W
Vo-
Vo+
SSW
X-
X+
SSE
NNW
Err
D 100 200 400 600 800 1000 1500 3000 [km]
MUF 6.0 6.1 6.3 6.7 7.2 8.0 10.3 16.0 [MHz]
SAO-X_DIDB_IONO_BLOB_ / 396fx512h 25 kHz 2.5 km / DPS-4D MHJ45 042 / 42.6 N 288.5 E
SAO Explorer v 3.4.11


Station YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
MILLSTONE HILL 2008 Apr15 106 000000 RSF 1 514 100 04+ A2
foF2 5.775
foF1 N/A
foF1p N/A
foE N/A
foEp 0.73
fxI 6.50
foEs N/A
fmin 1.27
MUF(D) 18.72
M(D) 3.24
D N/A
h`F 215.0
h`F2 215.0
h`E N/A
h`Es N/A
hmF2 278.5
hmF1 N/A
hmE N/A
yF2 76.1
yF1 N/A
yE N/A
B0 58.3
B1 5.90
C-level 11
Auto:
Artist5
500200
NoVal
NNE
E
W
Vo-
Vo+
SSW
X-
X+
SSE
NNW
Err
600
550
500
450
400
350
300
250
200
150
80
0 1 2 3 4 5 6 7 8
D 100 200 400 600 800 1000 1500 3000 [km]
MUF 6.4 6.5 6.8 7.3 7.9 8.9 11.6 18.7 [MHz]
SAO-X_DIDB_IONO_BLOB_ / 396fx512h 25 kHz 2.5 km / DPS-4D MHJ45 042 / 42.6 N 288.5 E
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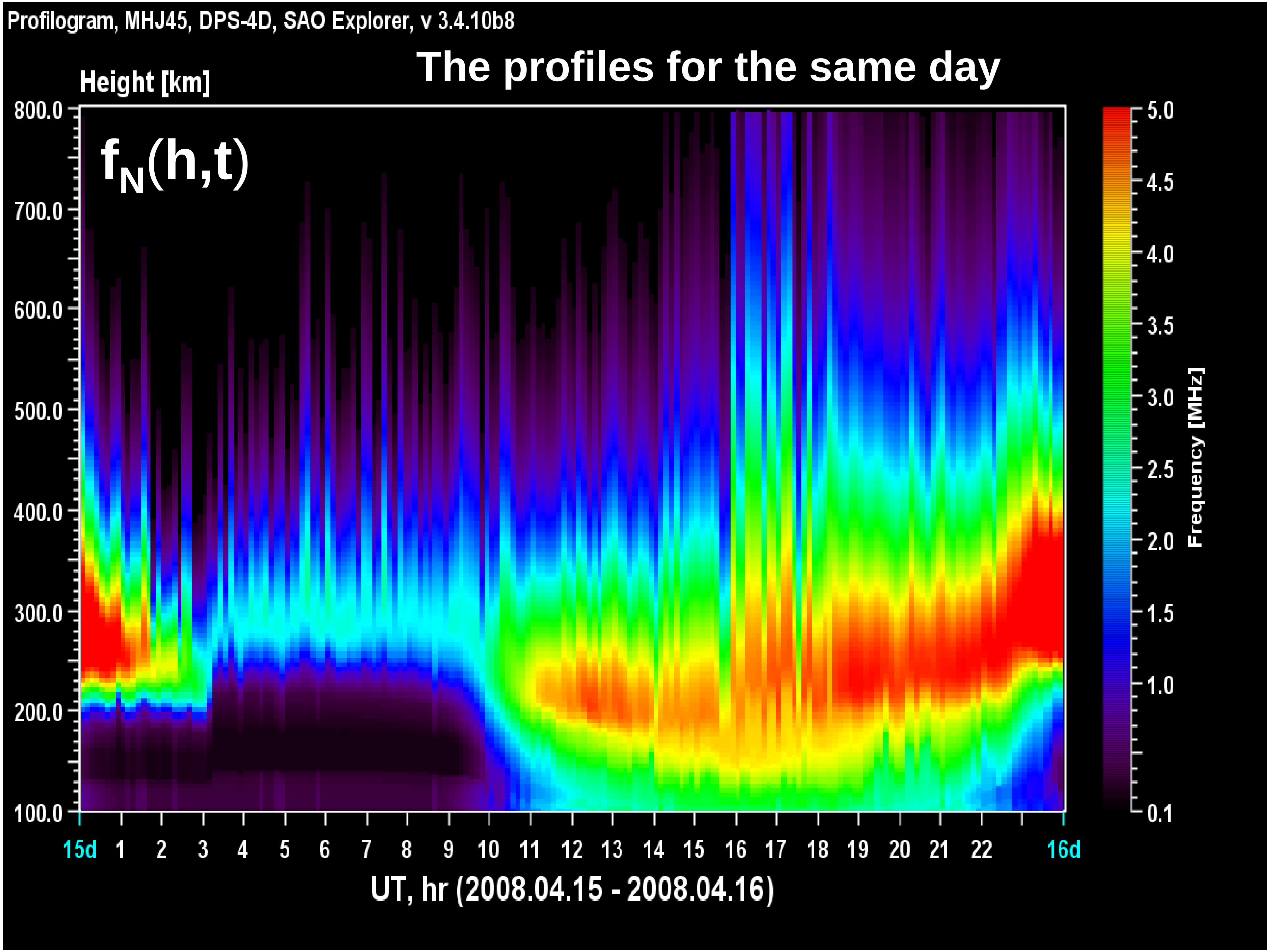


