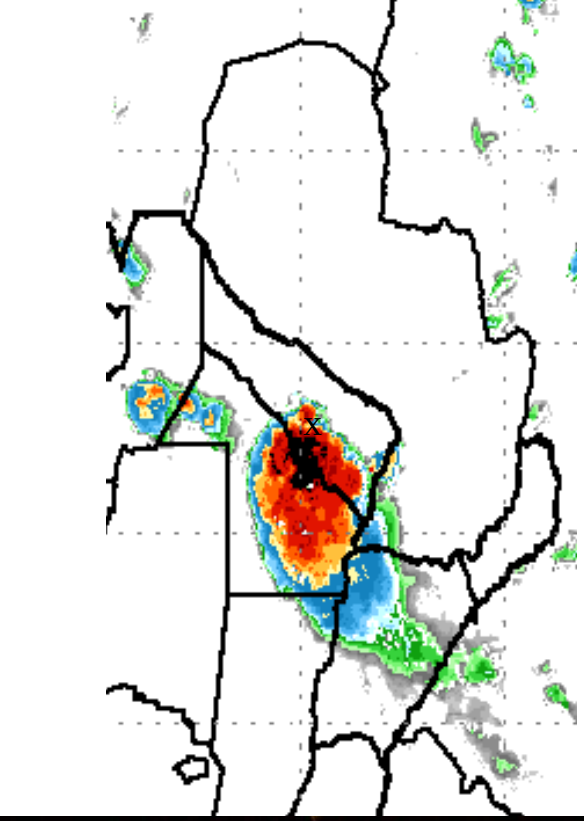
P-3 radar data during SALLJEX illustrated by the 22 January 2003 case study of an intense MCS

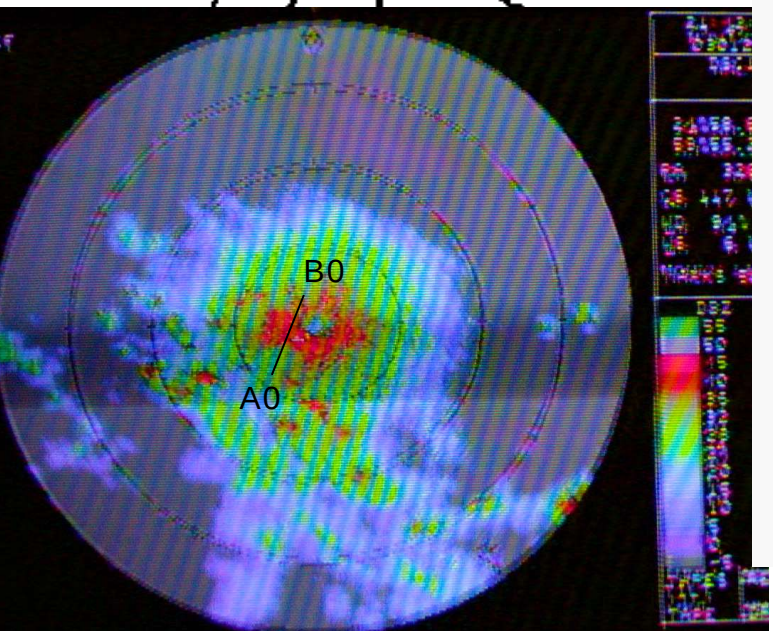
Edward J Zipser, Paola Salio, and Chuntao Liu, and Matilde Nicolini

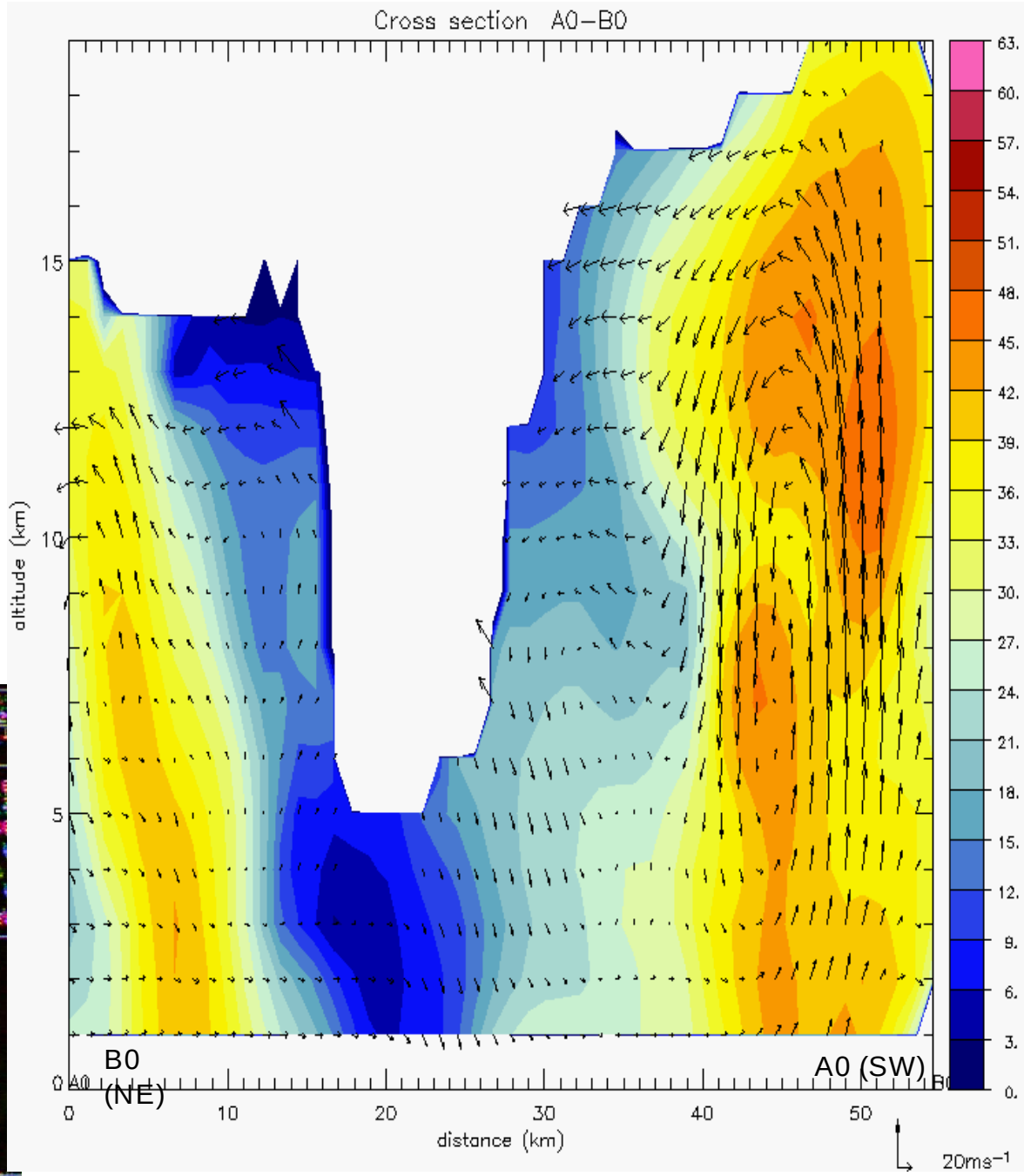
Thanks to P3 crew, John Gamache, Jose Meitin, Michael Bell, Haiyan Jiang, Yaping Li, Bryan White

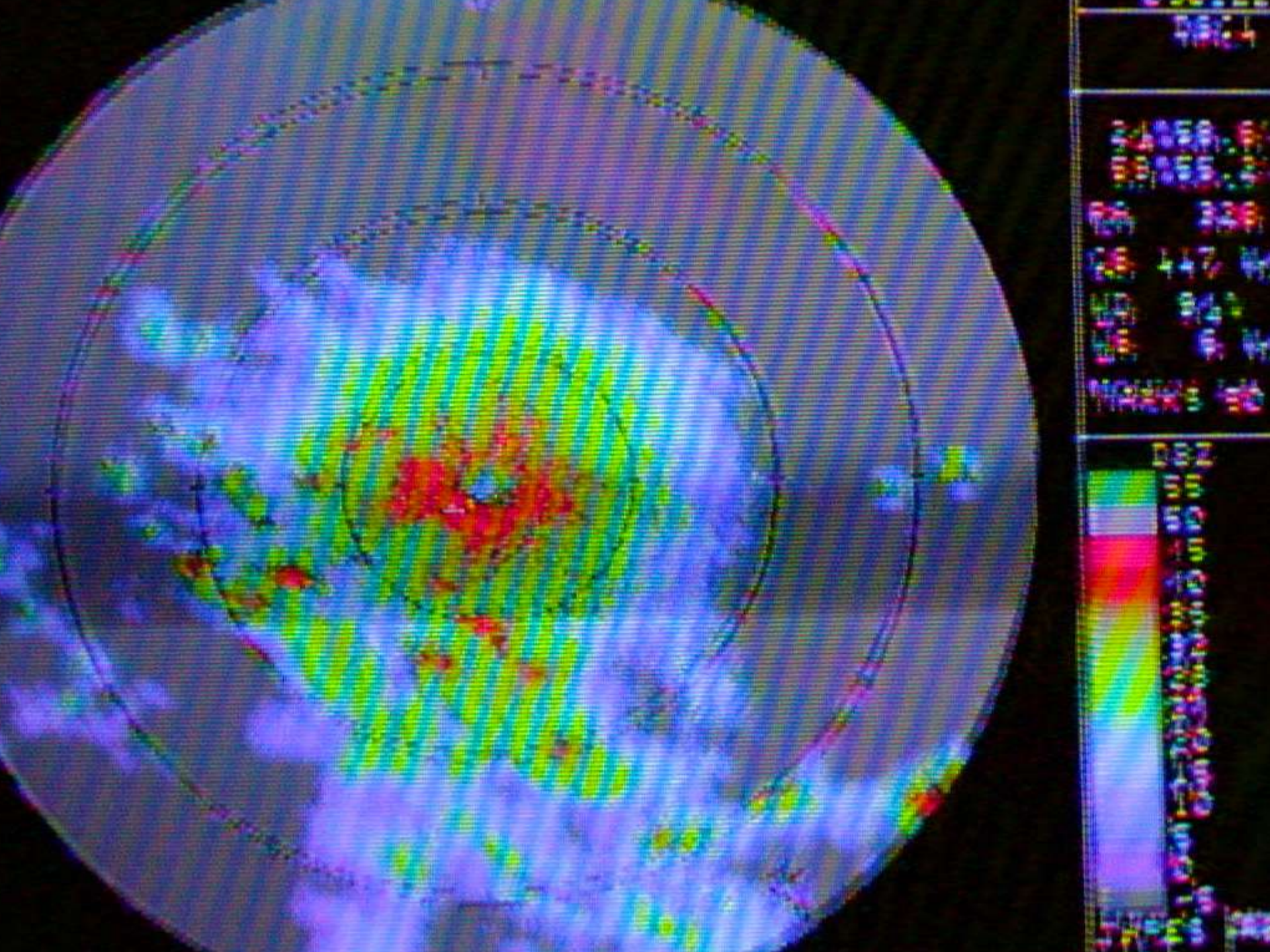
Brief Outline of Talk

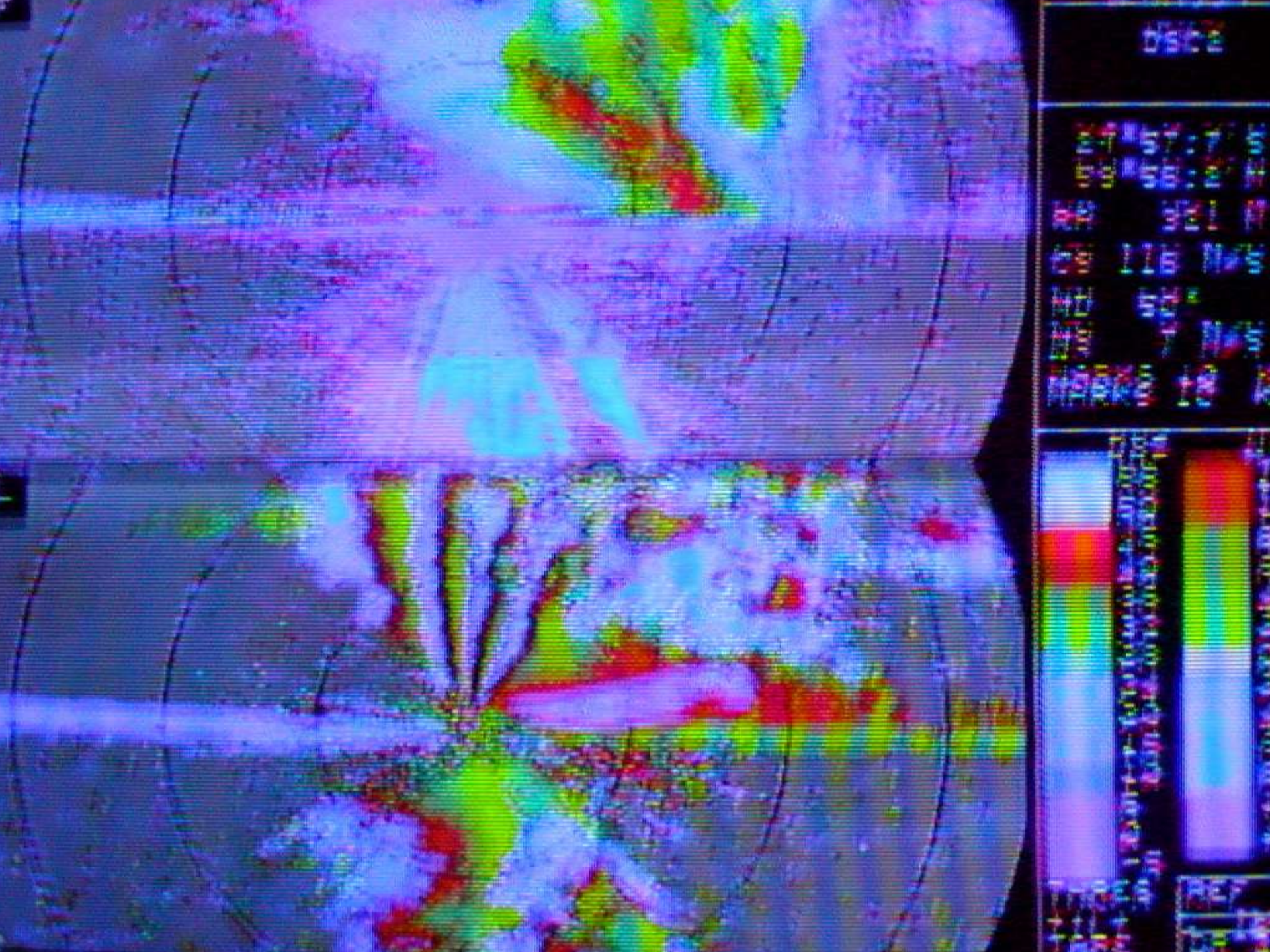
- Status of radar data for SALLJEX. Mostly available, with a few data gaps to be investigated. Best MCS case is 22 January, also formation stage of 11 January system. Some coverage of scattered convection on other days.
- Cross sections and plan view of reflectivity and Doppler velocity for 22 January case. These are preliminary results and more quality control must be accomplished.
- Quick summary of software and data processing procedures -- see me, Paola Salio, Jose Meitin for details

