3D wind field retrieval with 4DVAR technique for assimilation to LM

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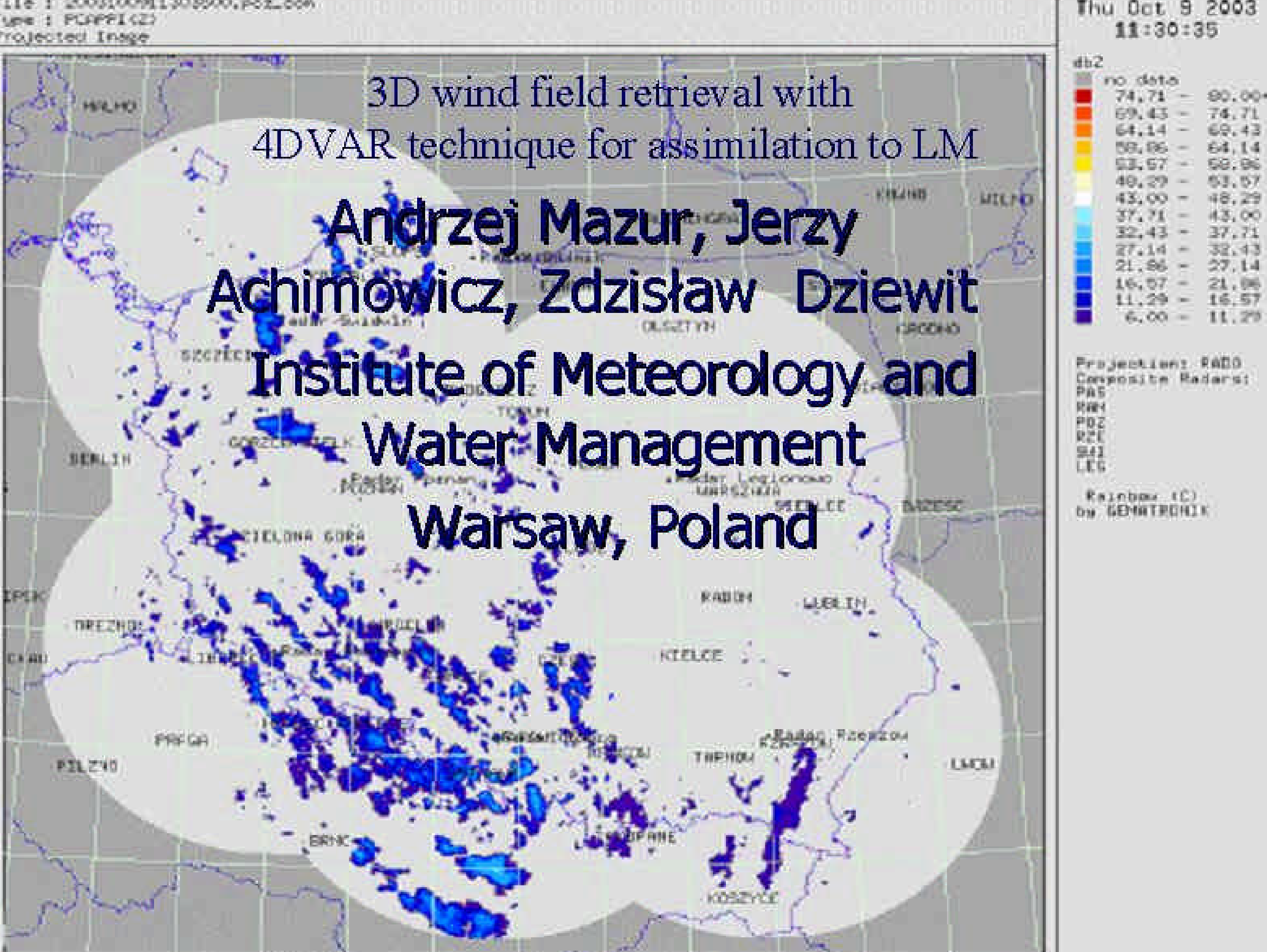


Goals:

- Method for assimilation of radar data that would be alternative to Latent Heat Nudging.
- Verification of "3D Simple Adjoint Velocity Retrivals from Single-Doppler Radar" method (J. Gao, M, Xue, Alan Shapiro *et al.*, Center for Analysis and Prediction of Storms, University of Oklahoma, Journal of Atmospheric and Oceanic Technology, vol. 18, 2001)

1) Choose a first guess for the control vector $\mathbf{Z} = (u_m, v_m, w_m, F_m, k_h,$ and $k_v)$ and integrate the advection equation (3a) with (3b) forward in time from $t = 0$ to T. Store the computed field.
2) Calculate the cost function using Eqs. (1), (2), (4), (6), (7), and (8) and the fields obtained from step 1.
3) Integrate the adjoint equation (16a) backward with (16b) in time from $t = T$ to 0, and calculate the gradients $(\partial J/\partial u_m, \partial J/\partial v_m, \partial J/\partial w_m, \partial J/\partial F_m, \partial J/\partial k_h,$ and $\partial J/\partial k_v)$ according to Eqs. (10)–(15).
4) Use a conjugate gradient or quasi-Newton minimization algorithm (Navon and Legler 1987) to obtain updated values of the control variables,