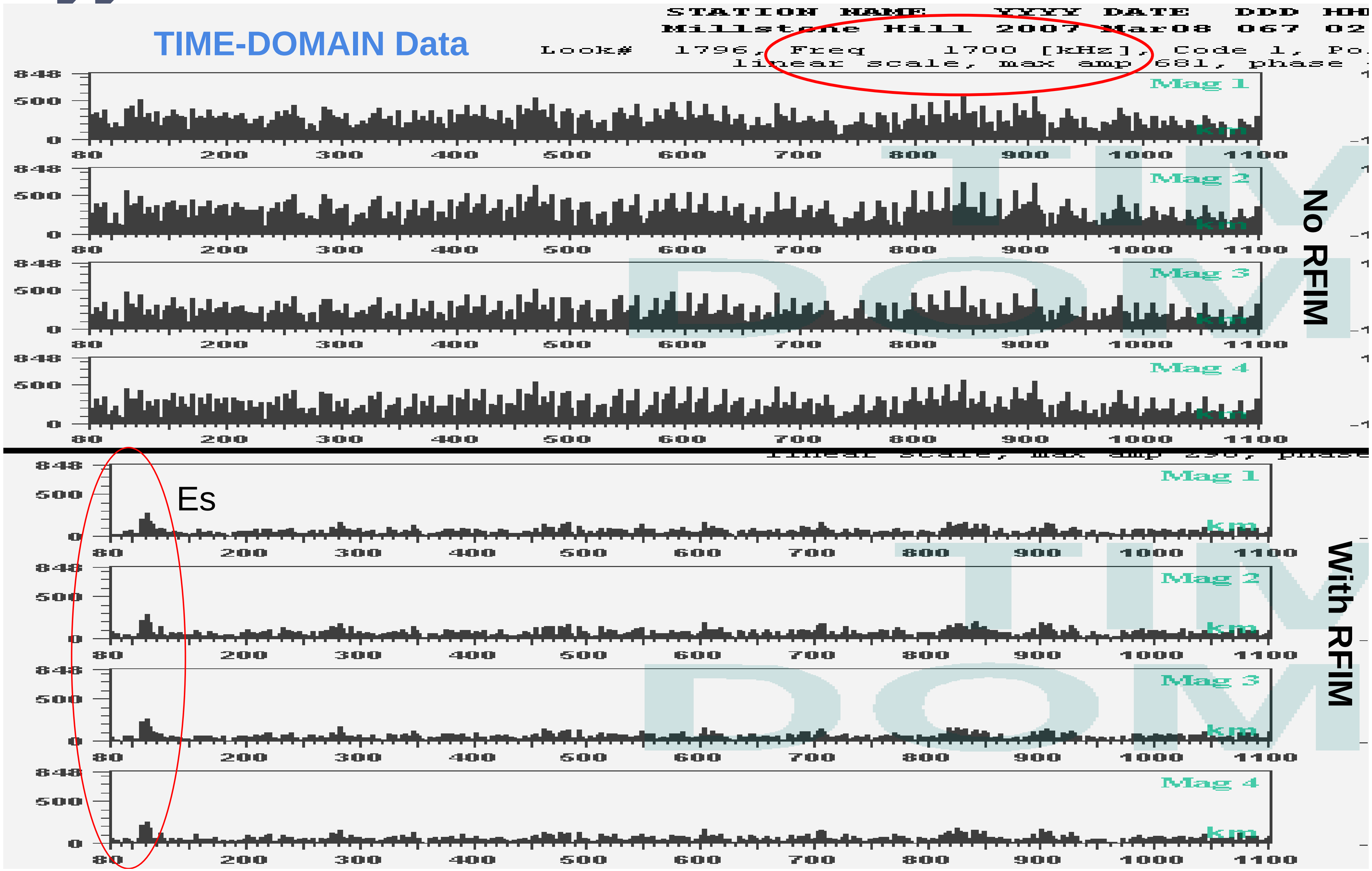
Profilogram, MHJ45, DPS-4D, SAO Explorer, v 3.4.10b8
The profiles for the same day
Height [km]
$f_N(h,t)$
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
15d 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 16d
UT, hr (2008.04.15 - 2008.04.16)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.1
Frequency [MHz]

RF Interference Mitigation Algorithm RFIM (patented)