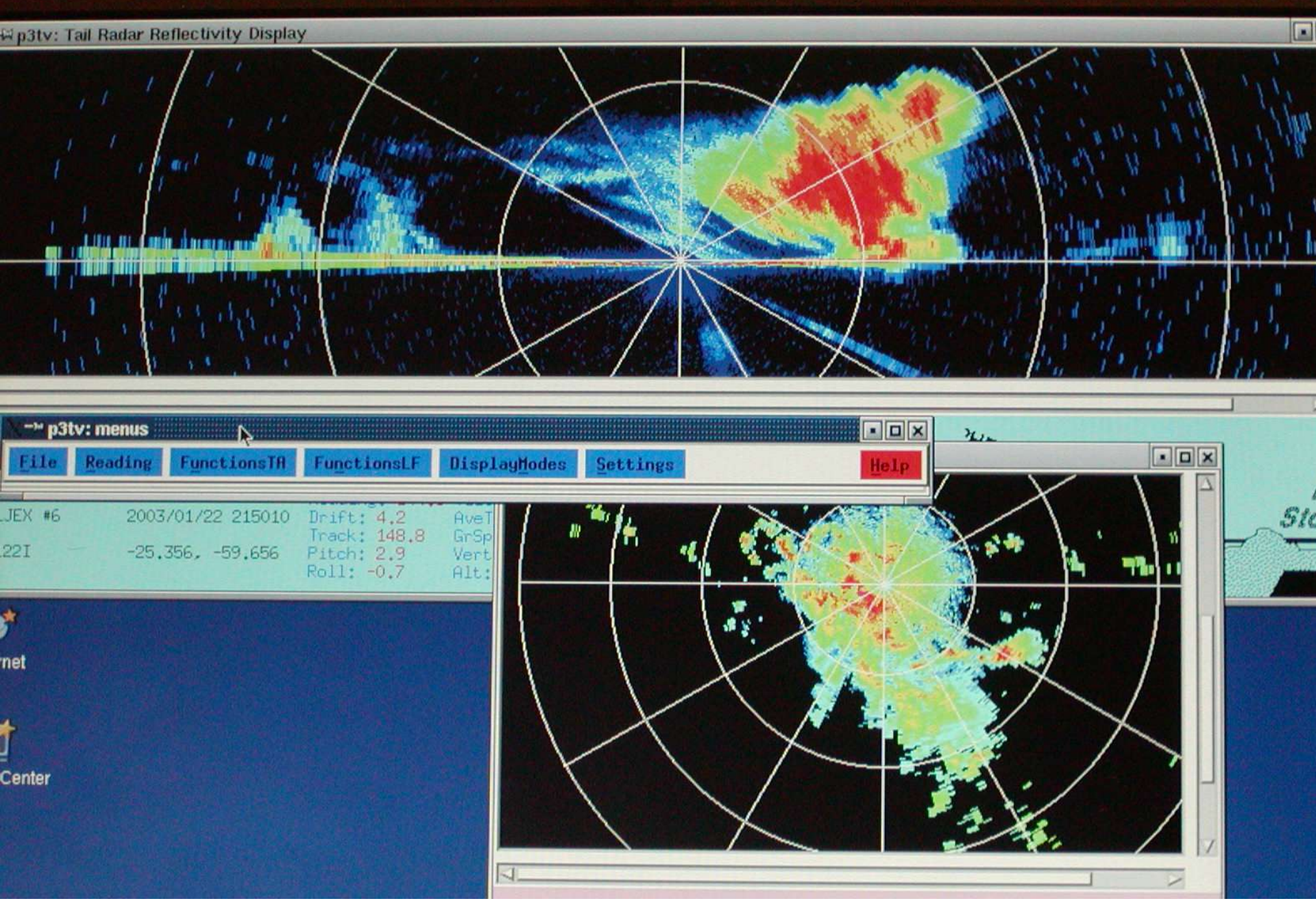


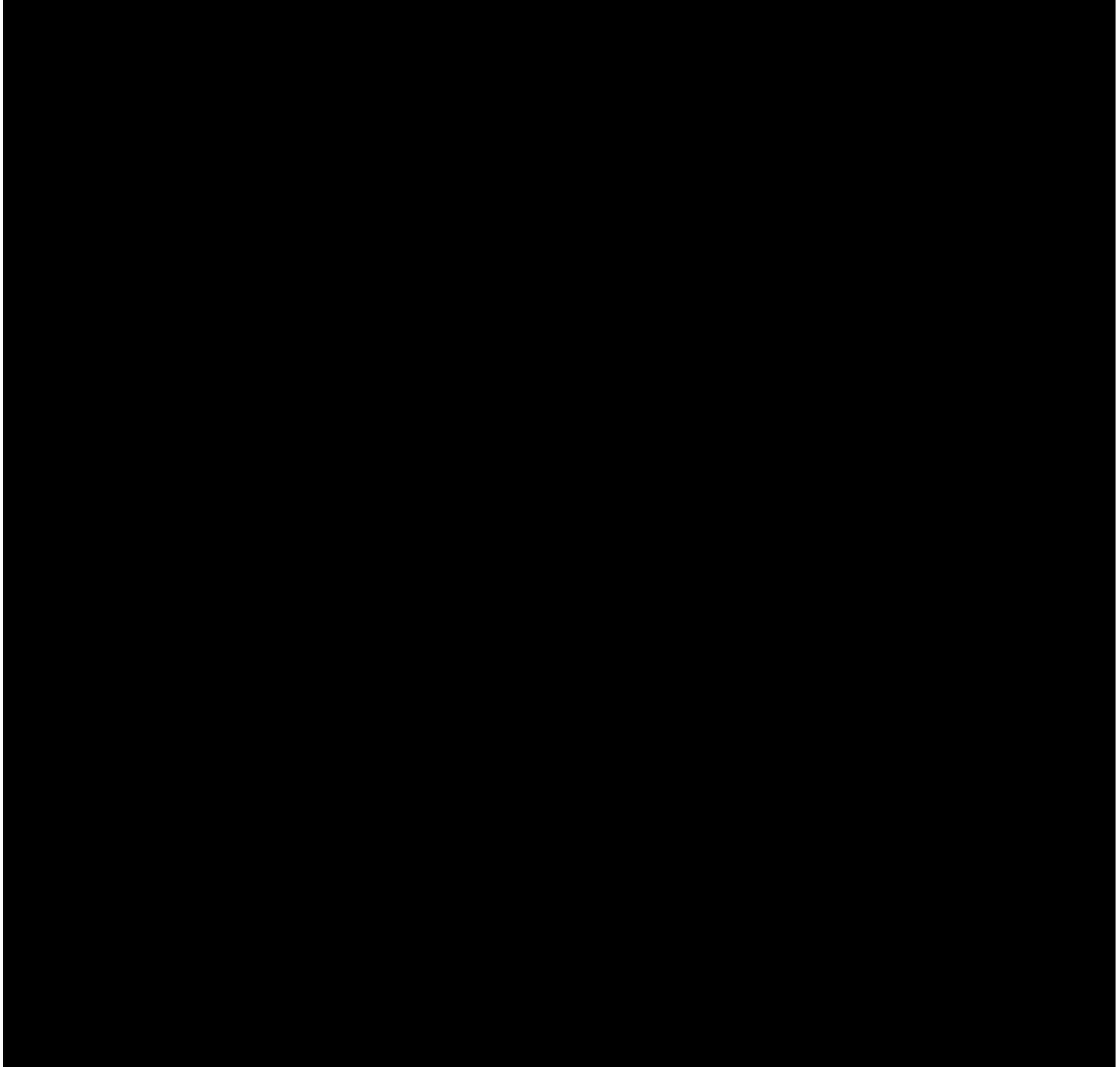

B0
A0

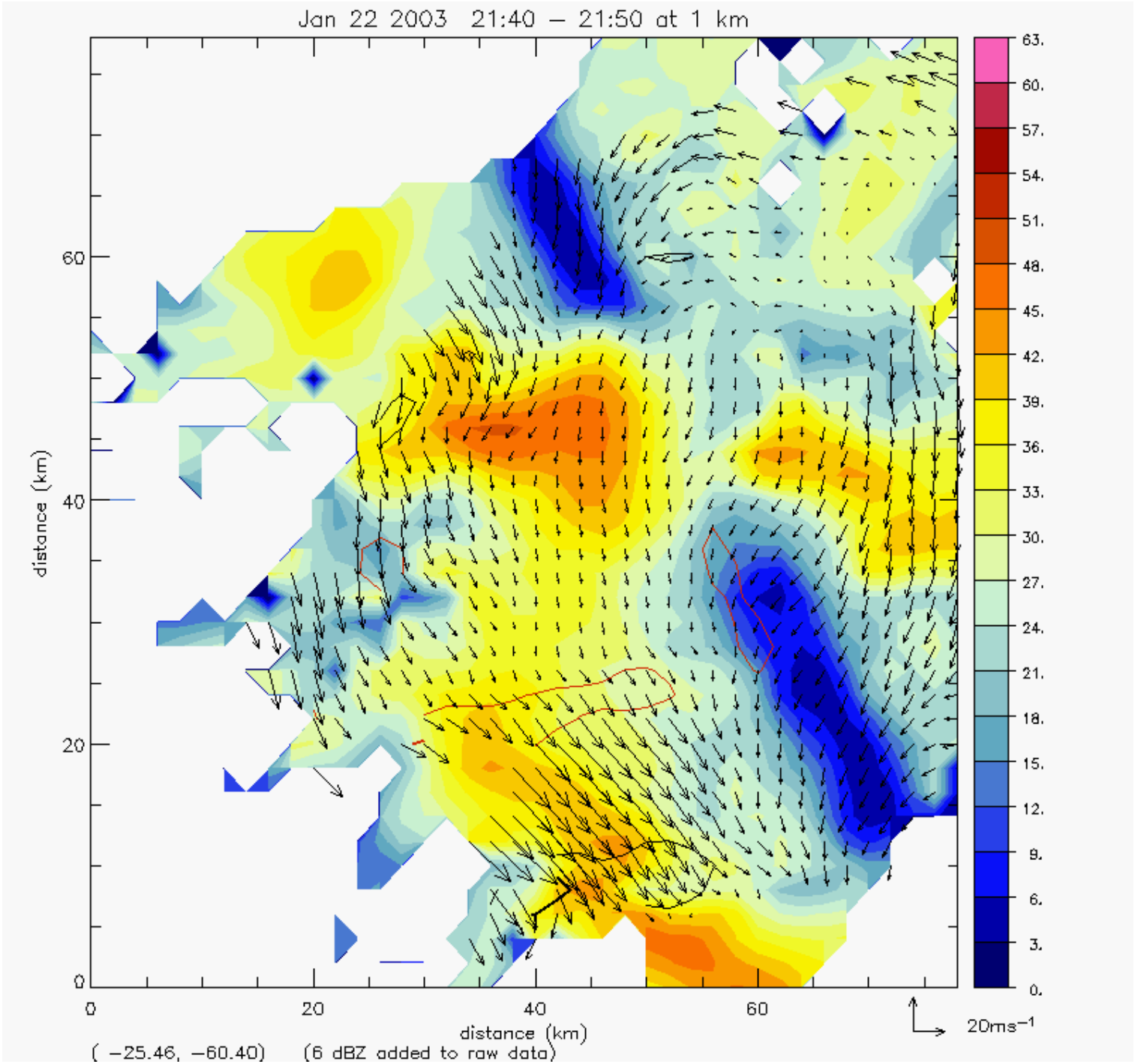

Cross section A0–B0
altitude (km)
15
10
5
0
0
10
20
30
40
50
distance (km)
B0
(NE)
A0 (SW)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹

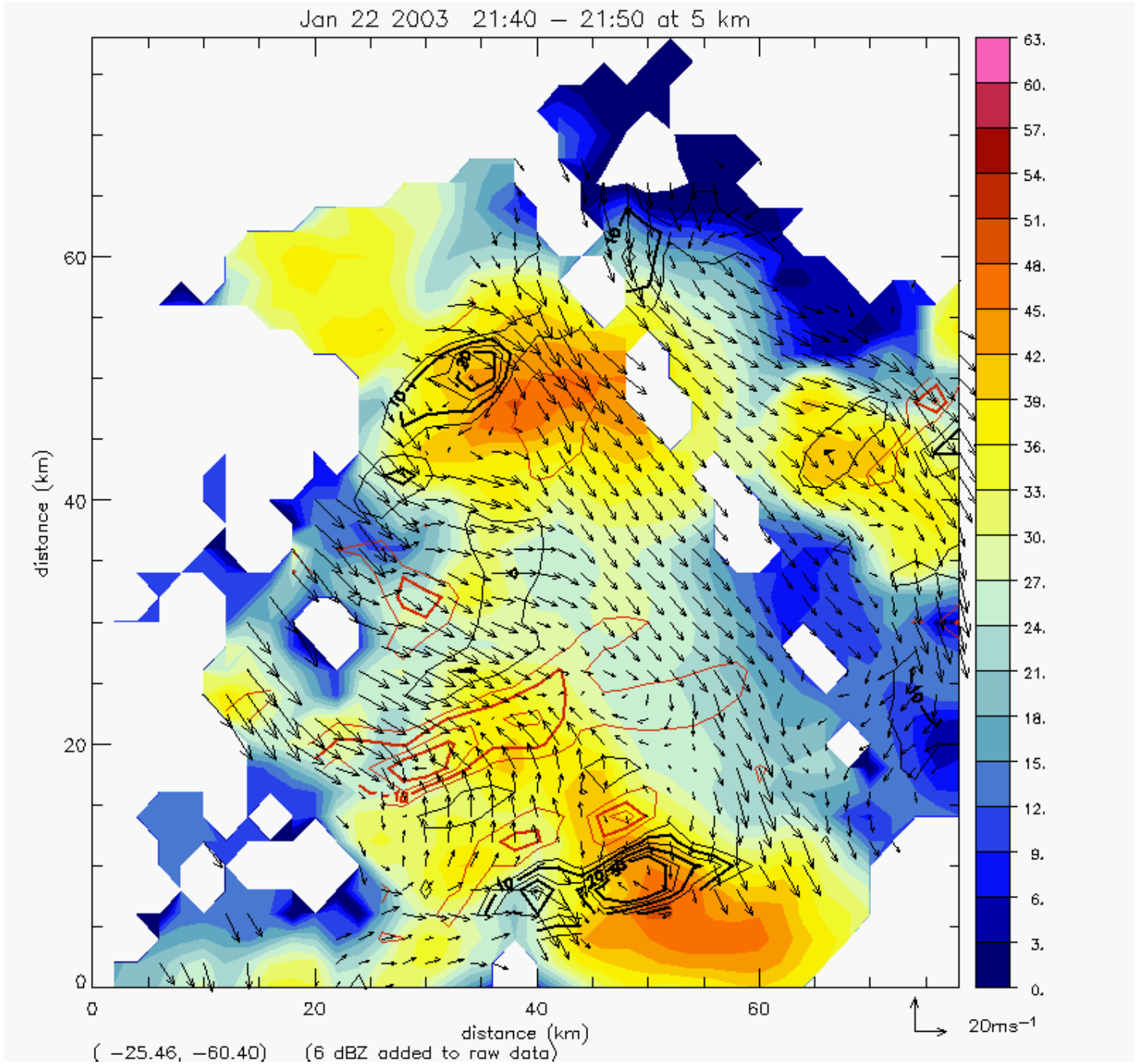


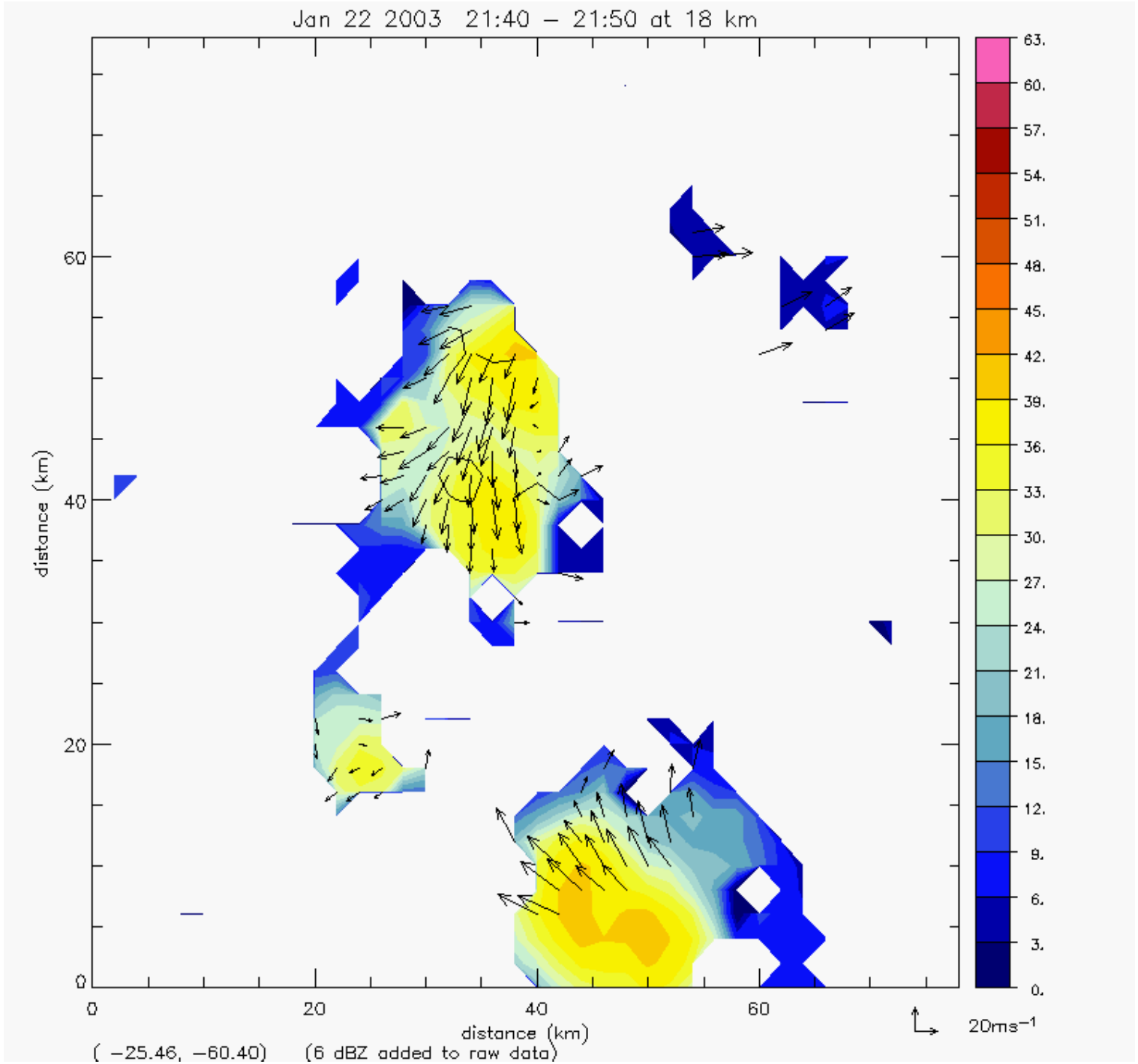


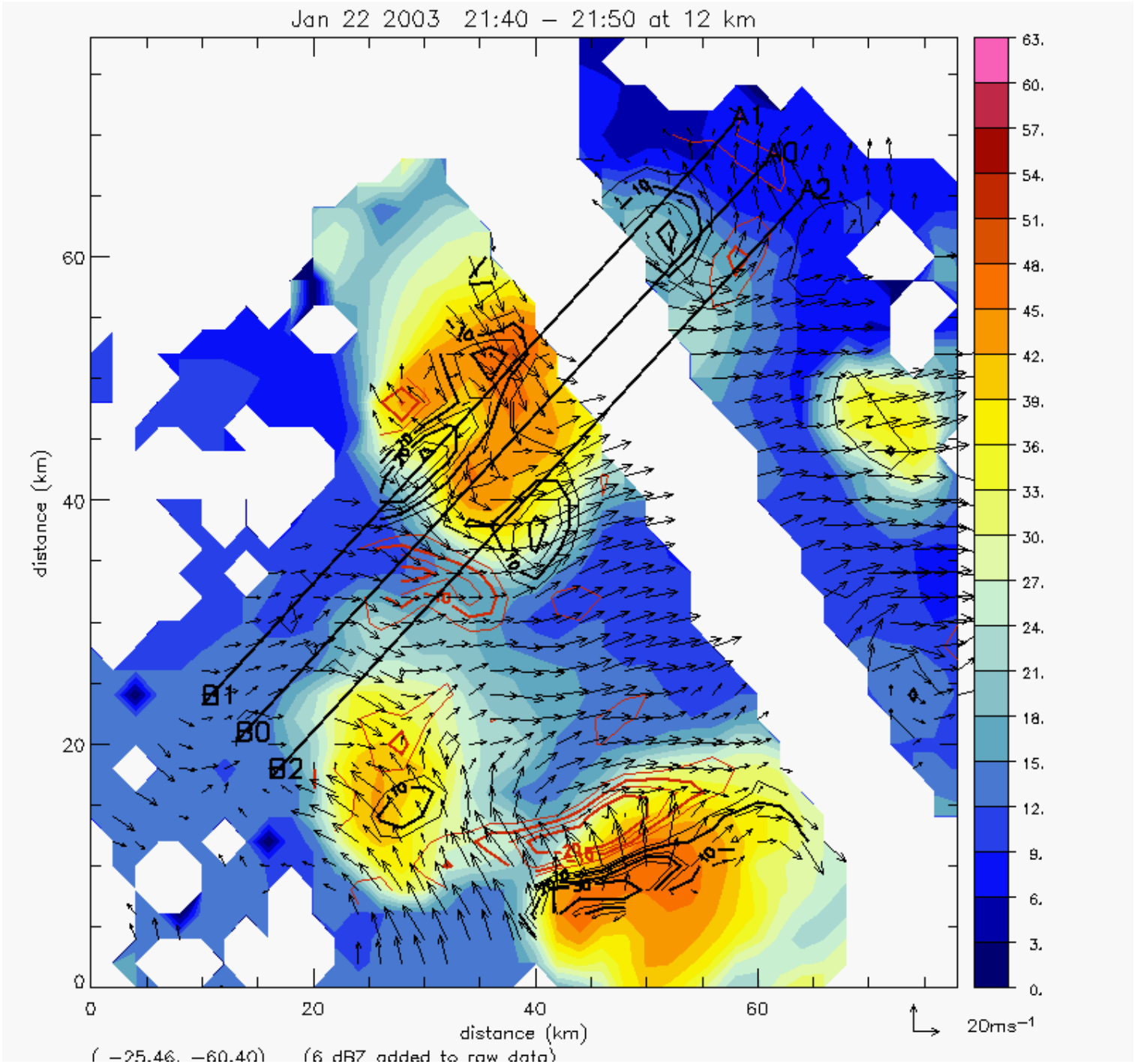

p3tv: Tail Radar Reflectivity Display
p3tv: menus
File
Reading
FunctionsTA
FunctionsLF
DisplayModes
Settings
Help
JEX #6
2003/01/22 215010
Drift: 4.2
Track: 148.8
Pitch: 2.9
Roll: -0.7
22I
-25.356, -59.656
rnet
Center

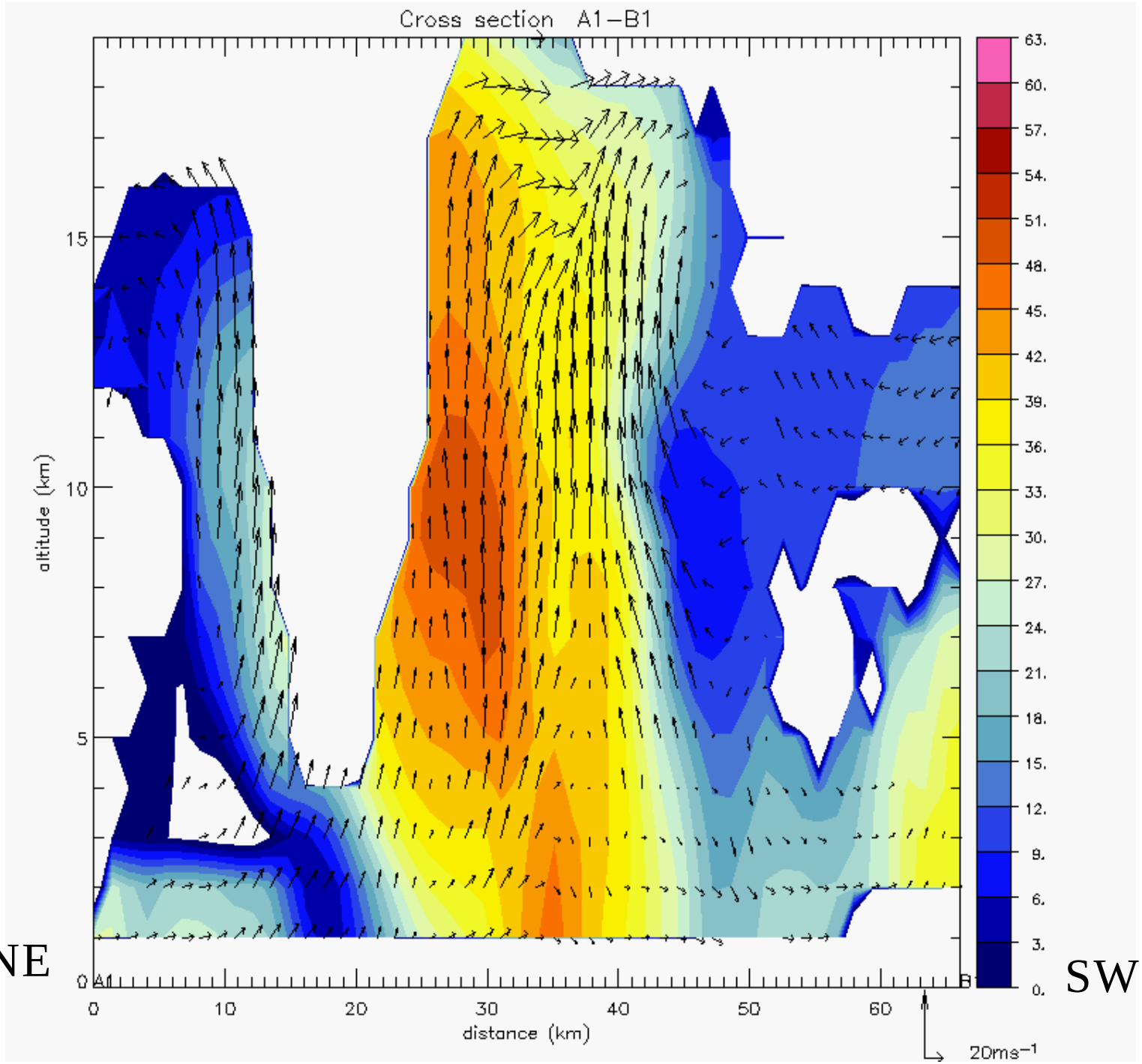



Jan 22 2003 21:40 – 21:50 at 1 km
distance (km)
0
20
40
60
distance (km)
0
20
40
60
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.40)
(6 dBZ added to raw data)


Jan 22 2003 21:40 – 21:50 at 5 km
distance (km)
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.40)
(6 dBZ added to raw data)

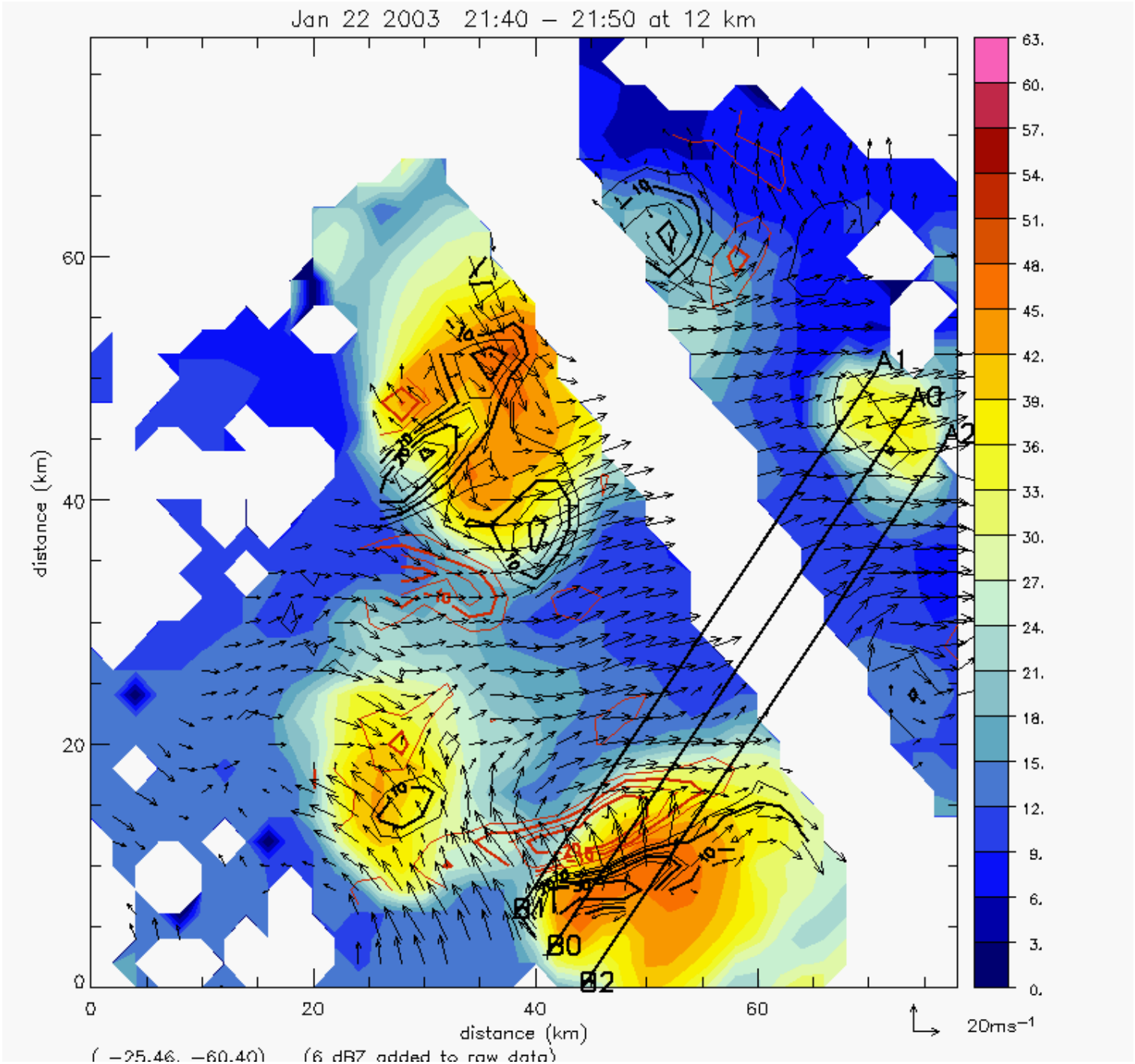

Jan 22 2003 21:40 – 21:50 at 18 km
distance (km)
0
20
40
60
distance (km)
0
20
40
60
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.40)
(6 dBZ added to raw data)

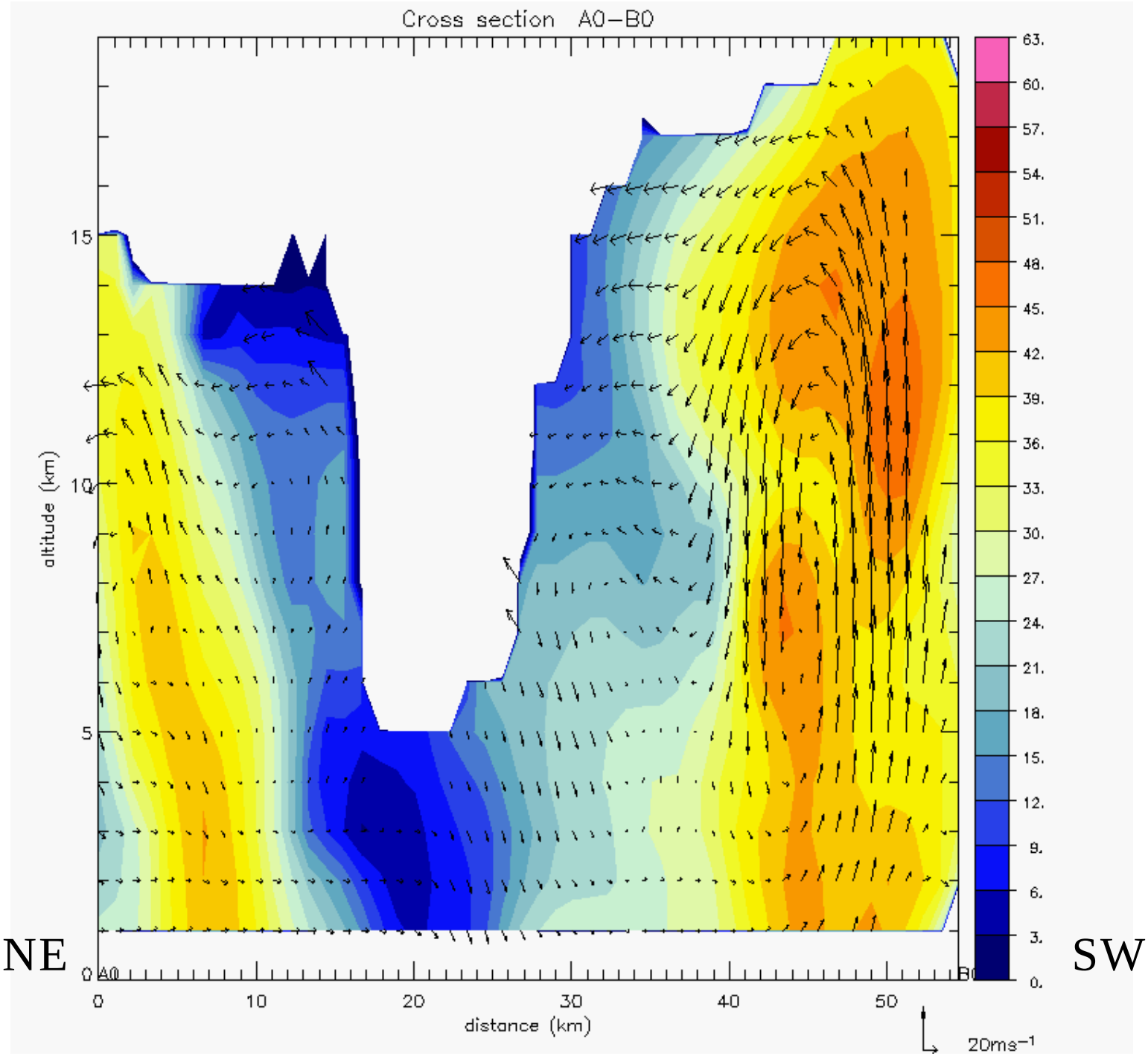

Jan 22 2003 21:40 – 21:50 at 12 km
A1
A0
A2
B1
B0
B2
distance (km)
distance (km)
0
20
40
60
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.40)
(6 dBZ added to raw data)


Cross section A1–B1
altitude (km)
0
5
10
15
A1
B1
0
10
20
30
40
50
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹

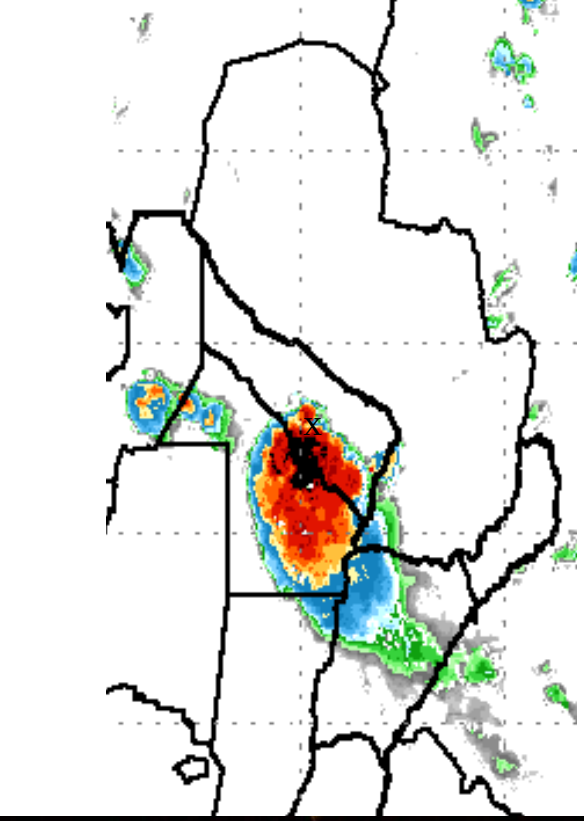
NE

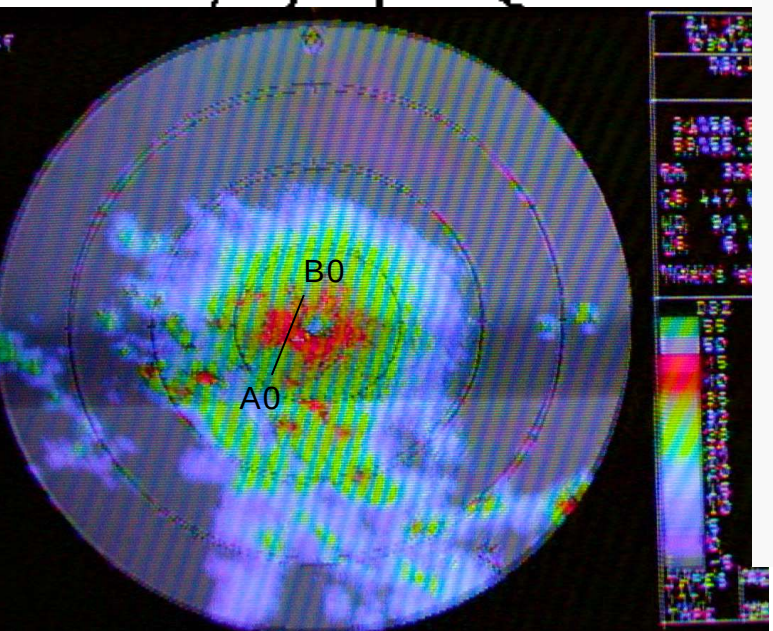
SW

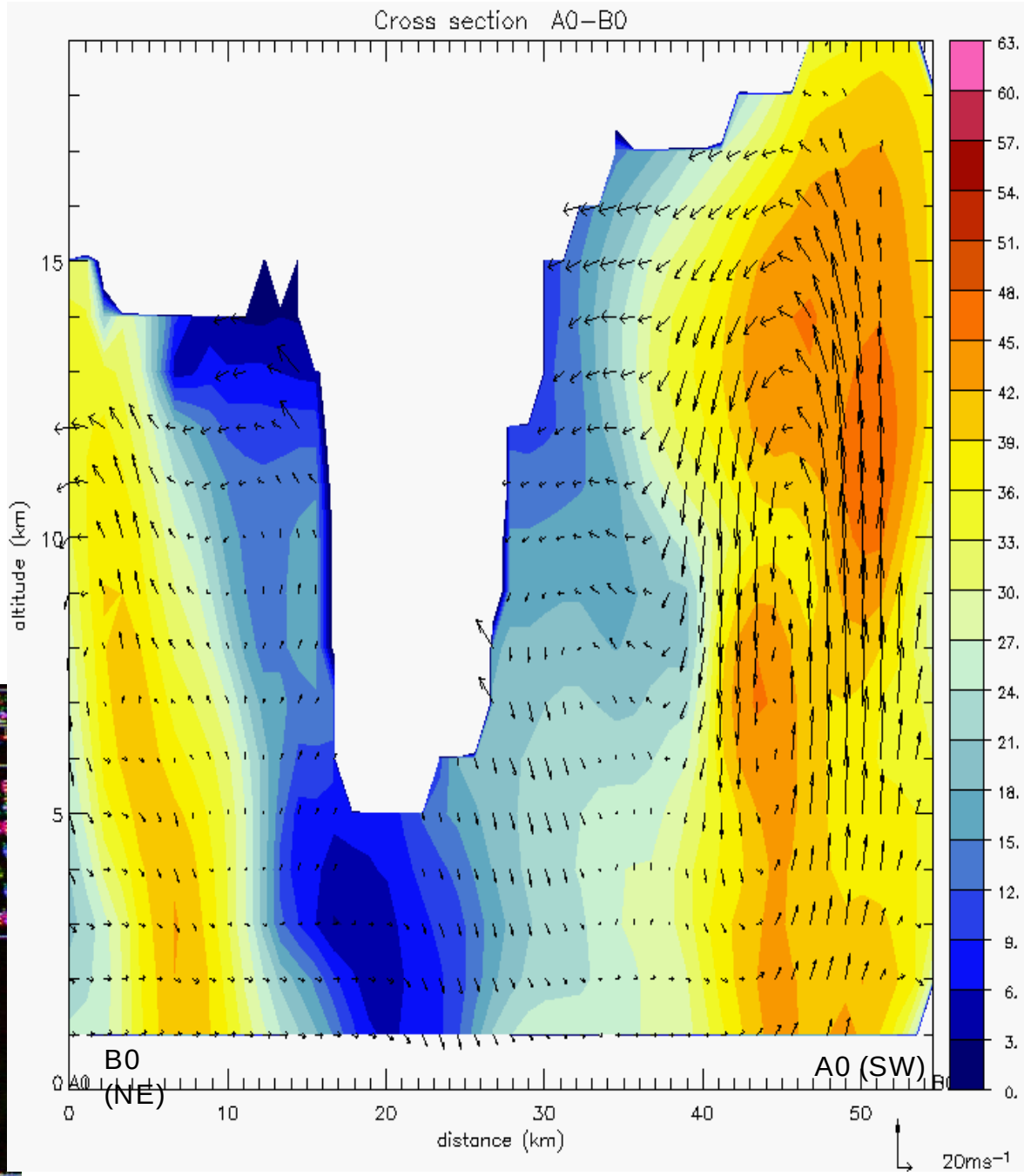

Jan 22 2003 21:40 – 21:50 at 12 km
distance (km)
distance (km)
0
20
40
60
A1
A0
A2
B1
B0
B2
20ms⁻¹
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
(−25.46, −60.40)
(6 dBZ added to raw data)

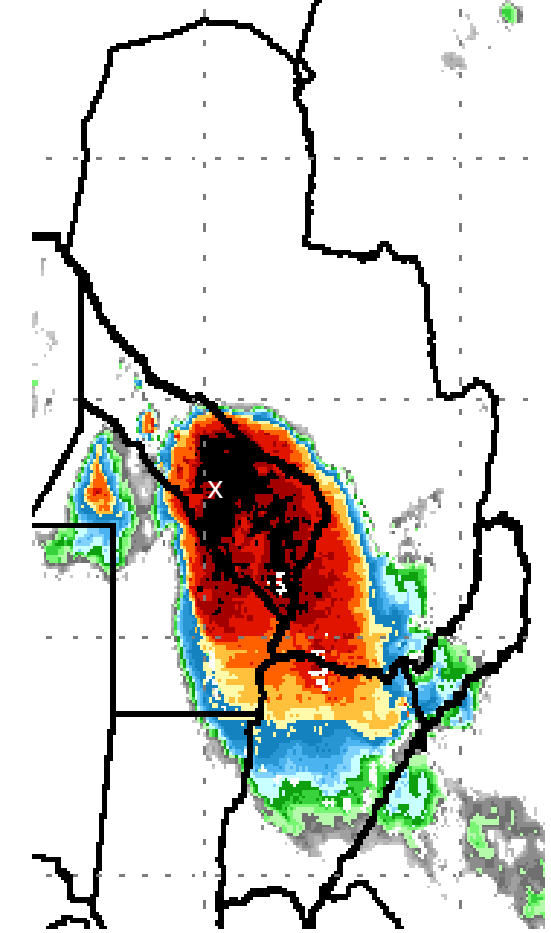

Cross section A0–B0
altitude (km)
15
10
5
0
A0
B0
0
10
20
30
40
50
distance (km)
20ms⁻¹
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.