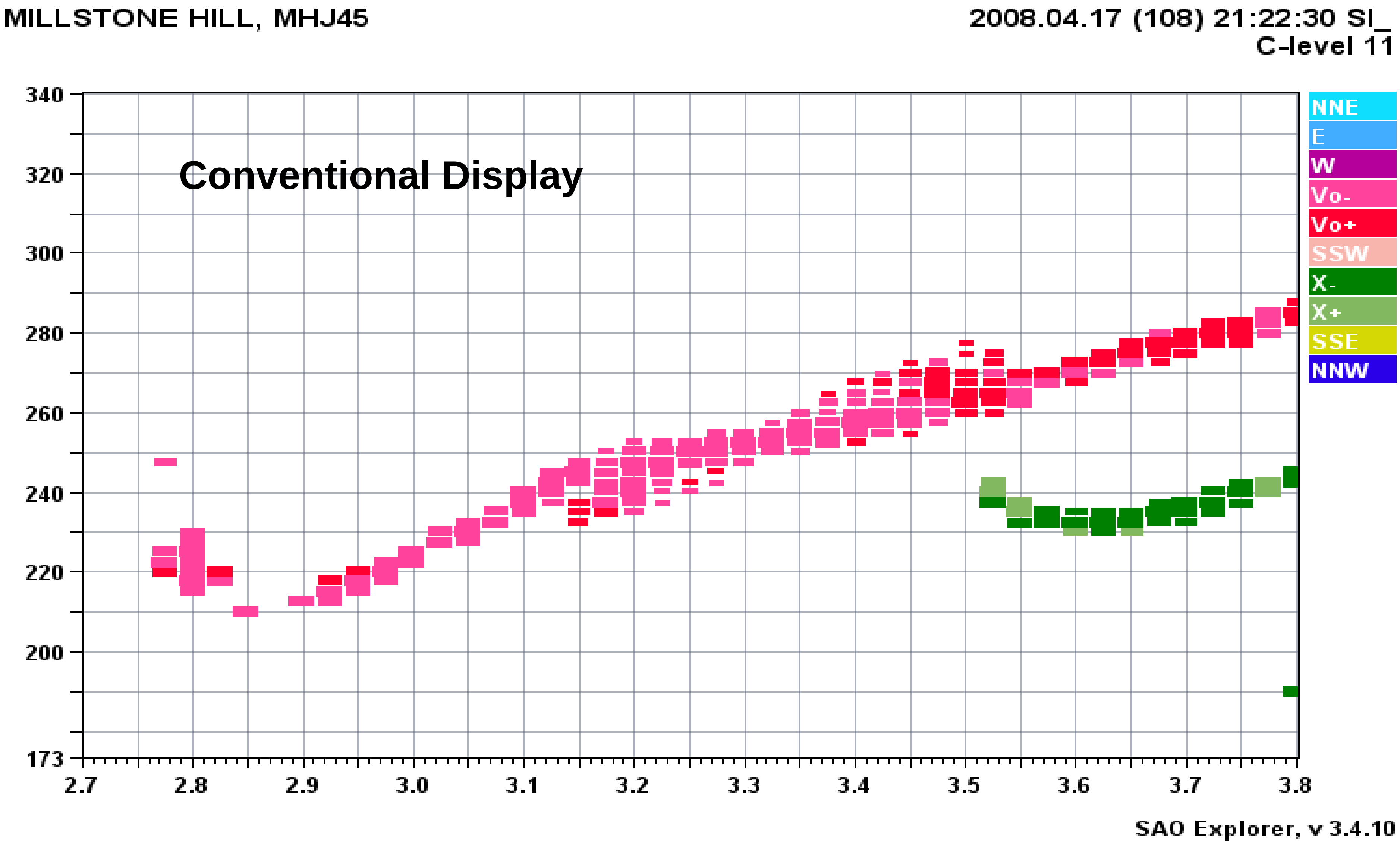
1. For strongest interferer: determine **precise** frequency, amplitude, and phase
2. Subtract the interferer signal from input data
3. Proceed with second strongest interferer
4. Etc. …

~40 dB signal-to-noise enhancement

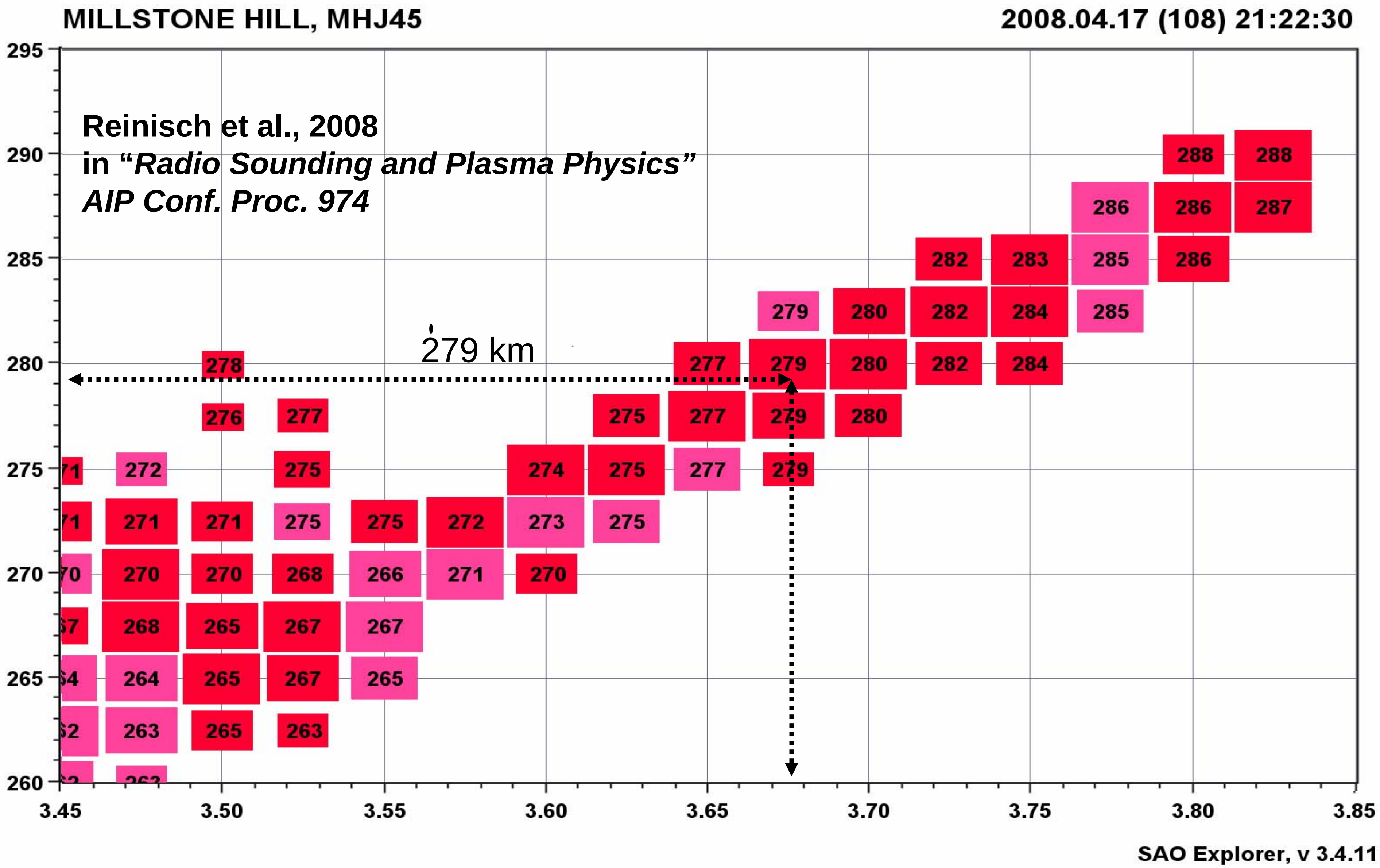
The power of RFIM



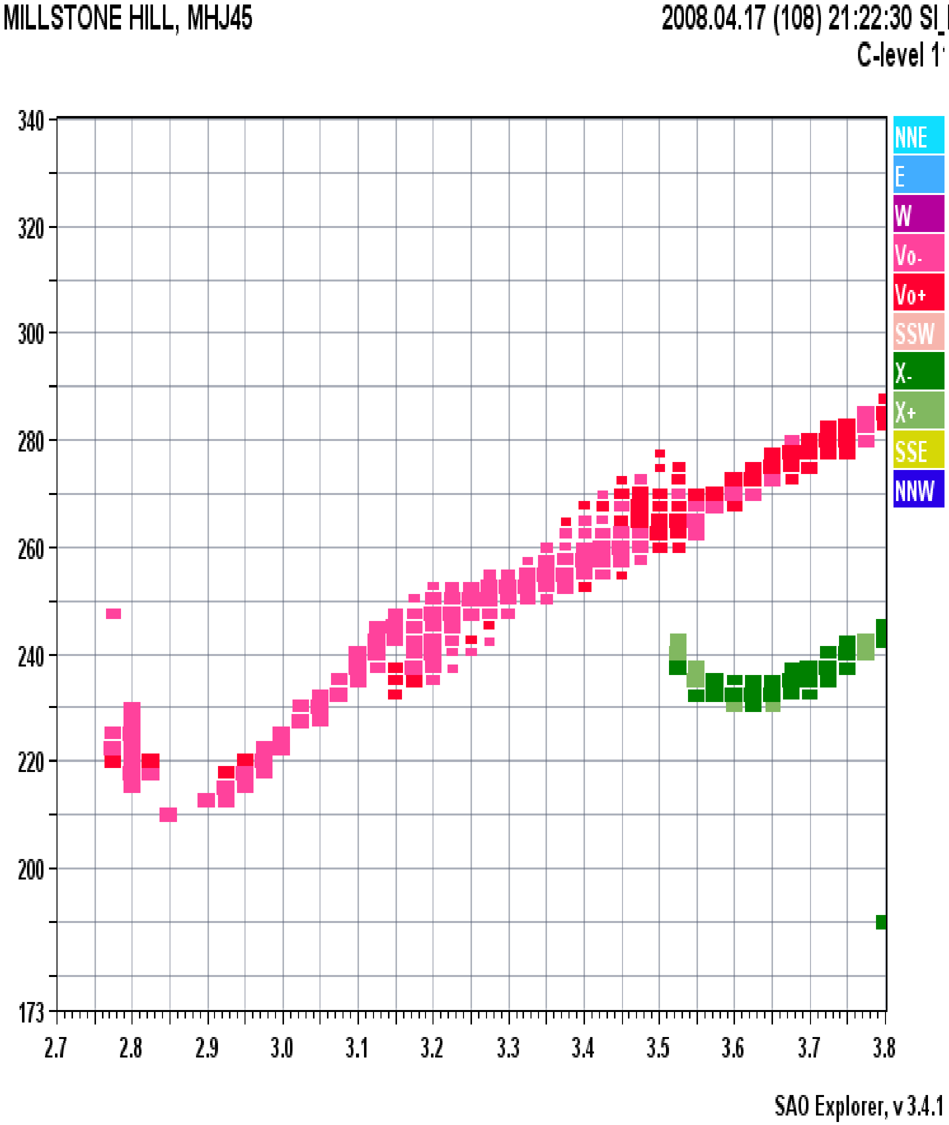
Precision Ranging using Phase-difference Technique