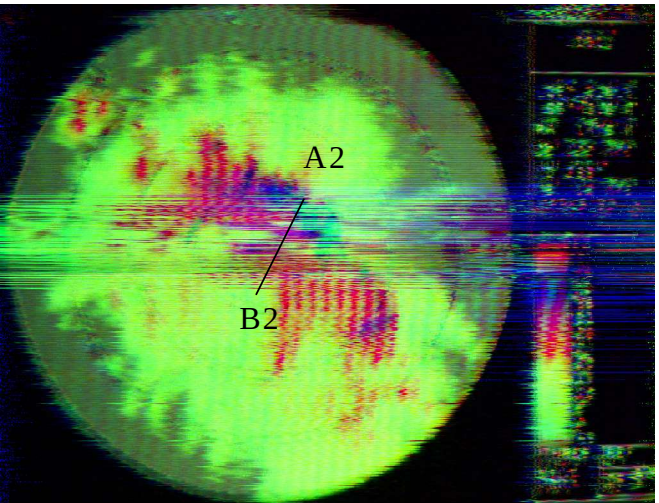
NE SW

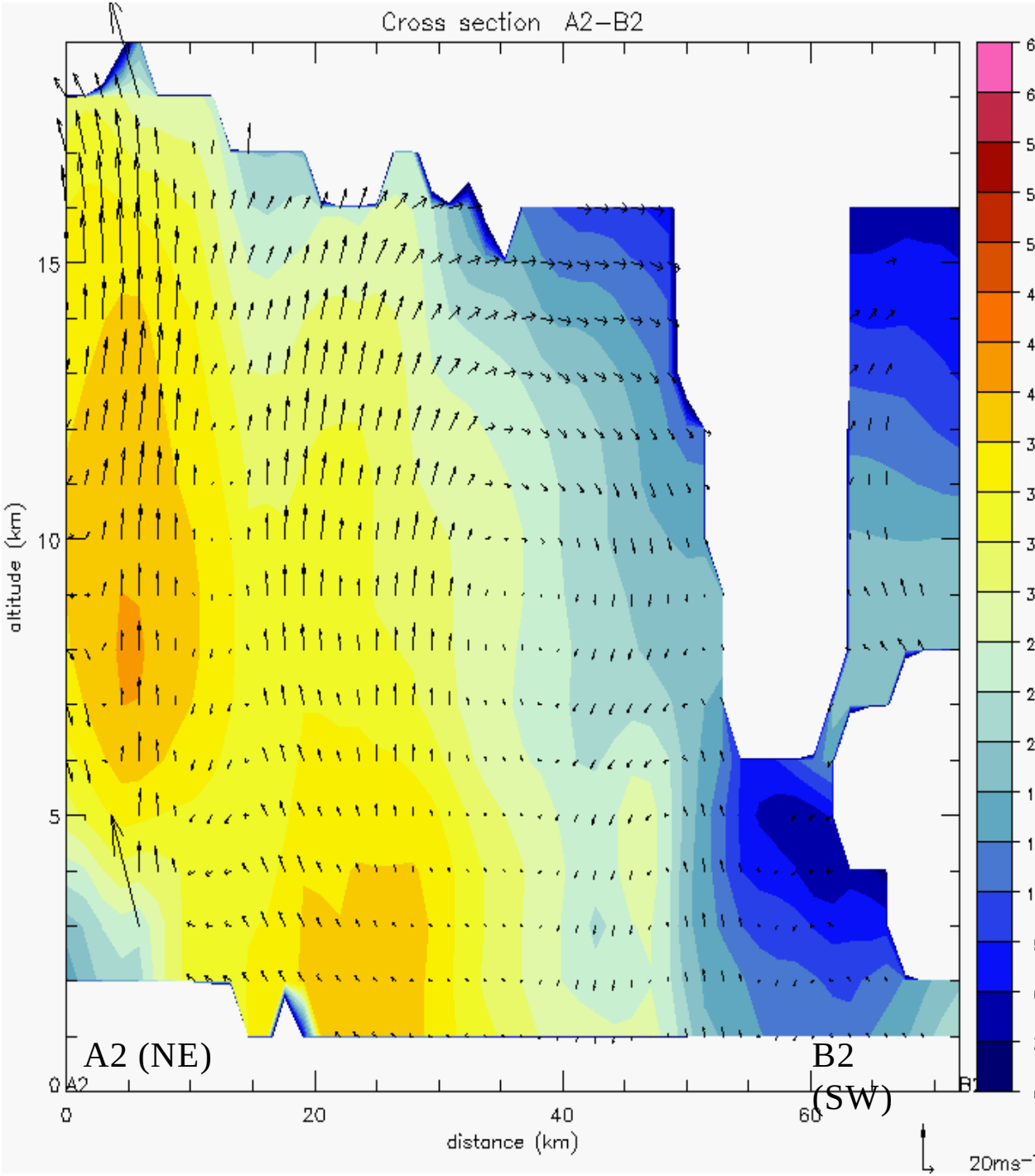


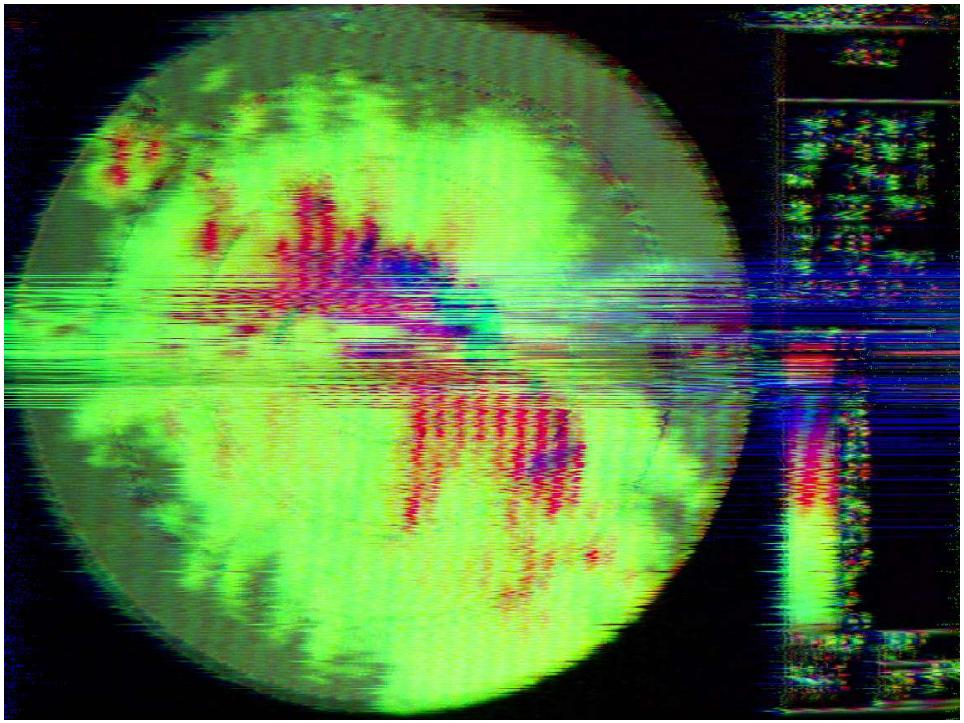

B0
A0

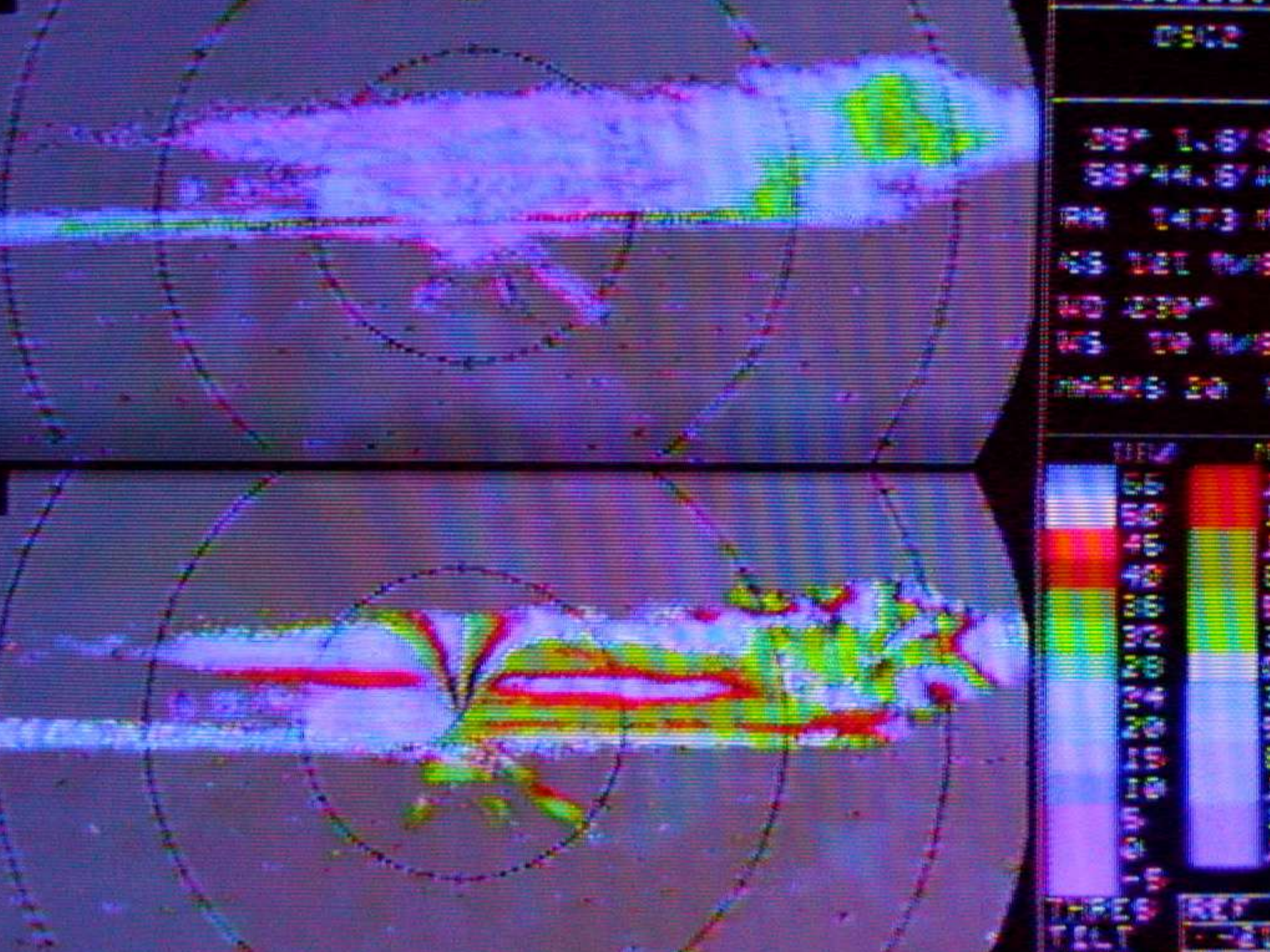

Cross section A0–B0
altitude (km)
15
10
5
0
0
10
20
30
40
50
distance (km)
B0
(NE)
A0 (SW)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹

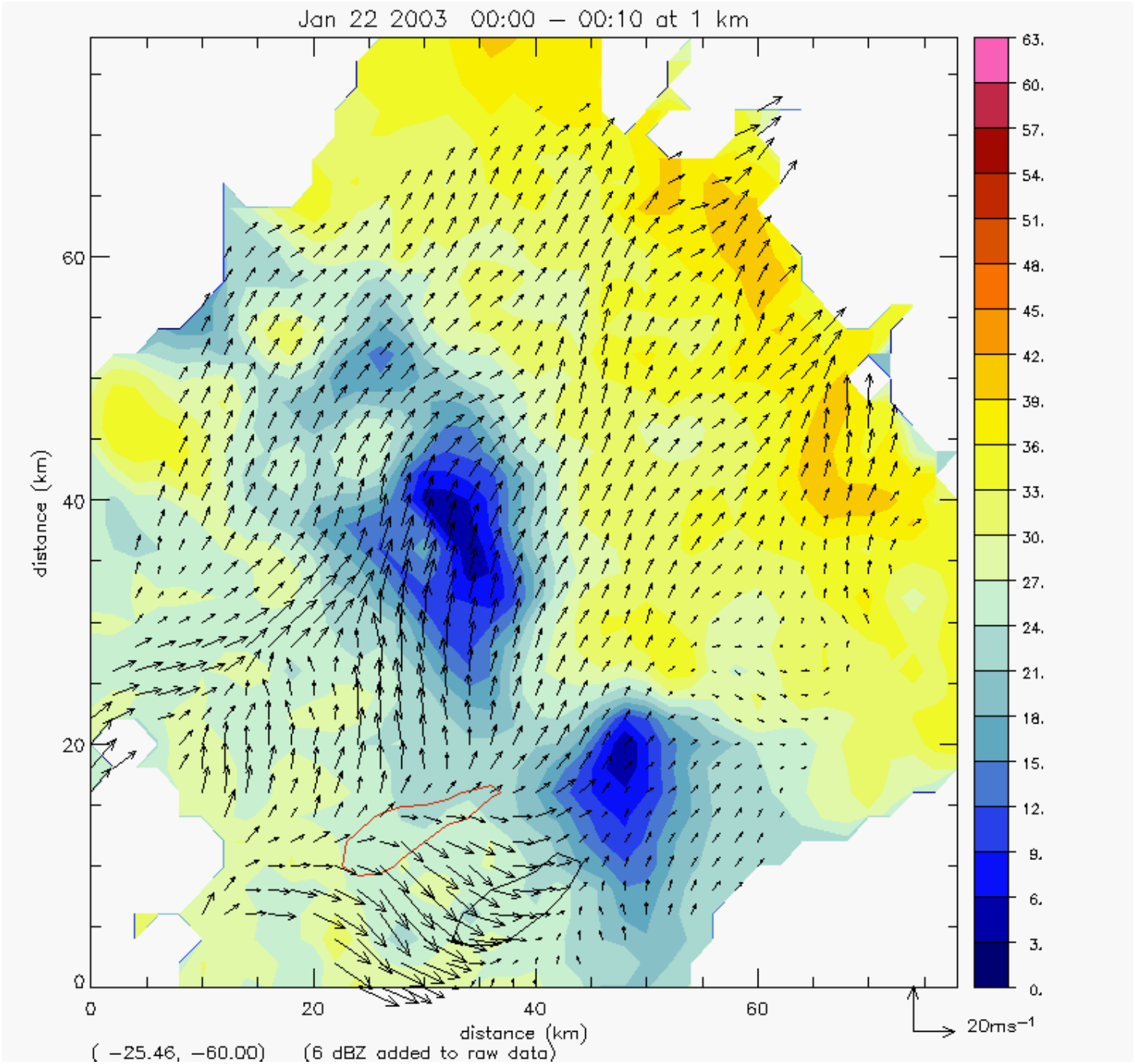

X

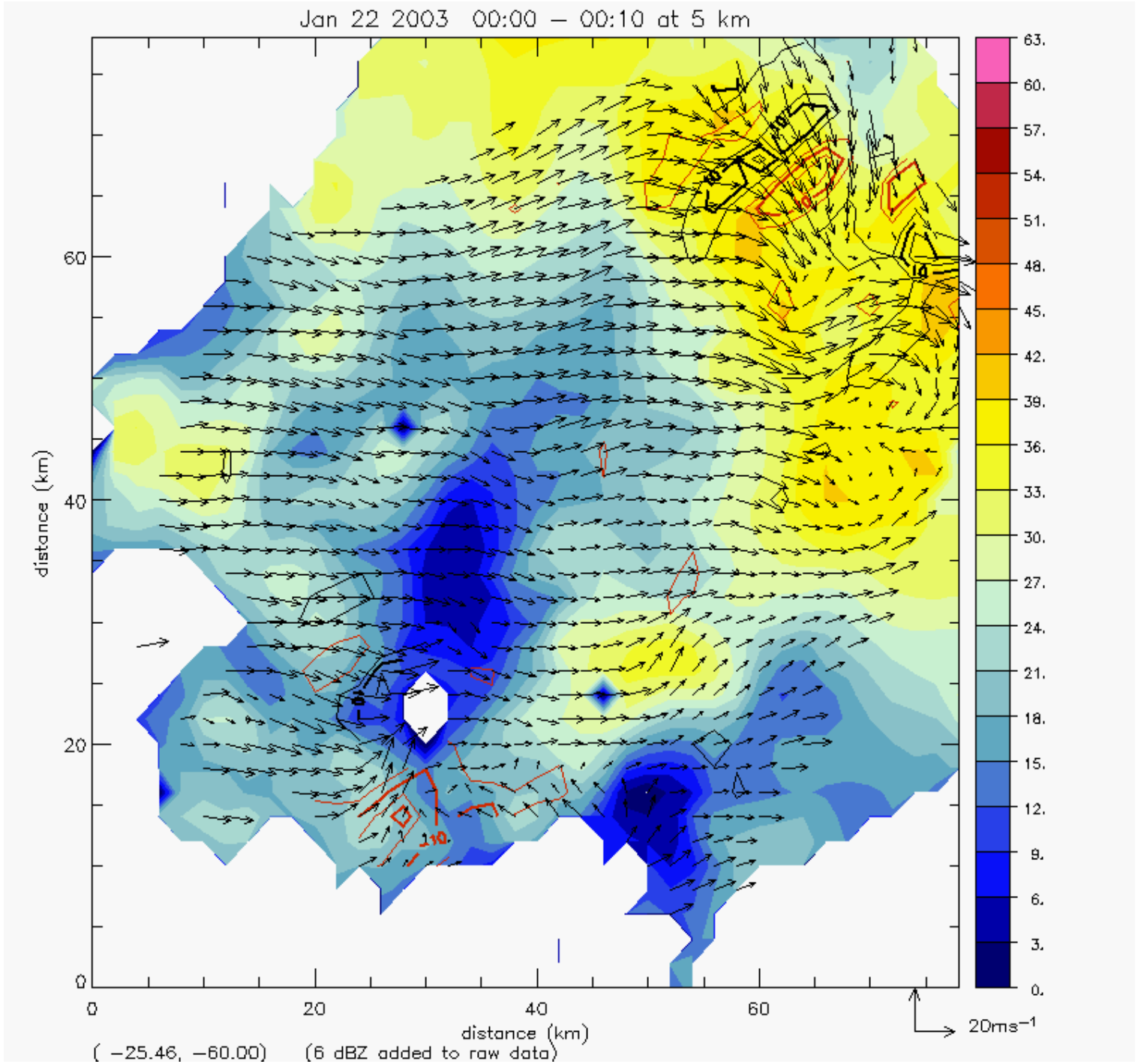

A2
B2

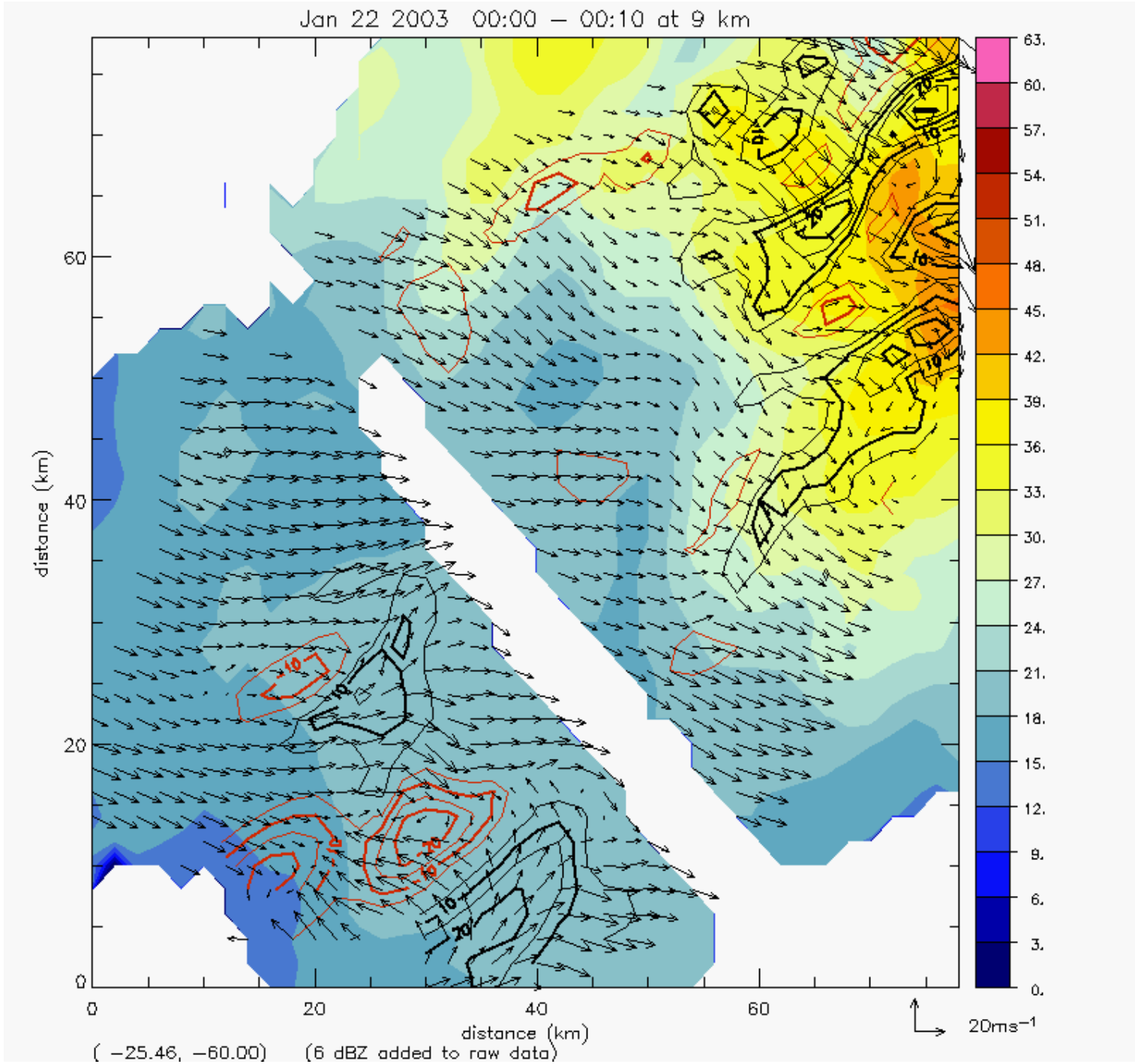

Cross section A2–B2
altitude (km)
0
5
10
15
0
20
40
60
distance (km)
A2
B1
A2 (NE)
B2
(SW)
20ms⁻¹

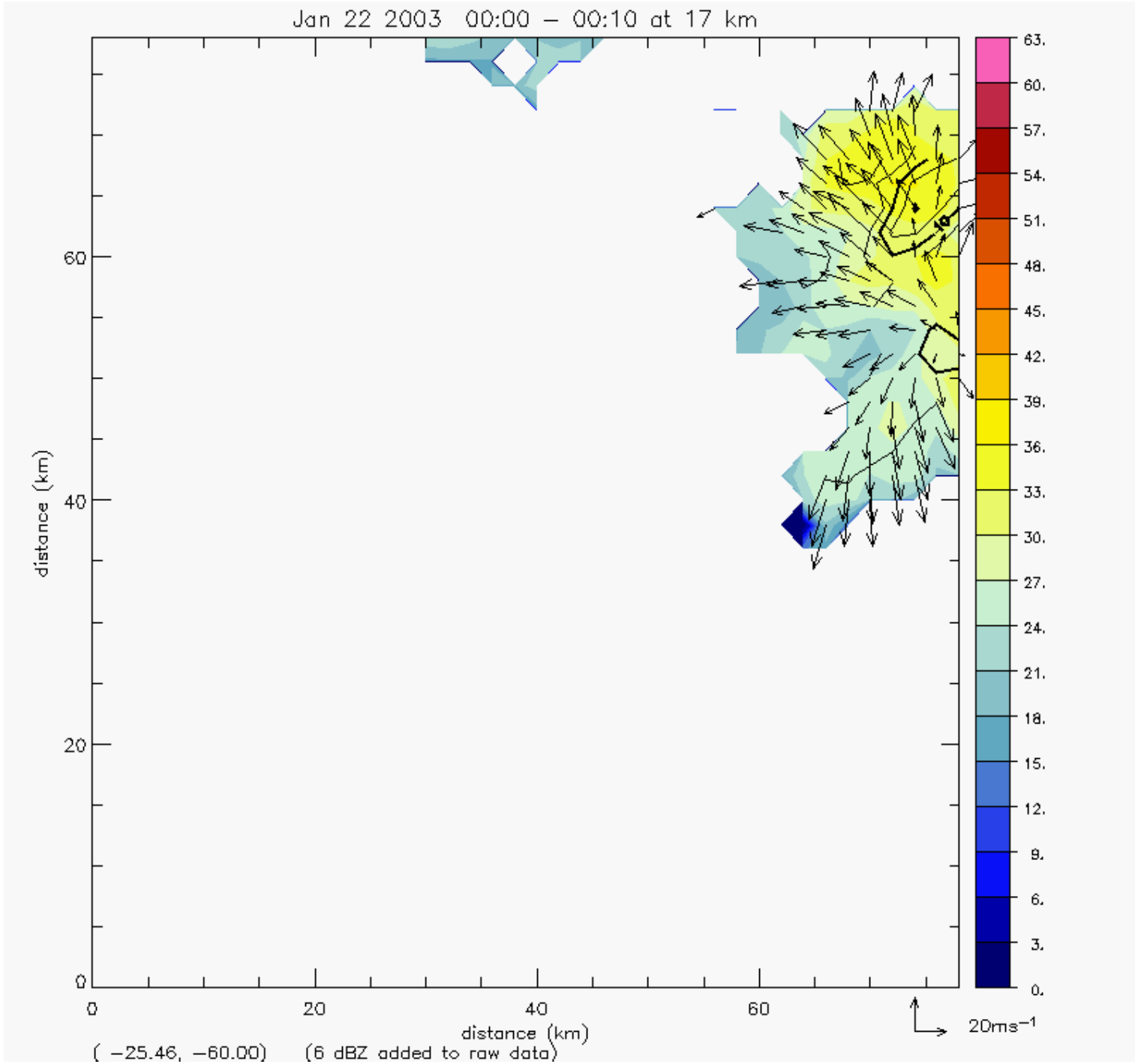


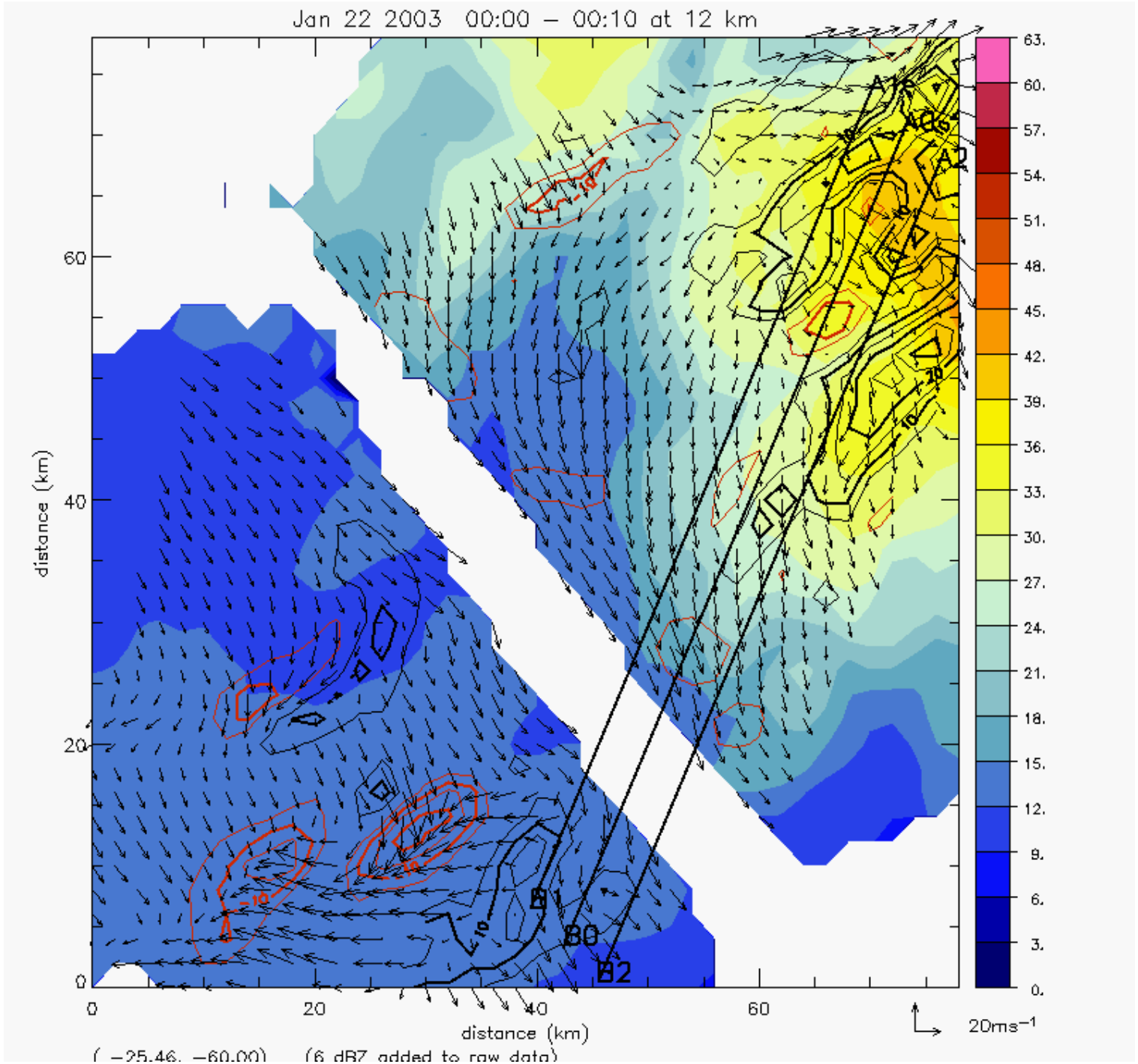


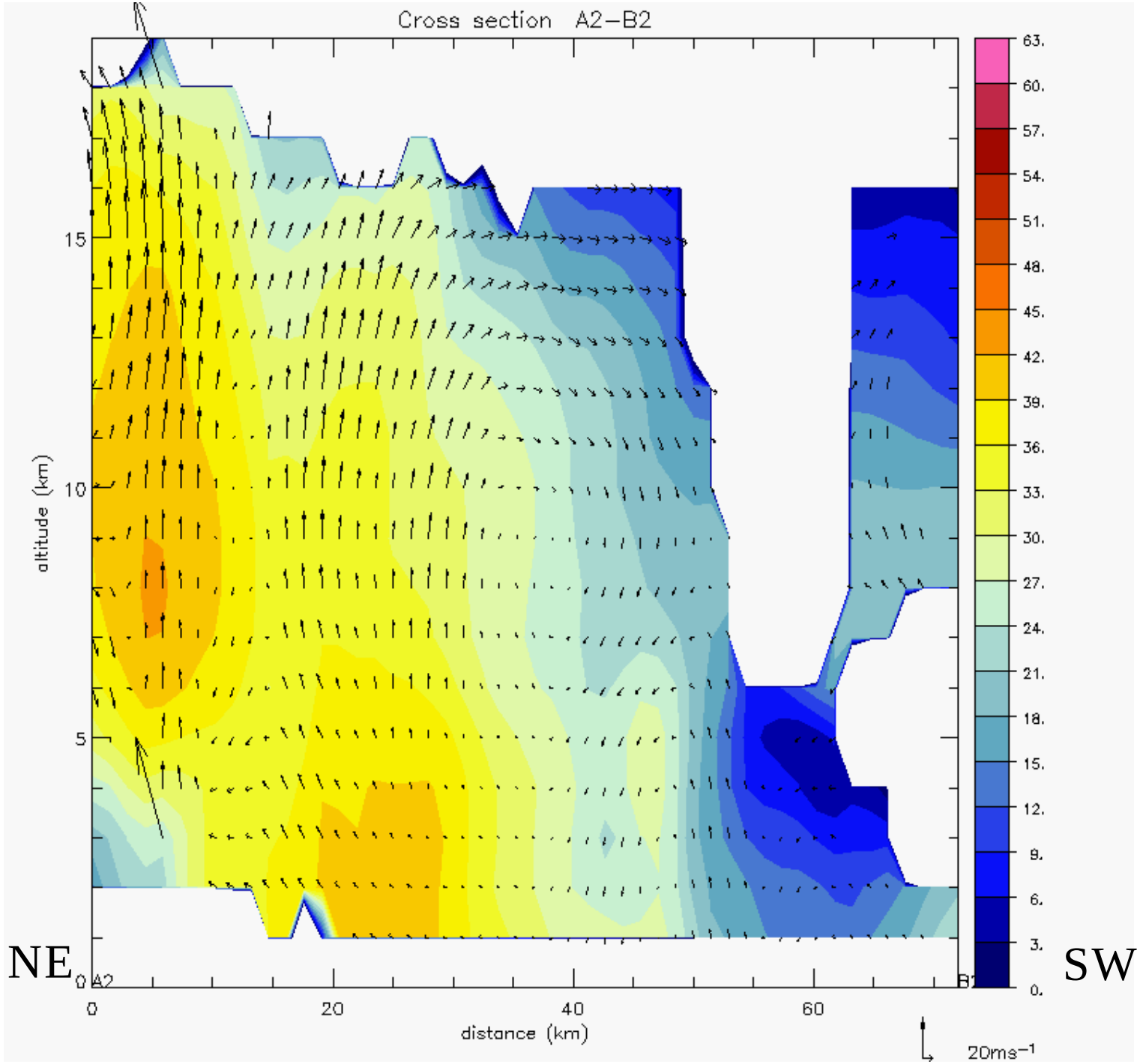

Jan 22 2003 00:00 – 00:10 at 1 km
distance (km)
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.00)
(6 dBZ added to raw data)


Jan 22 2003 00:00 – 00:10 at 5 km
distance (km)
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.00)
(6 dBZ added to raw data)

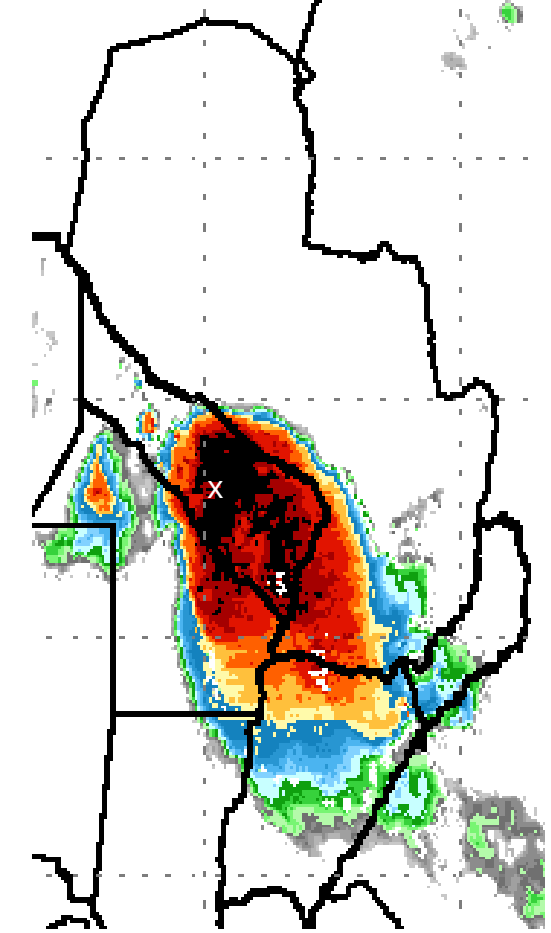

Jan 22 2003 00:00 – 00:10 at 9 km
distance (km)
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.00)
(6 dBZ added to raw data)

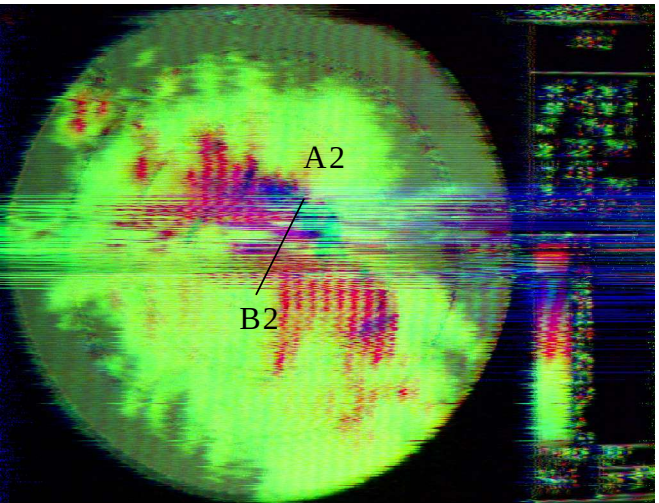

Jan 22 2003 00:00 – 00:10 at 17 km
distance (km)
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹
(−25.46, −60.00)
(6 dBZ added to raw data)

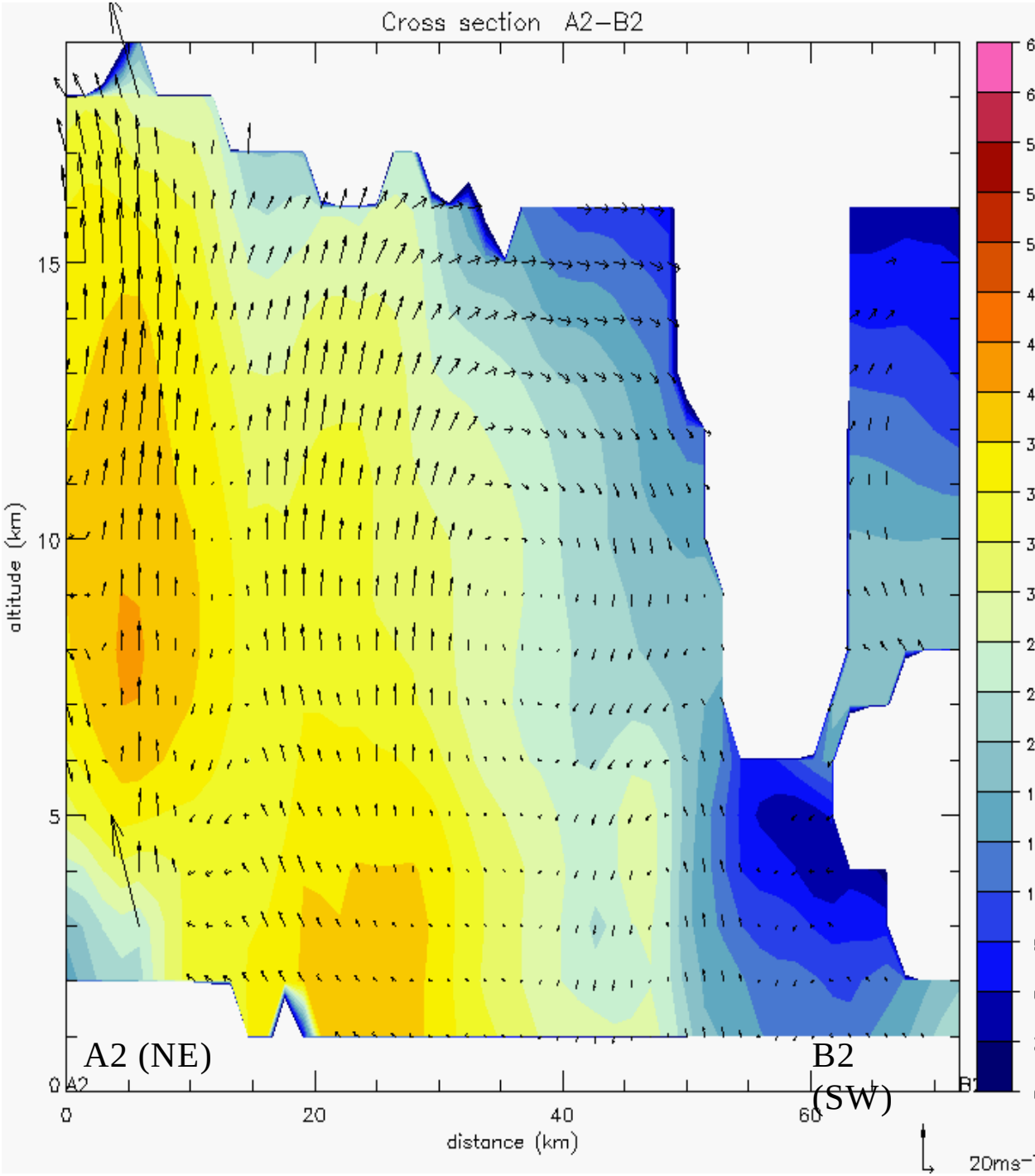

Jan 22 2003 00:00 – 00:10 at 12 km
distance (km)
0
20
40
60
A1
A2
B1
B0
B2
-10
10
20
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms^{-1}
(−25.46, −60.00)
(6 dBZ added to raw data)


Cross section A2–B2
altitude (km)
15
10
5
0
A2
B2
0
20
40
60
distance (km)
63.
60.
57.
54.
51.
48.
45.
42.
39.
36.
33.
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
20ms⁻¹

NE SW


X


A2
B2


Cross section A2–B2
altitude (km)
0
5
10
15
0
20
40
60
distance (km)
A2
B1
A2 (NE)
B2
(SW)
20ms⁻¹

SUMMARY

- Good data for 22 January case
- Early stage dominated by supercell storms
- Updraft speeds exceed 30 m/s
- Bow echo squall line appearance 2 hours later
- Anvil spreads rapidly near tropopause (Tb -80C)
- Precipitation efficiency may be quite low
- Data processing takes time and needs work

Aircraft radar data analysis

Soloii, Reorder and Doppler velocity analysis software

Chuntao Liu
Tropical Convective Research Group
Nov. 2003

Acknowledgment

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Dr. John Gamatche (John.Gamache@noaa.gov)

Helps and introduction from:

Michael Bell (mbell@atd.ucar.edu)

Suggestions from colleagues:

Dr. Ed. Zipser
Bryan White
Haiyan Jiang
Yaping Li
Paola Salio

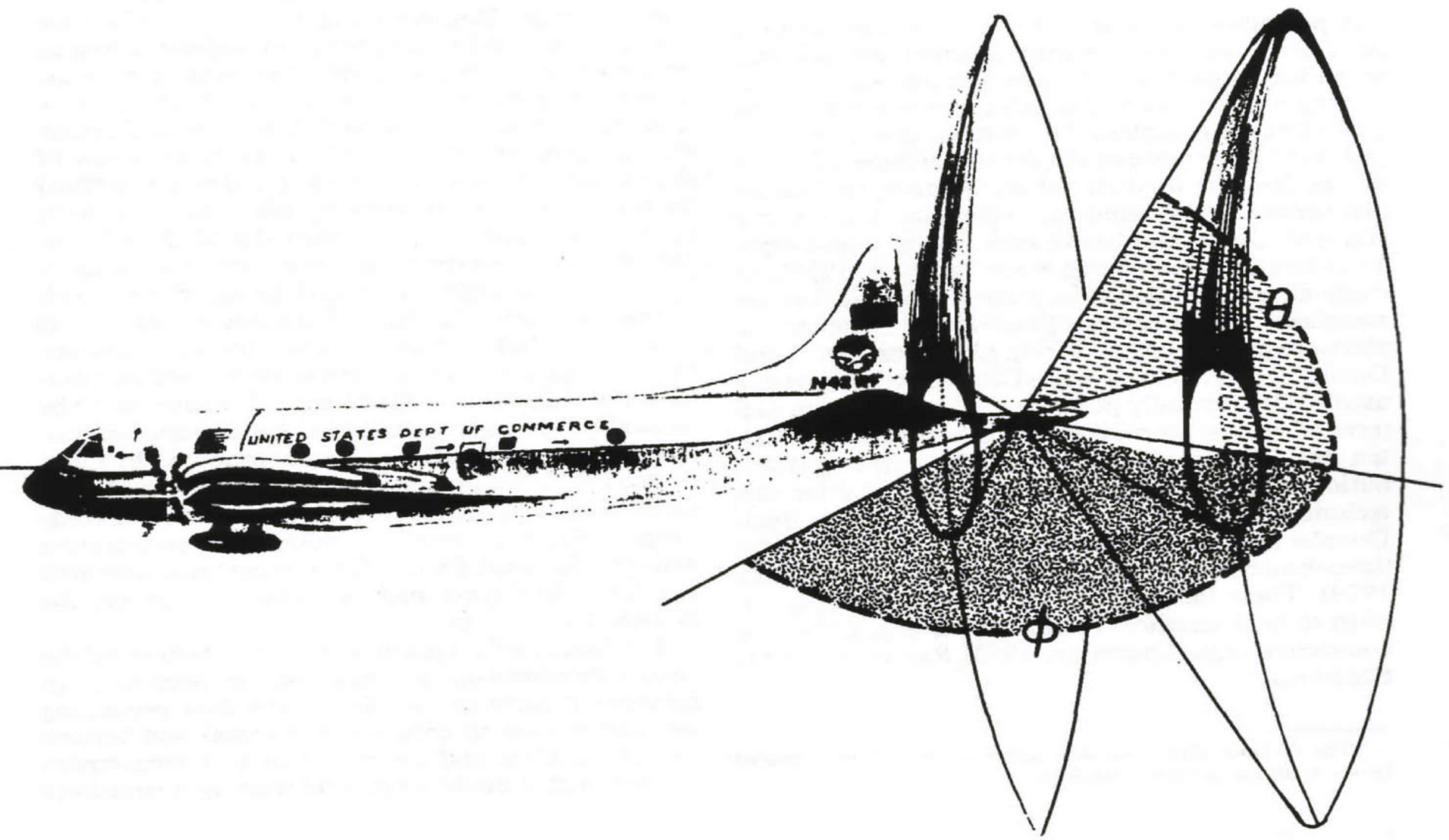


FIG. 1. Schematic diagram of the WP-3D tail radar scanning plane. The elevation angle (θ) is varied with azimuth (ϕ) to maintain an antenna pointing angle that is normal to the aircraft's ground track.

Radar data formats

1) Sweep file

Include the rays and cells data

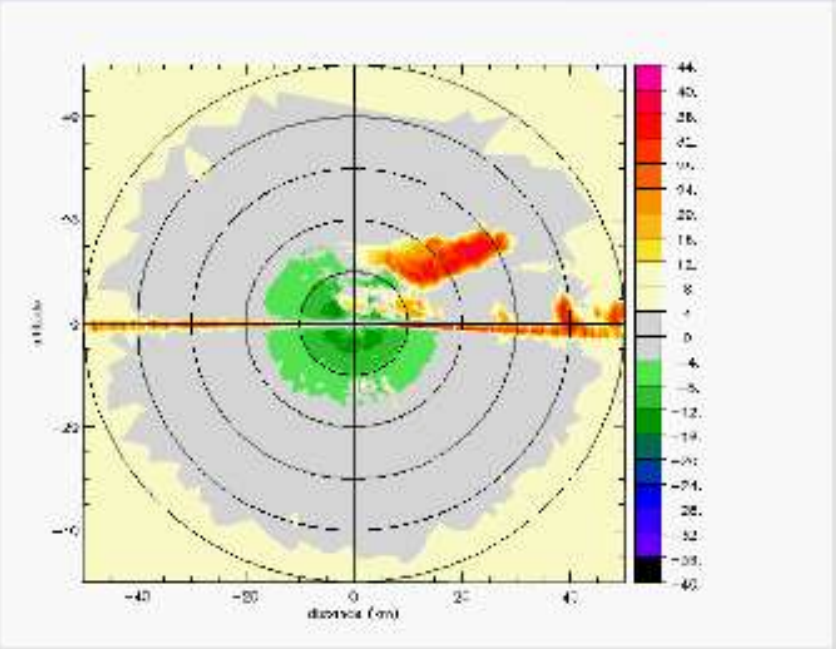
2) UF (Universal Format)

May be a volume or combined sweeps data

3) Netcdf

Easy to transfer among different platform

4) A typical aircraft sweep data includes



Radar instrument information:

CELL_SPACING 150.000 NYQUIST_VELOCITY 16.9050 BM_WIDTH -32768.0 BAND_WIDTH 2.00000e+06 XMTR_PWR -32768.0
TST_PLS_PWR -32768.0 TST_PLS_RNG0 -32768.0 TST_PLS_RNG1 -32768.0 WAVELENGTH 0.0322000 PRF 2.10000e+06

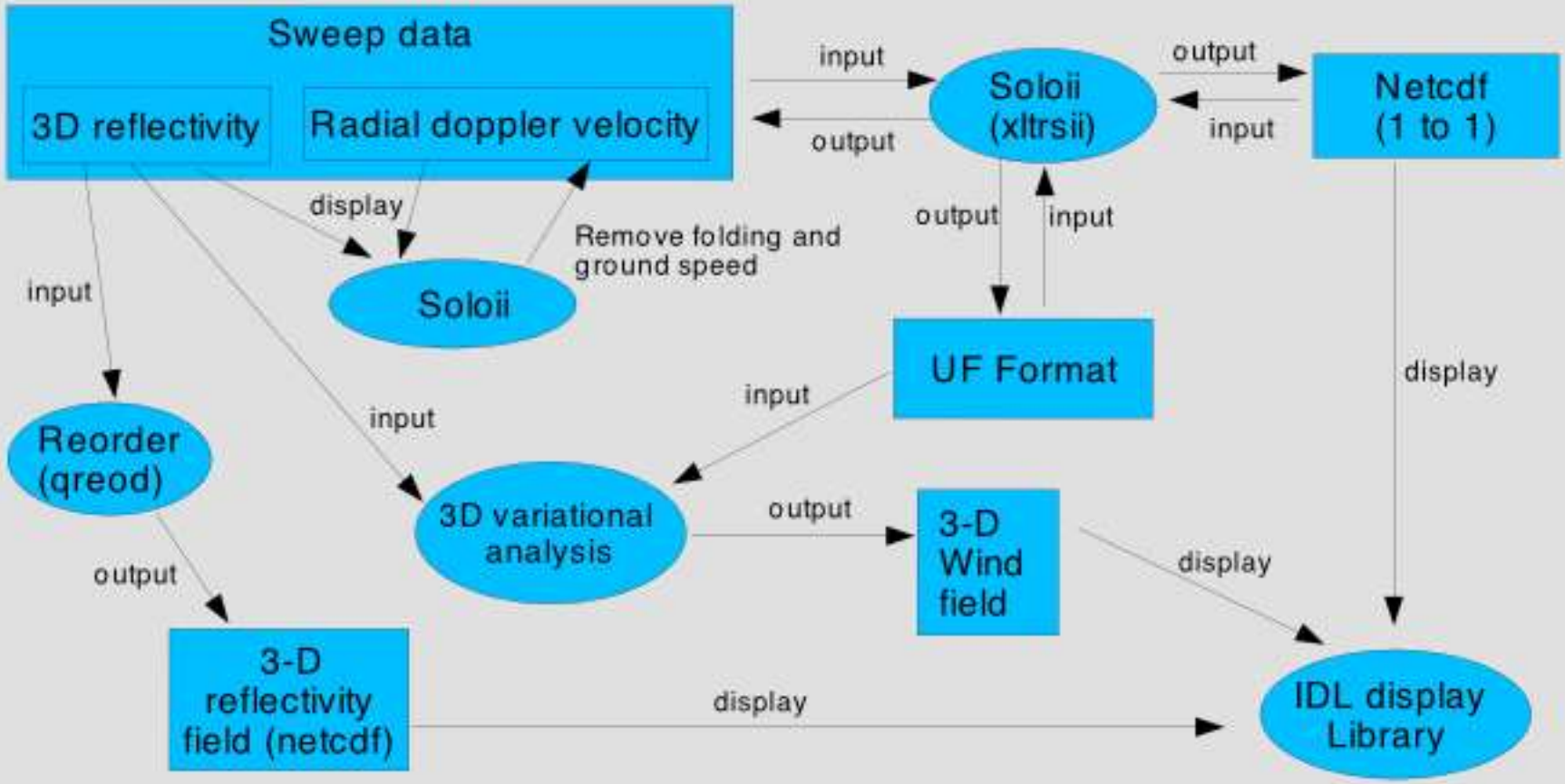
Aircraft information:

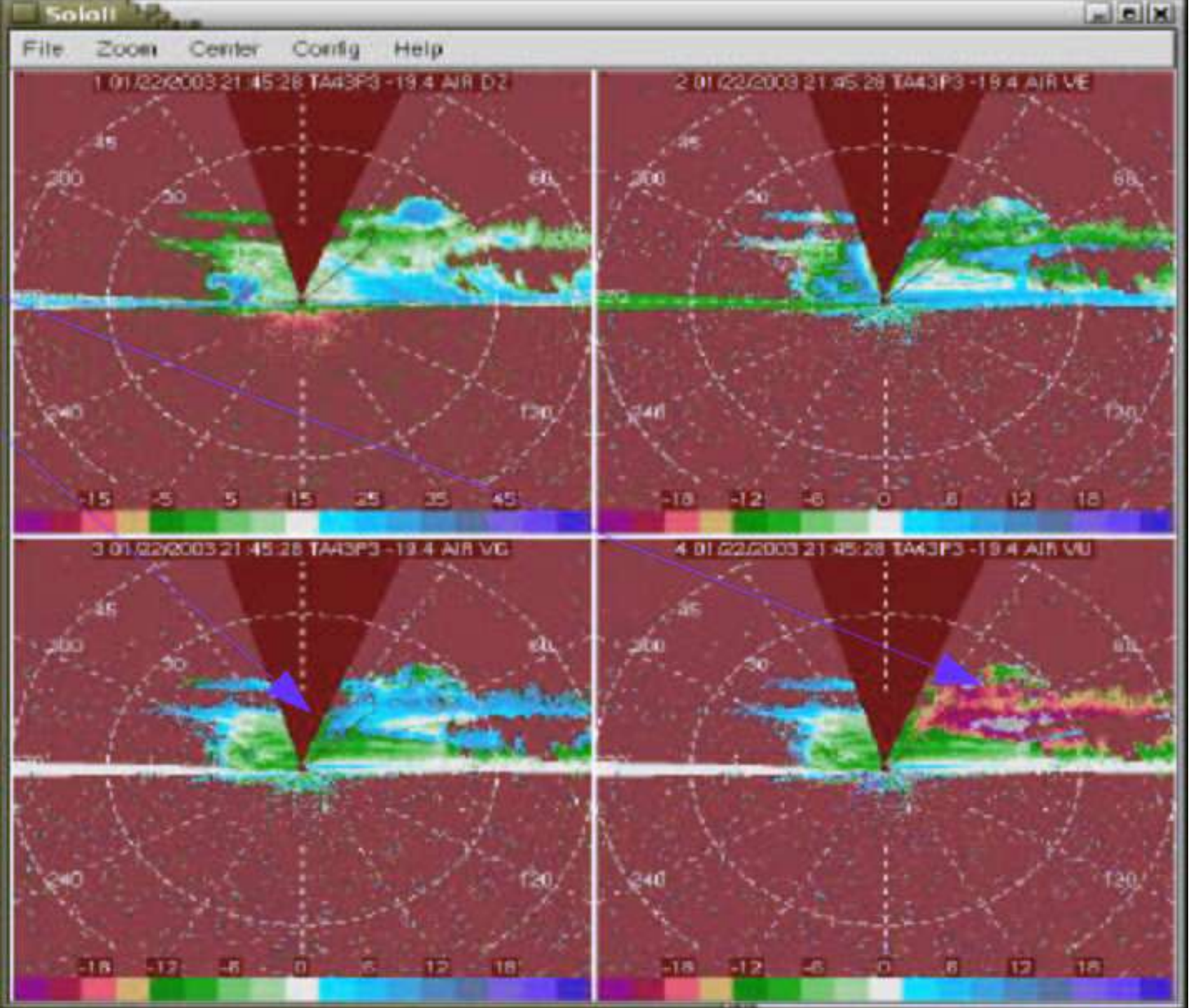
TIME_OFFSET Array[322] AZIMUTH Array[322] ELEVATION Array[322] CLIP_RANGE Array[322] LATITUDE Array[322] LONGITUDE Array[322]
ALTITUDE Array[322] ALTITUDE_AGL Array[322] ROTATION_ANGLE Array[322] TILT Array[322] HEADING Array[322] ROLL Array[322]
PITCH Array[322] DRIFT Array[322] NS_VELOCITY Array[322] EW_VELOCITY Array[322] VERTICAL_SPEED Array[322]
NS_WIND Array[322] EW_WIND Array[322] VERTICAL_WIND_SPEED Array[322]
AC_VEL_COMPONENT Array[322] HEADING_CHANGE Array[322] PITCH_CHANGE Array[322] TRUE_SCAN_RATE Array[322]