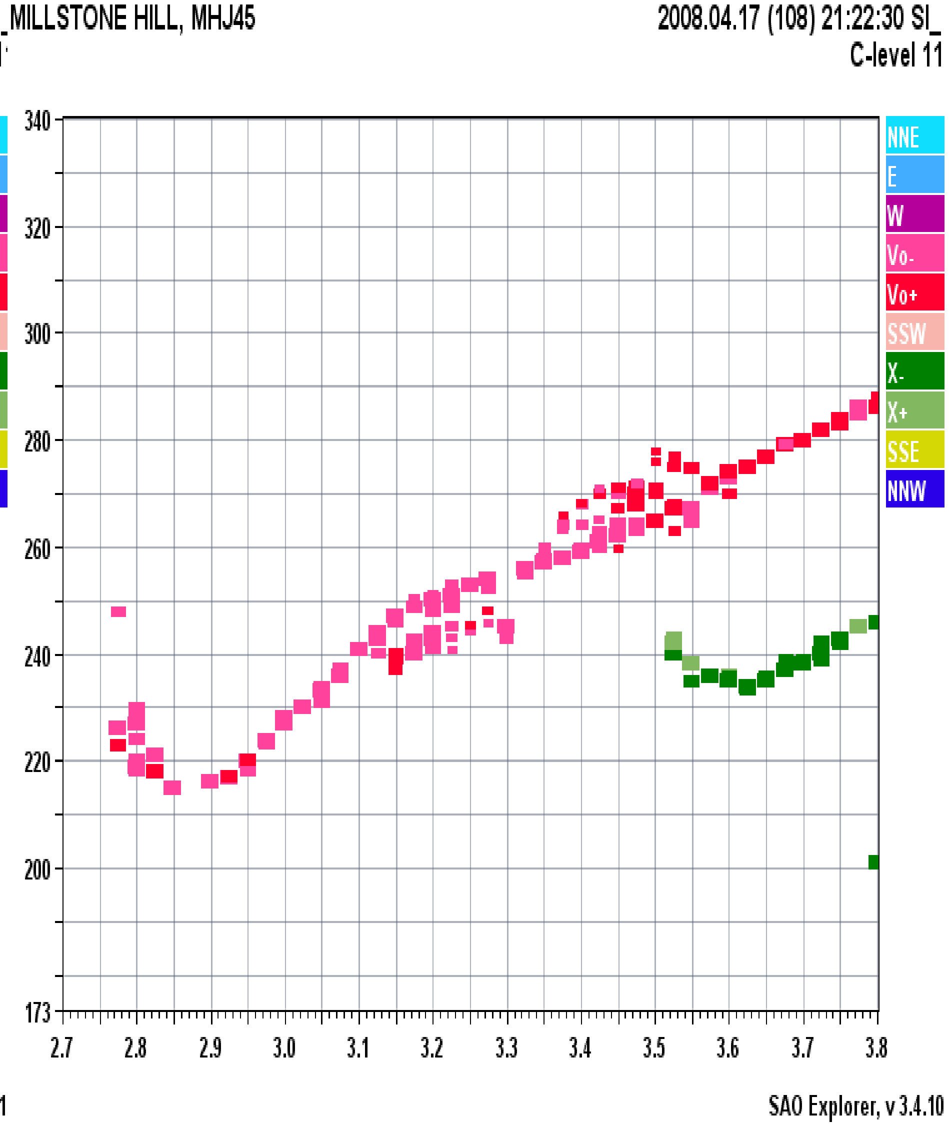


Precision Ranging using Phase-difference Technique – more accurate h'(f) traces!



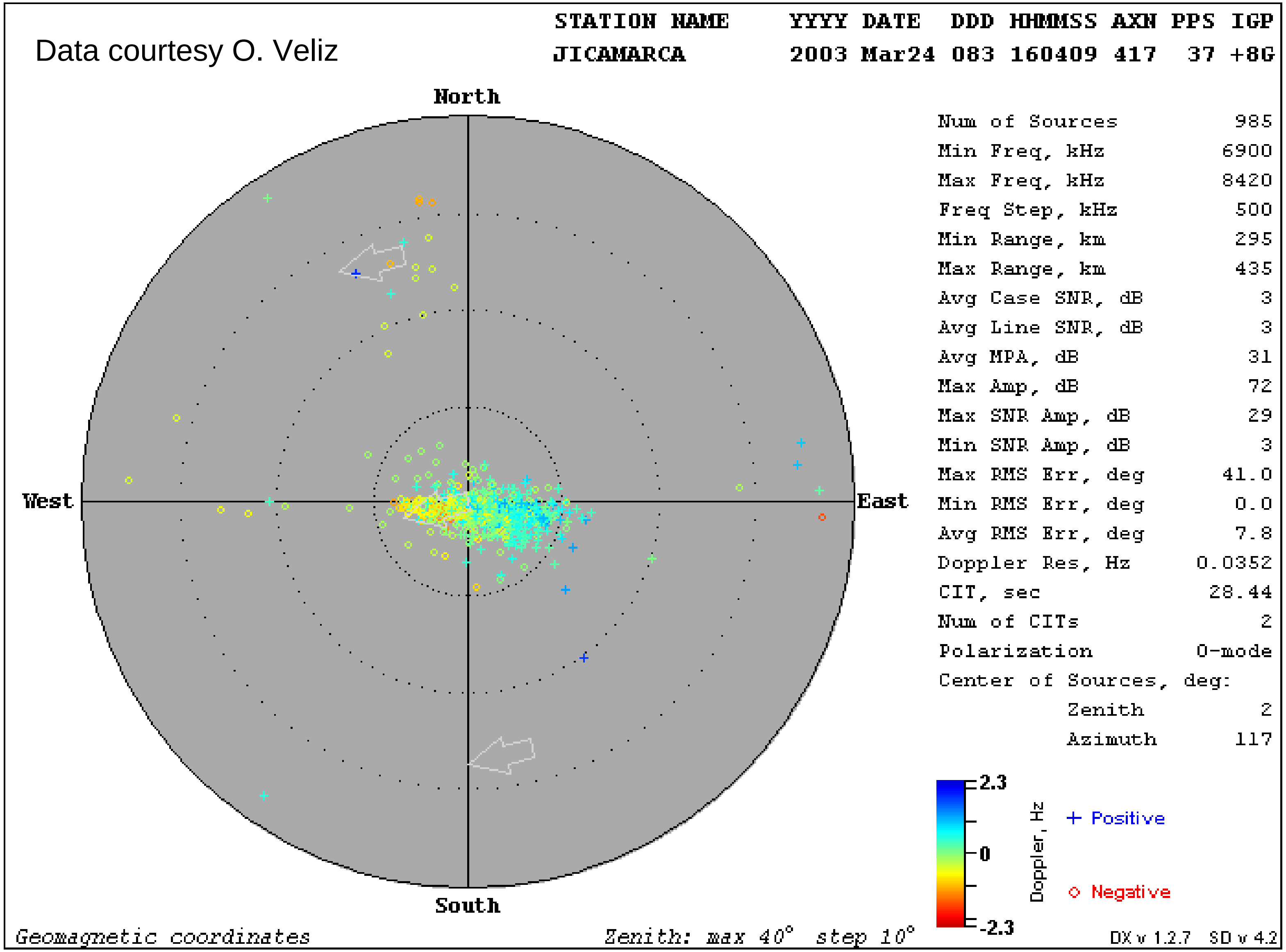
The effect of Precision Ranging (PR)