Radar Measurements:

DZ Array[472, 322] VE Array[472, 322]

Using Radar data

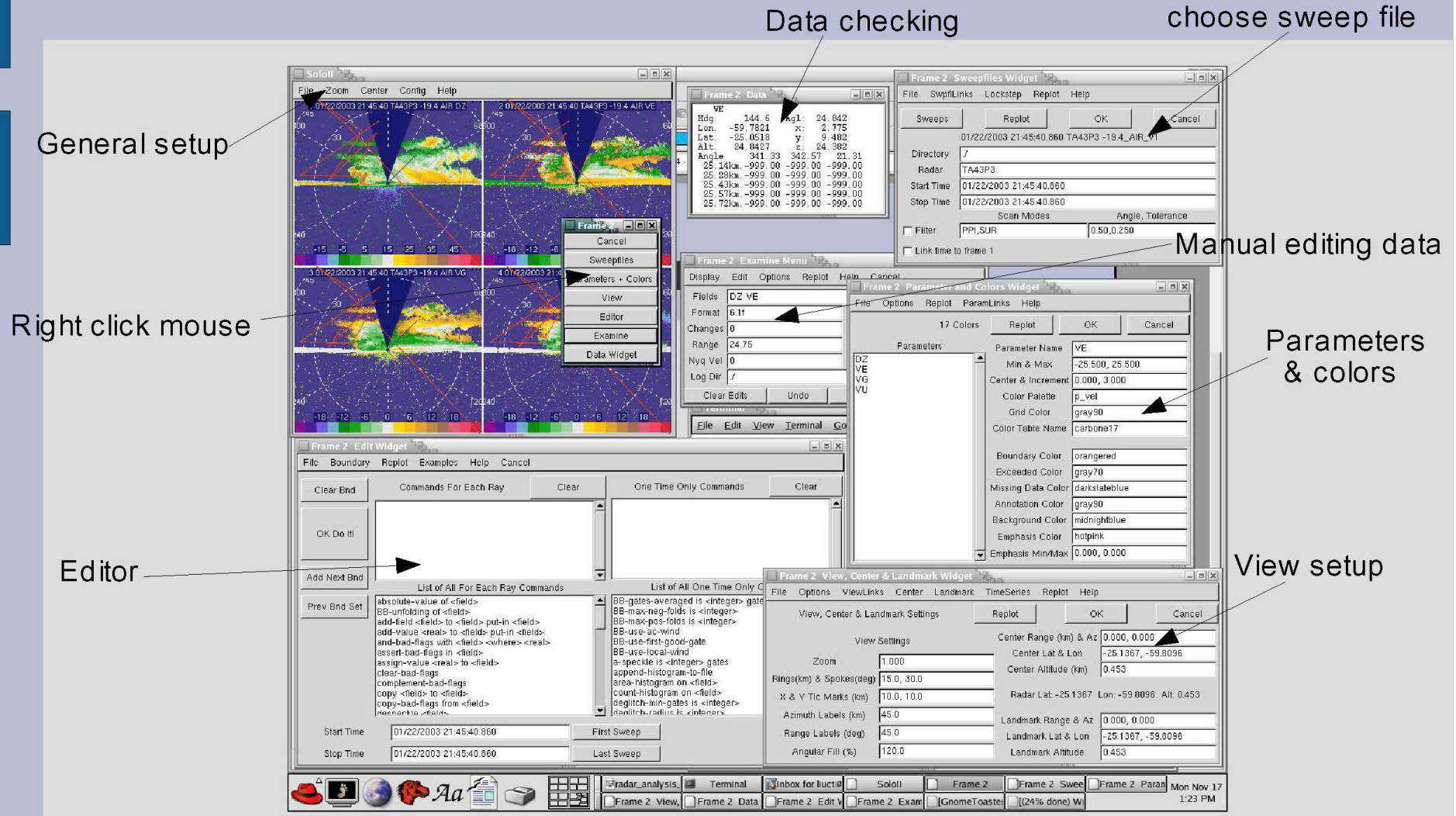




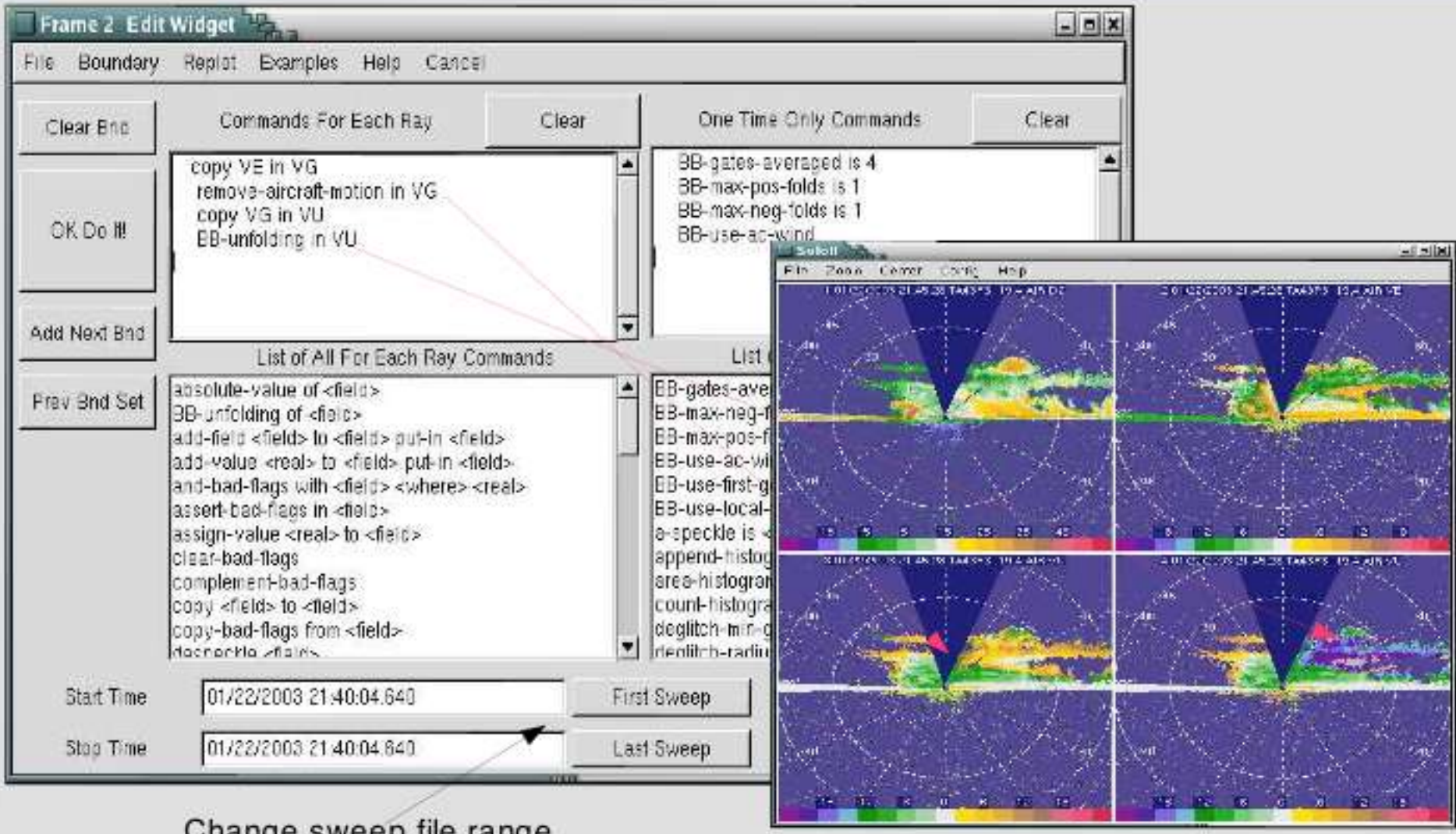
Sample sweep files

22 Jan 03 2145 UTC

Display sweep files by Soloii



Soloii editing



Reorder (3-D reflectivity)

INPUT: sweep files

Running reorder:

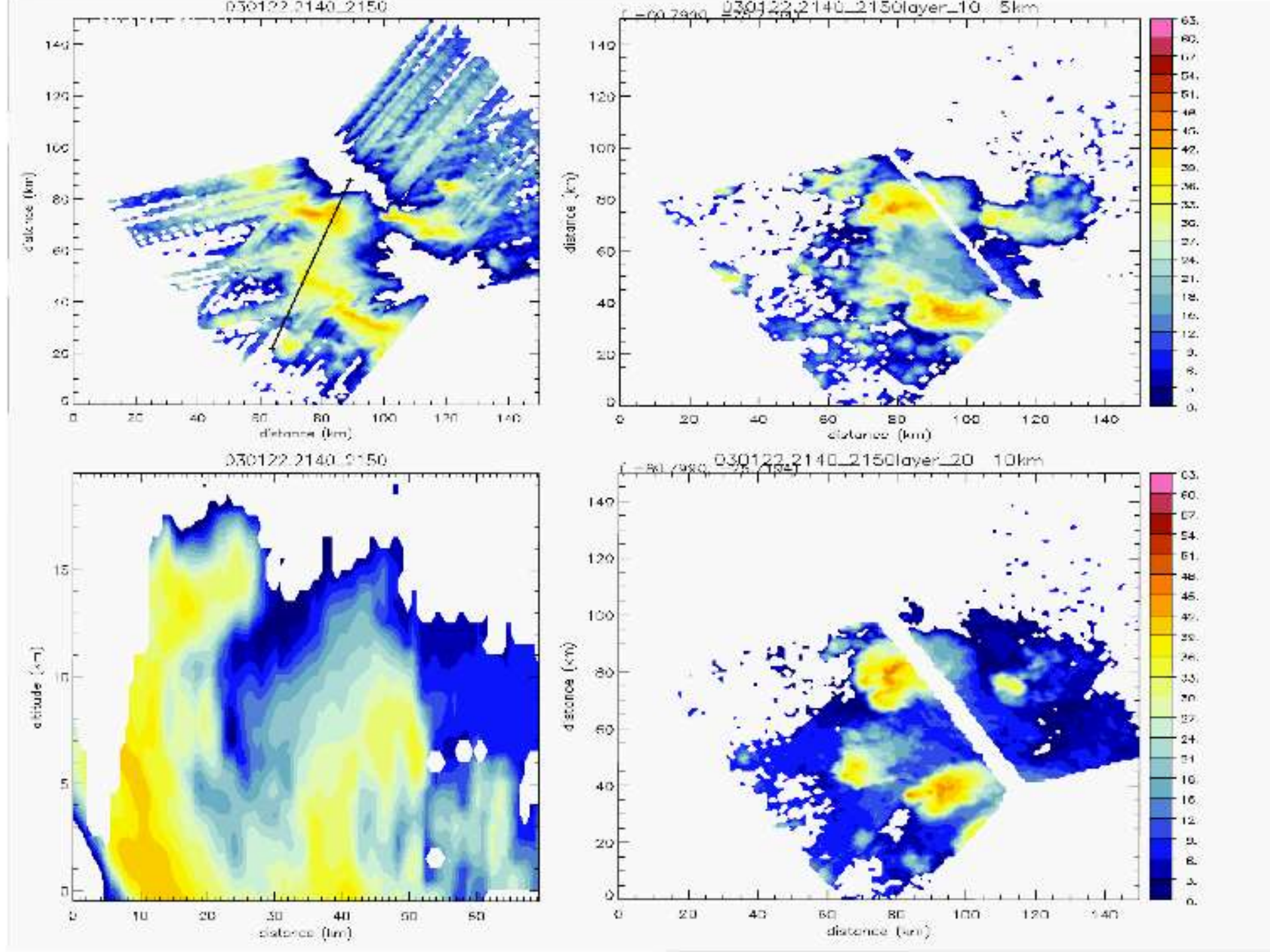
```
#
setenv SCRATCH ./out_reorder/
#
/home/liuct/tools/rds/bin/qreod < input.runreo
```

Note:

1) must use “qreod” instead of “qreou”
2) must have “AIRCRAFT” for Eldora & P3
3) may setup the 3-D grid up to 400x400x40
4) Data searching radius is about 1.0-1.5
   * sweep distance (100m/s, 6s per sweep)
5) Must set start and stop time
6) output is in Netcdf format

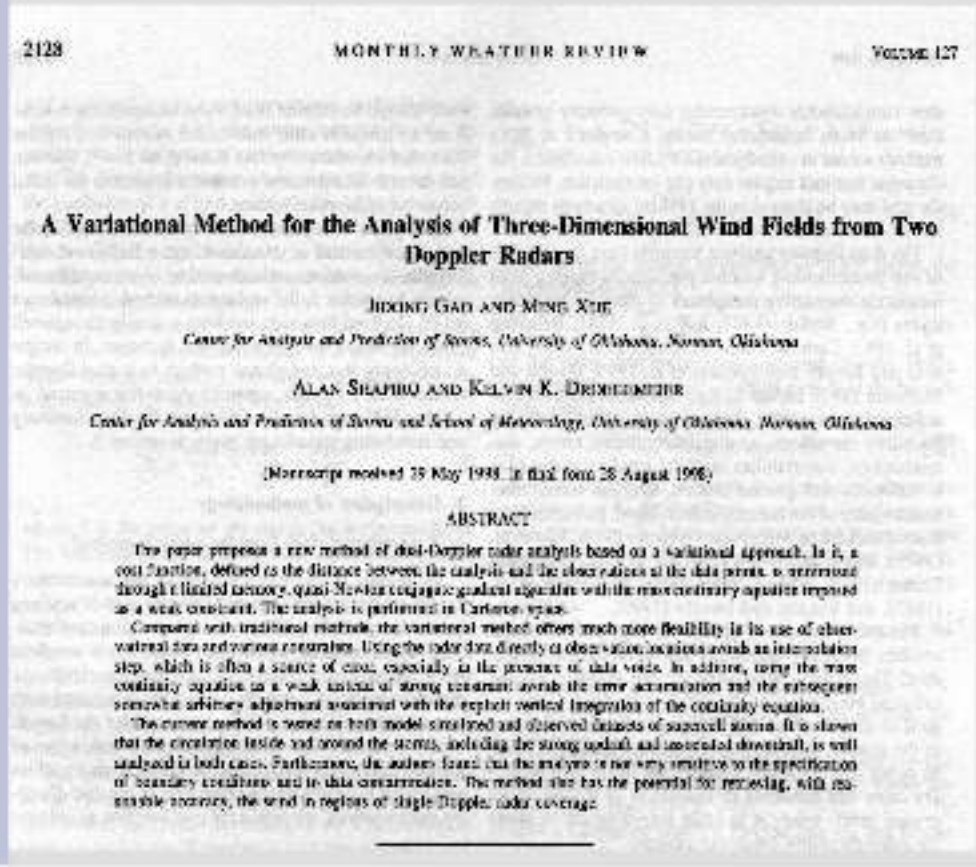
An example of Input.runreo:

```
DIRECTORY:"/data/zipser15/yaping/ELDORA/swp
INSTRUMENT:"TF";
OUTPUT:"reorder.out";
NETCDF:"./out_reorder";
AIRCRAFT;
WEIGHTING FUNCTION: CRESSMAN;
GLONGITITUDE:-81.32;
GLATITUDE:25.88;
XMIN:-150.;   XMAX:150.;
XSPACING:1.0; XRADIUS:0.6;
YMIN:-150.;   YMAX:150.;
YSPACING:1.0; YRADIUS:0.6;
ZMIN:0.0;     ZMAX:20.0;
ZSPACING:0.5; ZRADIUS:0.6;
DBZFIELD:DBZ,REFLEC;
FIELD:VT,VELOCITY;
DISPLAY:REFLEC,0,3;
START:28-jul-02,23:27;
STOP:28-jul-02,23:47;
```


030122.2140_2150
distance (km)
030122.2140_2150layer_10 5km
distance (km)
030122.2140_2150
altitude (km)
distance (km)
030122.2140_2150layer_20 10km
distance (km)

3-D variational analysis of wind field (1) Theory

- Matches the Doppler observations closely
- Satisfies the continuity equation and boundary conditions very closely
- Minimizes the noise/errors associated with observations and discretization



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A Variational Method for the Analysis of Three-Dimensional Wind Fields from Two Doppler Radars

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(Manuscript received 19 May 1998, in final form 28 August 1998)

ABSTRACT

The paper proposes a new method of dual-Doppler radar analysis based on a variational approach. In it, a cost function, defined as the distance between the analysis and the observations of the data points, is minimized through a limited memory, quasi-Newton conjugate gradient algorithm with the more customary equation imposed as a weak constraint. The analysis is performed in Cartesian space.

Compared with traditional methods, the variational method offers much more flexibility in its use of observational data and various constraints. Using the radar data directly as observations avoids an interpolation step, which is often a source of error, especially in the presence of data voids. In addition, using the wave continuity equation as a weak instead of strong constraint avoids the error accumulation and the subsequent unrealistic arbitrary adjustment associated with the explicit vertical integration of the continuity equation.

The current method is tested on both model simulated and observed datasets of supercell storms. It is shown that the circulation inside and around the storms, including the strong updraft and associated downdraft, is well analyzed in both cases. Furthermore, the authors found that the analysis is not very sensitive to the specification of boundary conditions and to data contamination. The method also has the potential for retrieving, with reasonable accuracy, the wind in regions of single Doppler radar coverage.

$$J = J_O + J_B + J_D + J_S, \tag{1}$$

$$J_O = \frac{1}{2}\sum_{m,n} \lambda_{m,n}(\mathbf{C}\mathbf{V}_r^{m,n} - \mathbf{V}_{rob}^{m,n})^2, \tag{2}$$

$$J_B = \frac{1}{2}\left[\sum_{ijk} \lambda_{ub}(u - u_b)^2 + \sum_{ijk} \lambda_{vb}(v - v_b)^2 + \sum_{ijk} \lambda_{wb}(w - w_b)^2\right], \tag{3}$$

$$J_D = \frac{1}{2}\sum_{ijk} \lambda_D D^2, \tag{4}$$

$$J_S = \frac{1}{2}\left[\sum_{ijk} \lambda_{us}(\nabla^2 u)^2 + \sum_{ijk} \lambda_{vs}(\nabla^2 v)^2 + \sum_{ijk} \lambda_{ws}(\nabla^2 w)^2\right]. \tag{5}$$

Here J_o is the difference between the analyzed radial ve-

Input: Reflectivity, radial doppler velocity sweeps in UF format

Running procedure:

1) Interpolating the data onto target coordinate
2) Variational analysis
3) Readout result

3-D variational analysis of wind field (2) Interpolation

Running:

```
> wind_interpolate
  Enter command file name:
  job_wind_interpolate
  ...
```

Notes:

1) Input data is UF format containing all sweeps
2) Variable name (DB VU) must be the same as shown in Soloii
3) system motion is not used for our case

An example of the file job_wind_interpolate:

```
03012H1                                   description
SALLJEX                                   description
2                                          number of radars
../uf/ufd.1030122214004.TA43P3.0.tape
214000 215000                             time period
../uf/SUMFILE_TA                          first output file
../uf/ufd.1030122214010.TF43P3.0.tape
214000 215000                             time period
../uf/SUMFILE_TF                          second output file
1. 4.                                     system motion
214500                                    time to define system center
-25.1 -60.0                               center of the grid
1. 1. 1.0                                 spacing
40. 40. 0. 0.                             horizontal center
80 80 17                                  grid number
2. 2.                                     data searching range
1.5 1.5                                   gaussian weight
VU                                        Velocity variable name
DB                                        Reflectivity variable name
```

3-D variational analysis of wind field (3) Solution

Running:

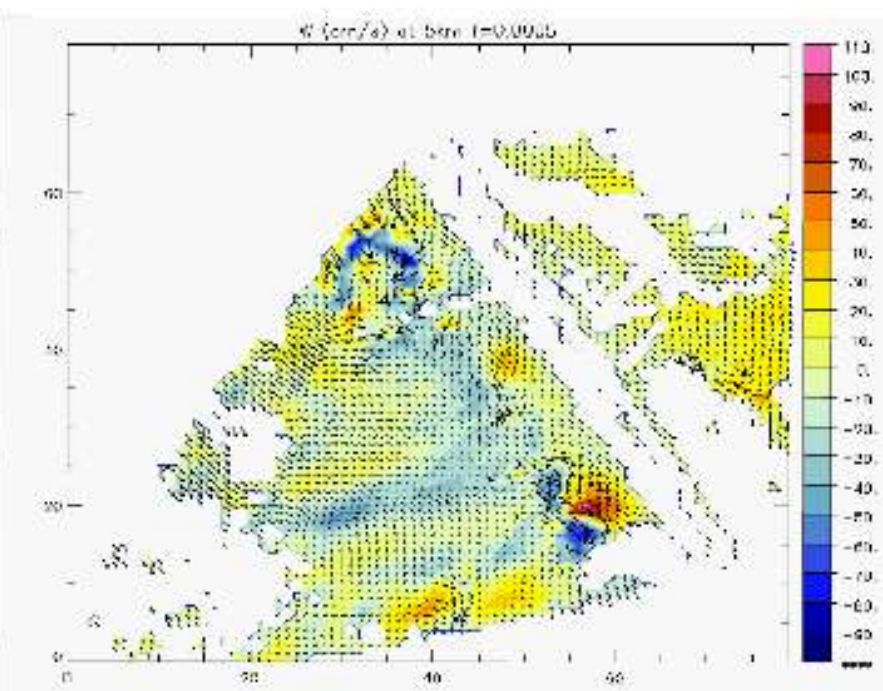
```
> wind3_fill
  Enter command file name:
  job_wind3_fill
  ...
> index_ascii     (readout solution)
```

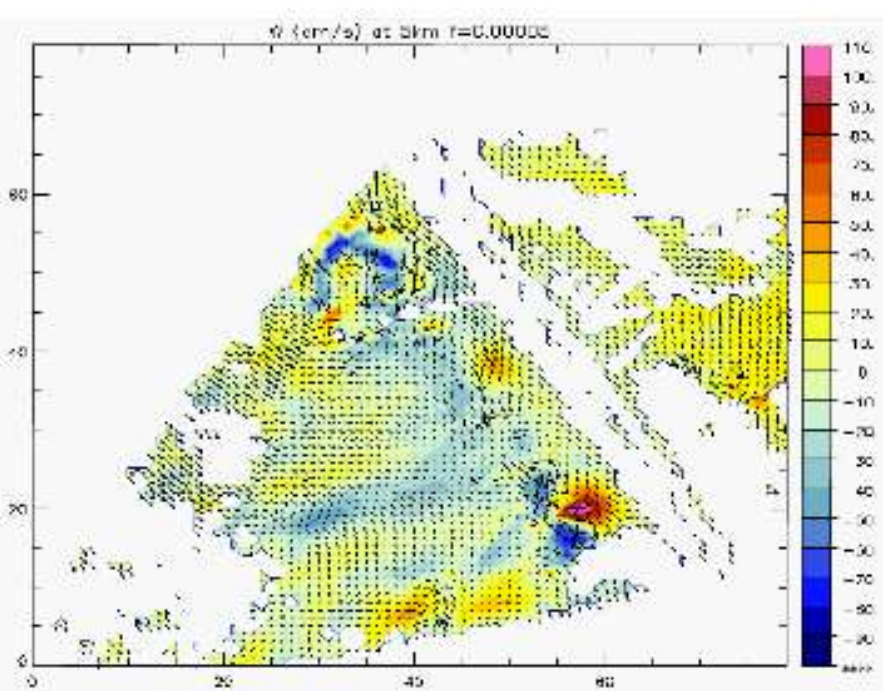
Notes:

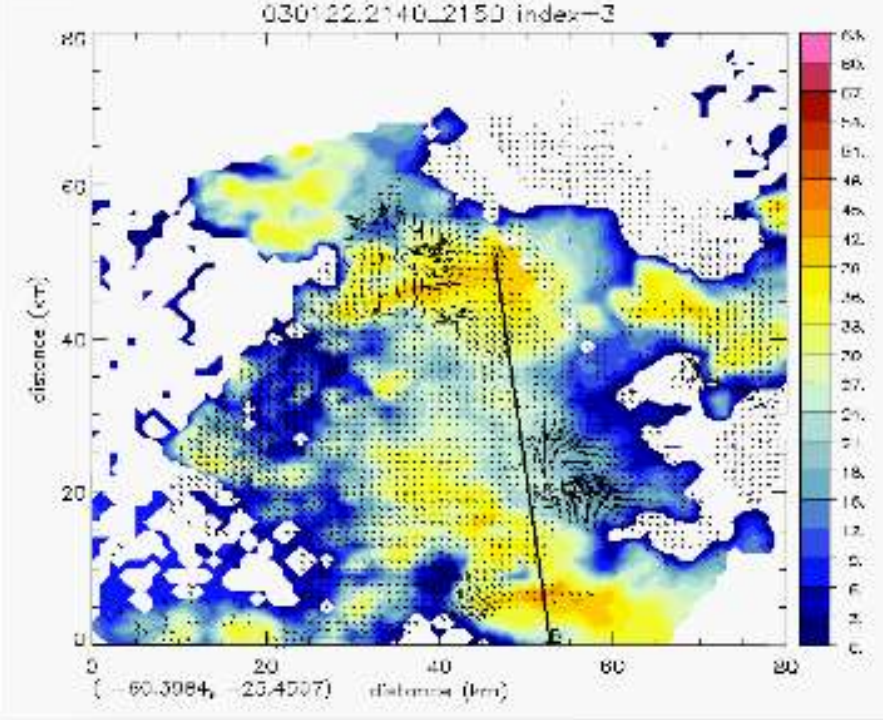
1) Input data is output files from wind_interpolate
2) Grid must be the same as setup in job_wind_interpolate
3) Iteration constrain does not work, must change the fortran code. “solvesparse_itpack.f” current constrain is set as 0.0005
4) 'wind3_fill.w' and 'solution' are two output files needed by index_ascii

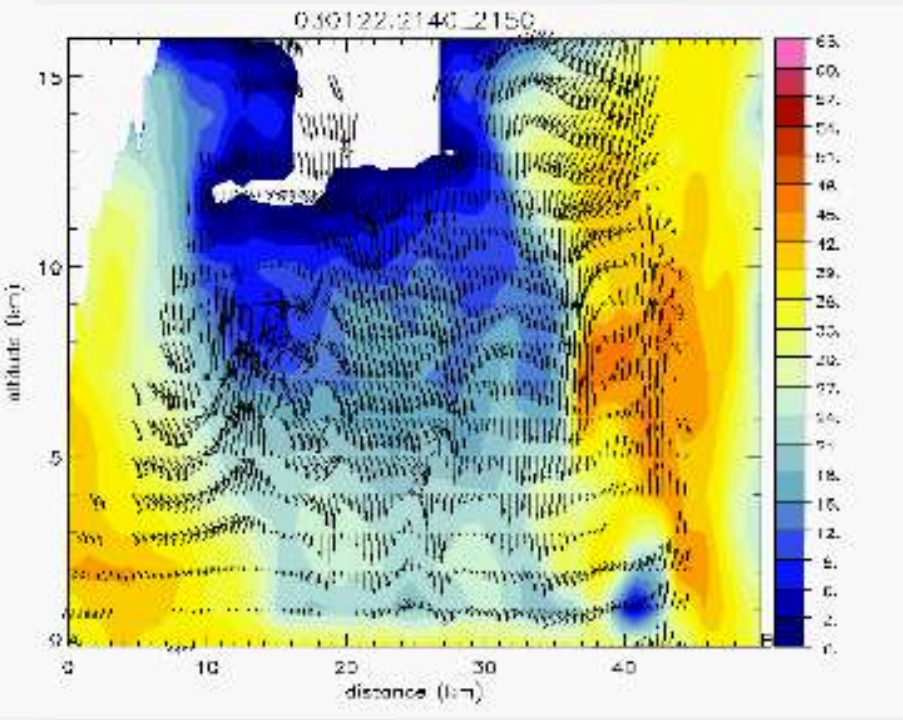
An example of job_wind3_fill:

030122H1	Description
SALLJEX	Description
2	Number of radars
214000 214500	start and stop time
../uf/SUMFILE_TA	Input for the radar #1
214000 214500	start and stop time
../uf/SUMFILE_TF	Input for the radar # 2
-25.0 -60.3	Grid center
1. 1. 1.0	Grid spacing
40. 40. 0. 0.	horizontal center
80 80 17	grid number
1000.	weight for solving
1. 1.	height of melting level
20. 30.	snow and rain dBz
wind3_fill.w	output file
0.005	iteration constrain






030122.2140_2150 index=3
distance (nm)


030122.2140_2150
altitude (km)
distance (nm)

Software & IDL codes

Location of Compiled Softwares:

SOLO: /usr/local/bin
soloii xltrsii

Reorder: /home/liuct/tools/rds/bin
qreod qreou

Doppler_Wind: /home/liuct/tools/wind
wind_interpolate wind3_fill
index_ascii

Note:

1. The source codes of these software can be found under:
   /home/liuct/tools/rds
   /home/liuct/tools/wind

2. All compiled under linux

ALL IDL programs are at: /home/liuct/idllib/pub

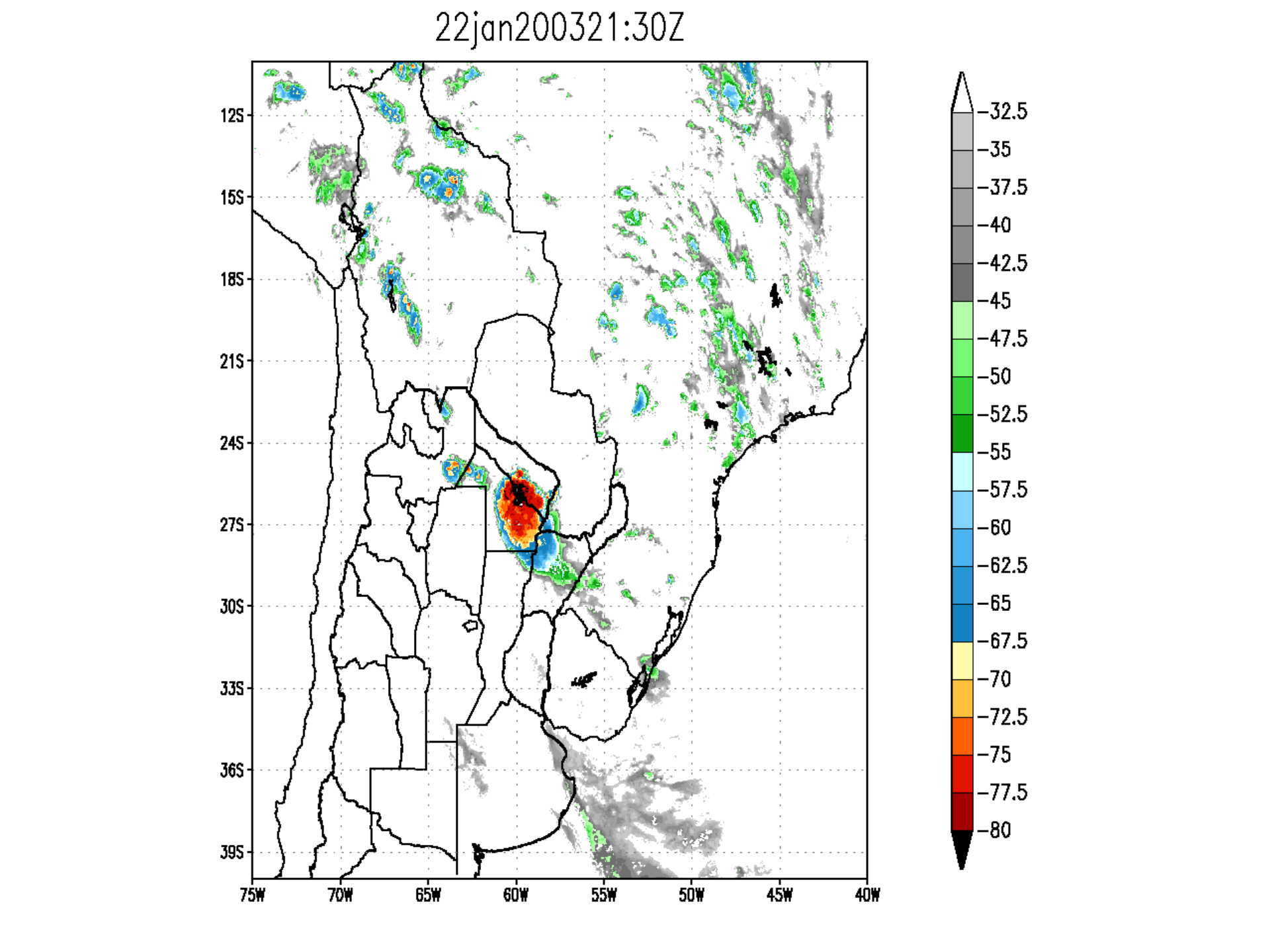
Small tools :
c_liu.clr colorbar.pro colortable_liu.pro
draw_circle.pro fitt.pro outpng.pro
velovect_new.pro windd.pro

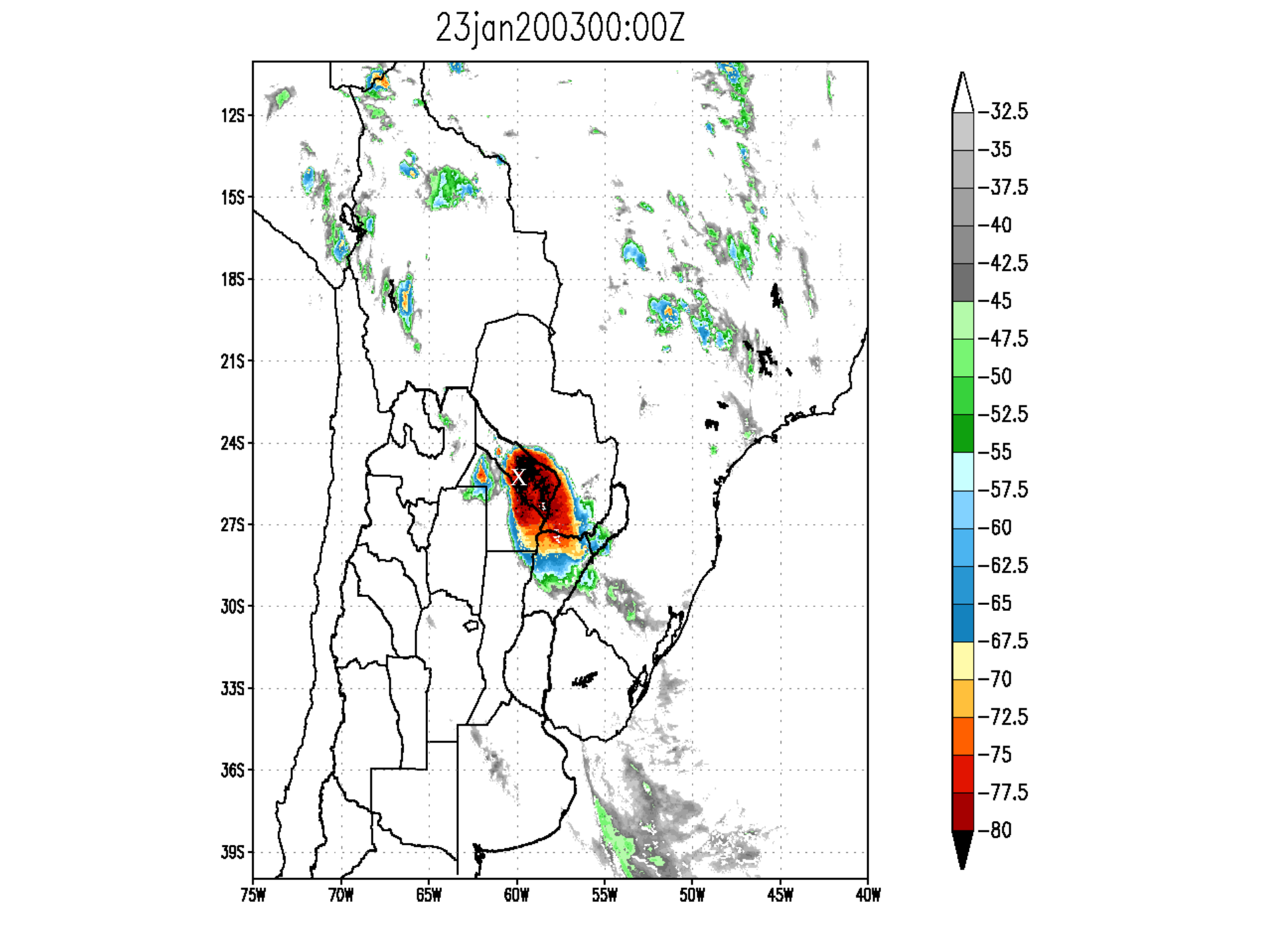
Field plot (2-D or 3-D grid data display):
plot_2d_field.pro plot_3d_field.pro
plot_3d_layers.pro
plot_3d_cross_curve.pro plot_3d_cross.pro
plot_3d_cross_wind.pro

Data reading:
compare_reorder.pro
compare_reorder_wind.pro
readin_reorder.pro
readin_sweep.pro
read_ncdf.pro

Sweep file and pixels display:
plot_pixels_color.pro plot_sweep.pro

Map combined plotting tools:
pmapcon.pro pmapvect.pro map_vec.pro


22jan200321:30Z
12S
15S
18S
21S
24S
27S
30S
33S
36S
39S
75W
70W
65W
60W
55W
50W
45W
40W
-32.5
-35
-37.5
-40
-42.5
-45
-47.5
-50
-52.5
-55
-57.5
-60
-62.5
-65
-67.5
-70
-72.5
-75
-77.5
-80


23jan200300:00Z
12S
15S
18S
21S
24S
27S
30S
33S
36S
39S
75W
70W
65W
60W
55W
50W
45W
40W
X
-32.5
-35
-37.5
-40
-42.5
-45
-47.5
-50
-52.5
-55
-57.5
-60
-62.5
-65
-67.5
-70
-72.5
-75
-77.5
-80