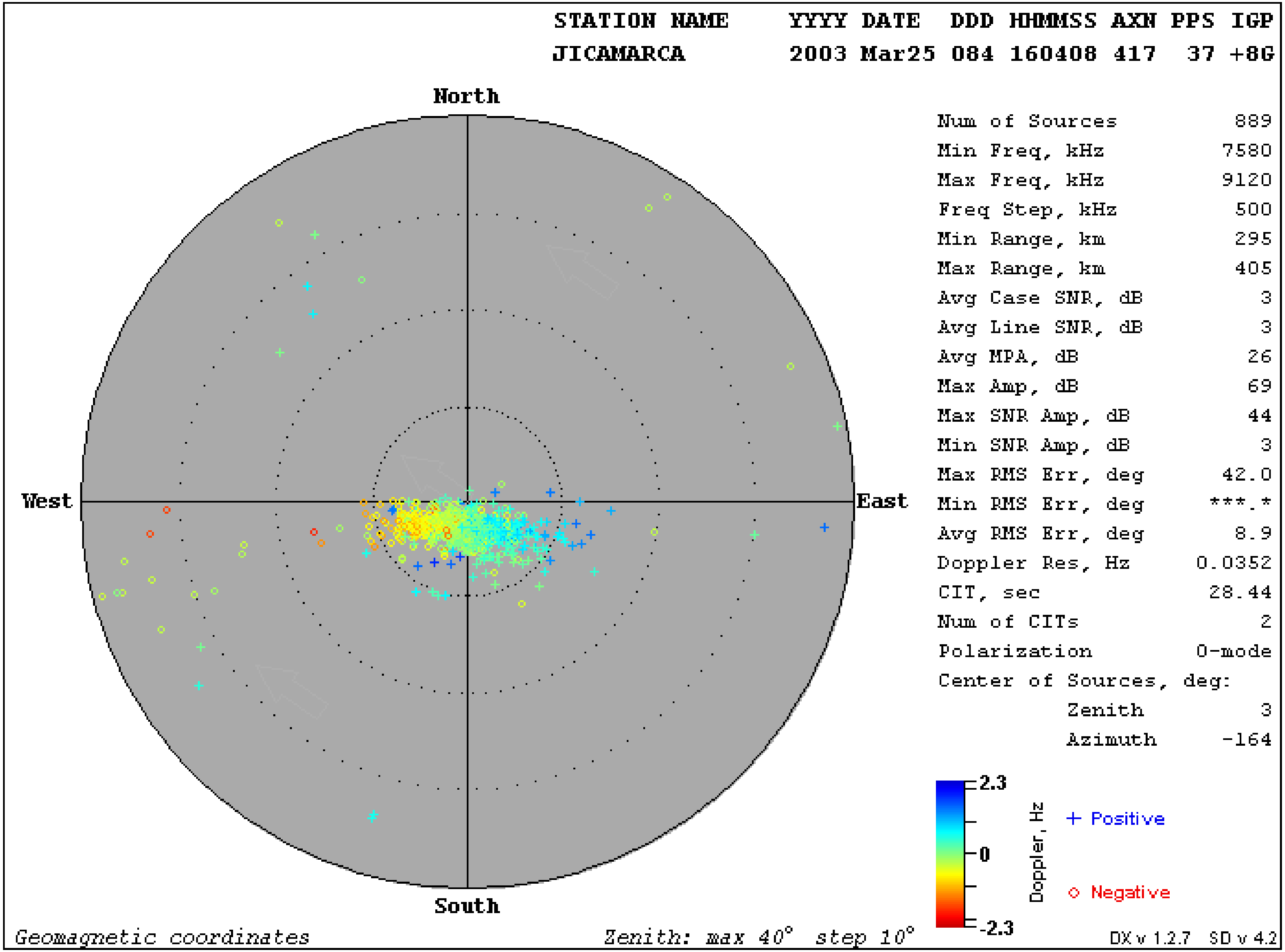


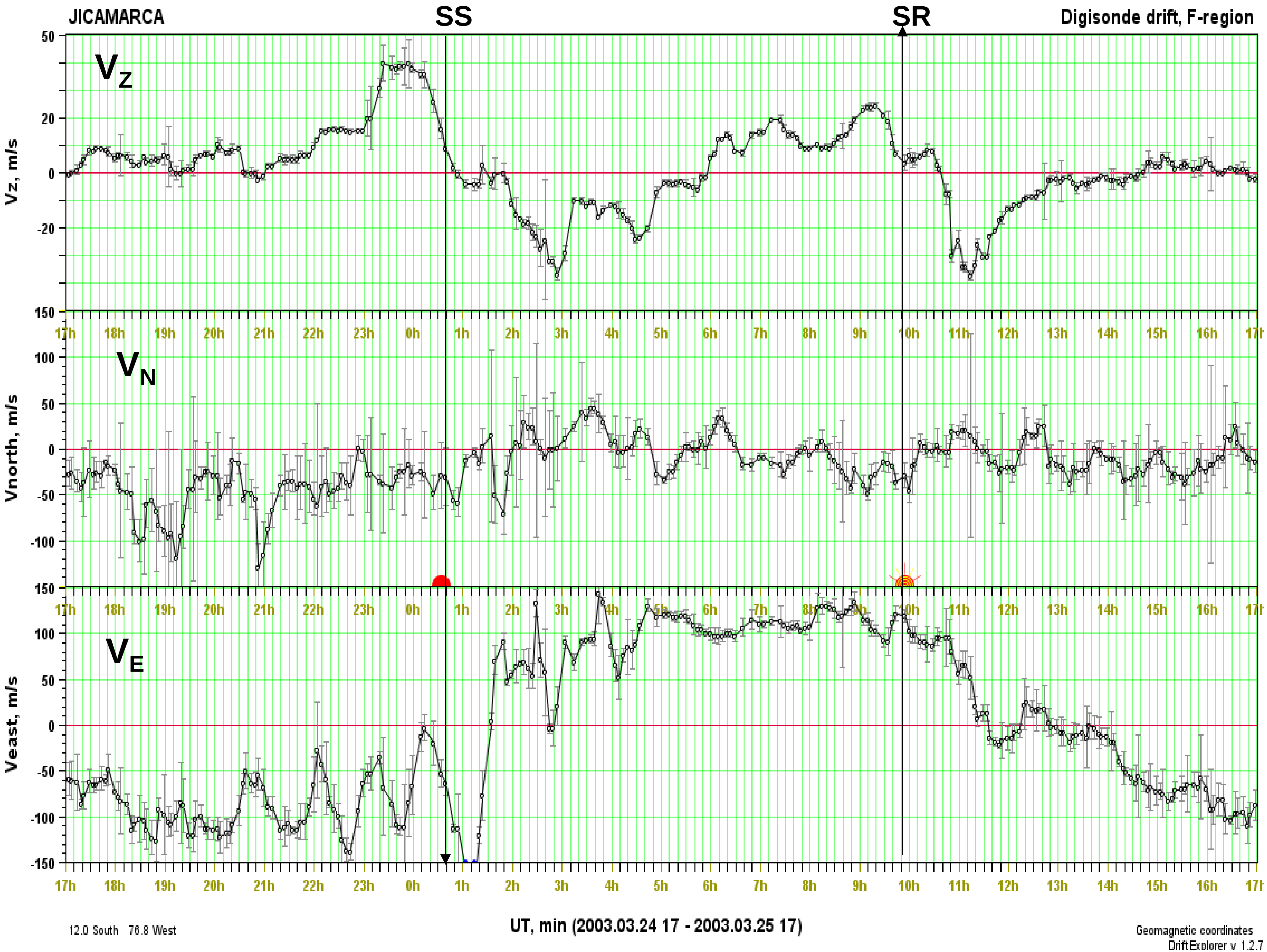


Classic Ionogram Display **Ionogram Display with PR**

Doppler-Interferometry: Skymaps & Drift



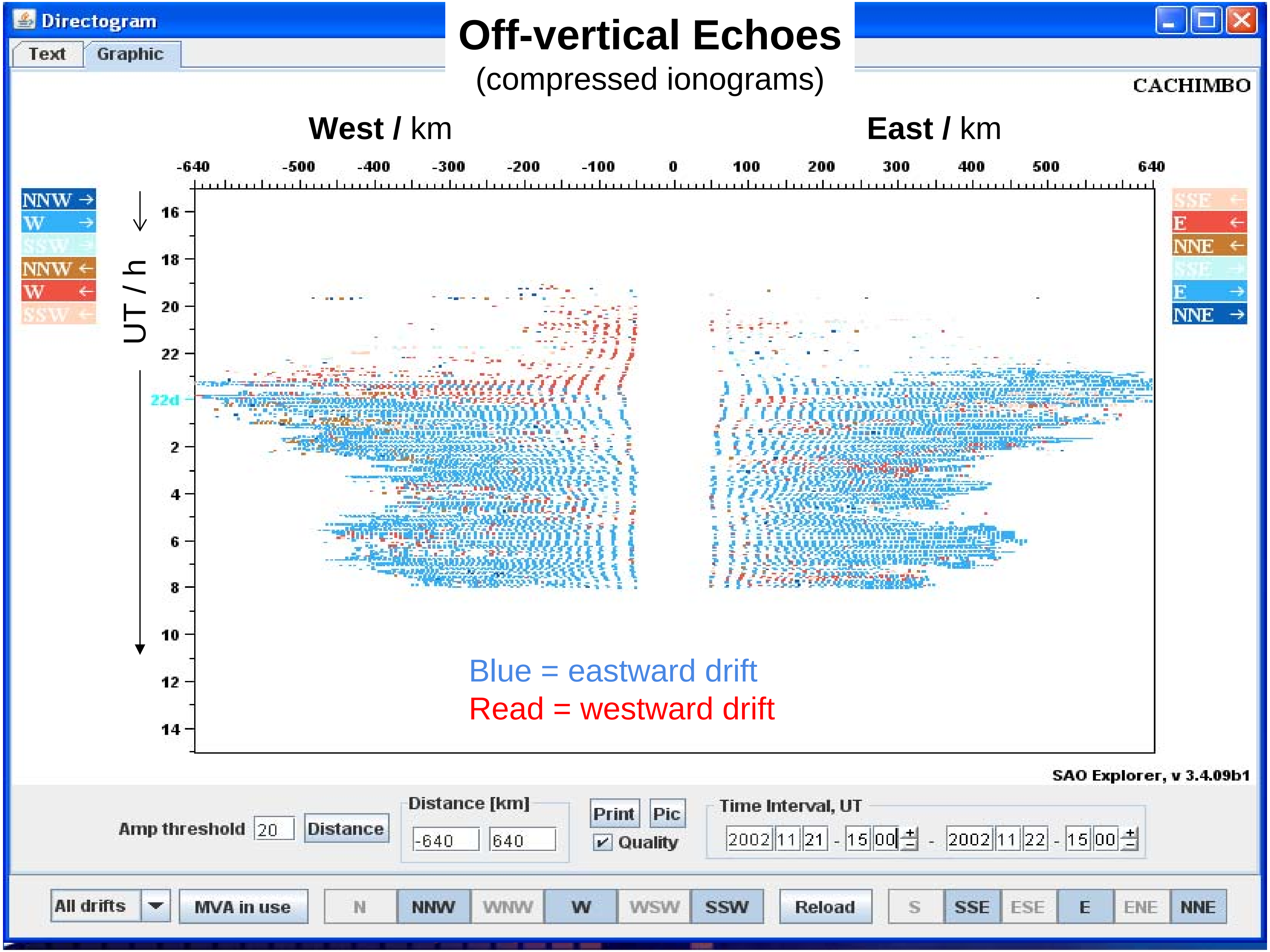

STATION NAME YYYY DATE DDD HHMMSS AXN PPS IGP
JICAMARCA 2003 Mar25 084 160408 417 37 +8G
North
West
East
South
Num of Sources 889
Min Freq, kHz 7580
Max Freq, kHz 9120
Freq Step, kHz 500
Min Range, km 295
Max Range, km 405
Avg Case SNR, dB 3
Avg Line SNR, dB 3
Avg MPA, dB 26
Max Amp, dB 69
Max SNR Amp, dB 44
Min SNR Amp, dB 3
Max RMS Err, deg 42.0
Min RMS Err, deg ***.*
Avg RMS Err, deg 8.9
Doppler Res, Hz 0.0352
CIT, sec 28.44
Num of CITs 2
Polarization O-mode
Center of Sources, deg:
Zenith 3
Azimuth -164
2.3
0
-2.3
Doppler, Hz
+ Positive
o Negative
Geomagnetic coordinates
Zenith: max 40° step 10°
DX v 1.2.7 SD v 4.2



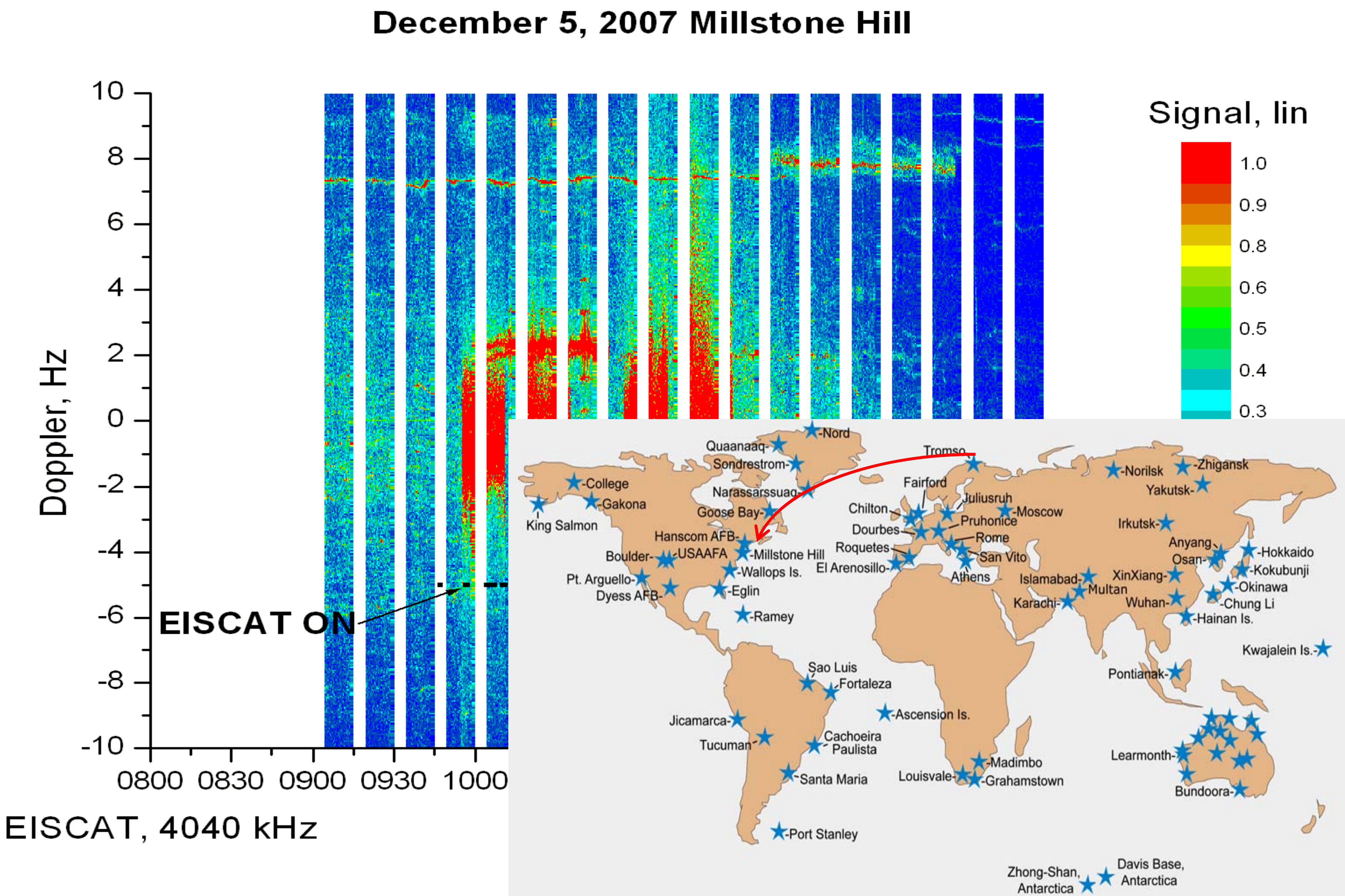
JICAMARCA
SS
SR
Digisonde drift, F-region
Vz
Vz, m/s
VN
Vnorth, m/s
VE
Veast, m/s
17h 18h 19h 20h 21h 22h 23h 0h 1h 2h 3h 4h 5h 6h 7h 8h 9h 10h 11h 12h 13h 14h 15h 16h 17h
12.0 South 76.8 West
UT, min (2003.03.24 17 - 2003.03.25 17)
Geomagnetic coordinates
DriftExplorer v 1.2.7

Off-vertical Echoes

(compressed ionograms)



DPS-4D at Millstone Hill
Receiving EISCAT Heater Signal



Summary

- Real time assessment of ionosphere now possible with modern **networked** ionosondes
- Real time data dissemination and assimilation: GAIM ….
- Automatic error assessment of EDPs

What is still missing?? **Fleet of topside vertical ionospheric sounders for accurate global assessment of the ionosphere**