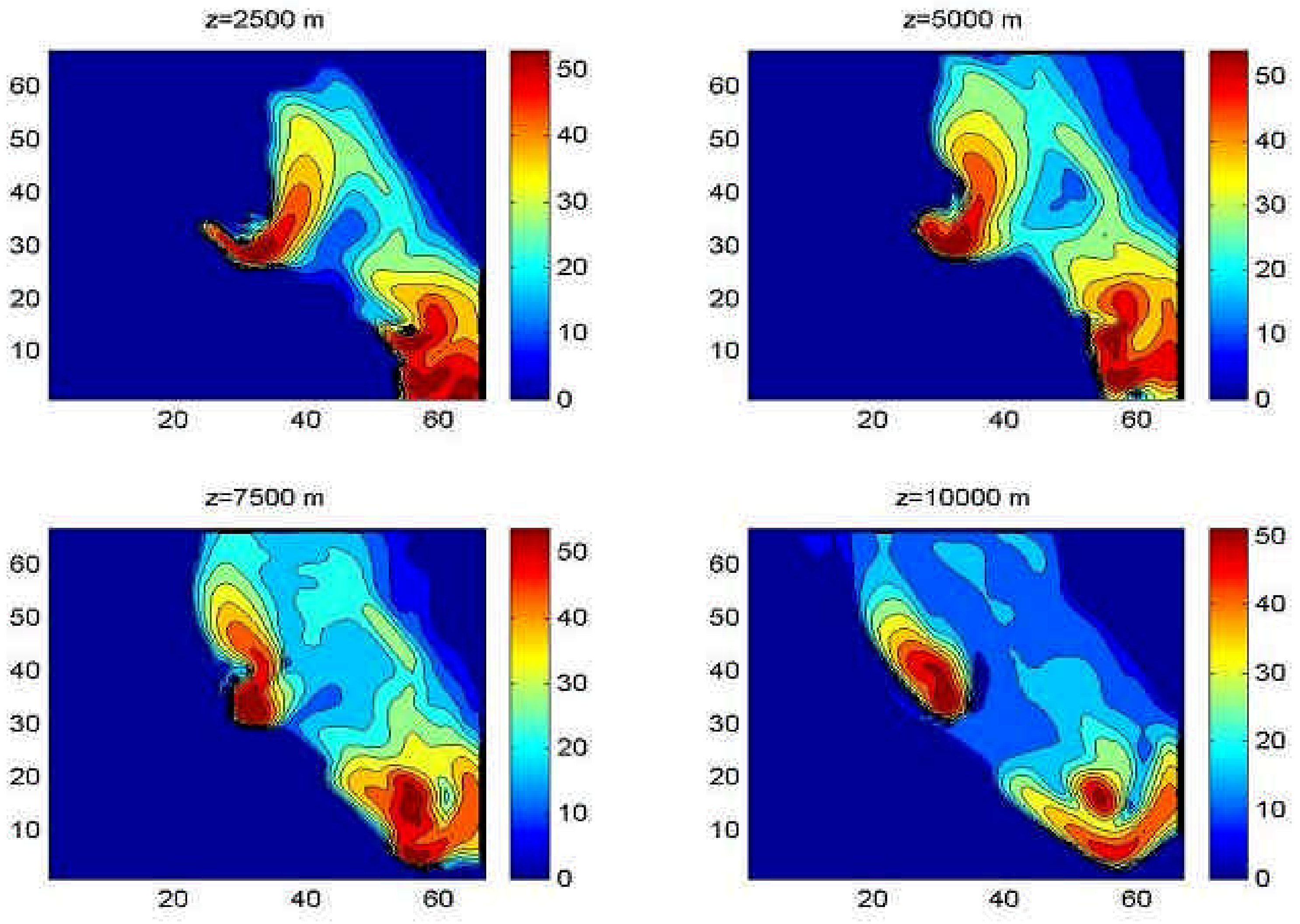
$$Z_{ijk}^{(n)} = Z_{ijk}^{(n-1)} + \alpha f\left(\frac{\partial J}{\partial Z}\right)_{ijk}, \quad (18)$$

where n is the number of iterations, α is the optimal step size obtained by the "line-search" process in optimal control theory (Gill et al. 1981), and $f(\partial J/\partial Z)_{ijk}$ is the optimal descent direction obtained by combining the gradients from several former iterations.

5) Check whether the optimal solution has been found by computing the norm of the gradients or the value of J to see if they are less than a prescribed tolerance. If the criteria are satisfied, stop iterating and output the optimal control vector (u_m, v_m, w_m, F_m, k_h, and k_v).

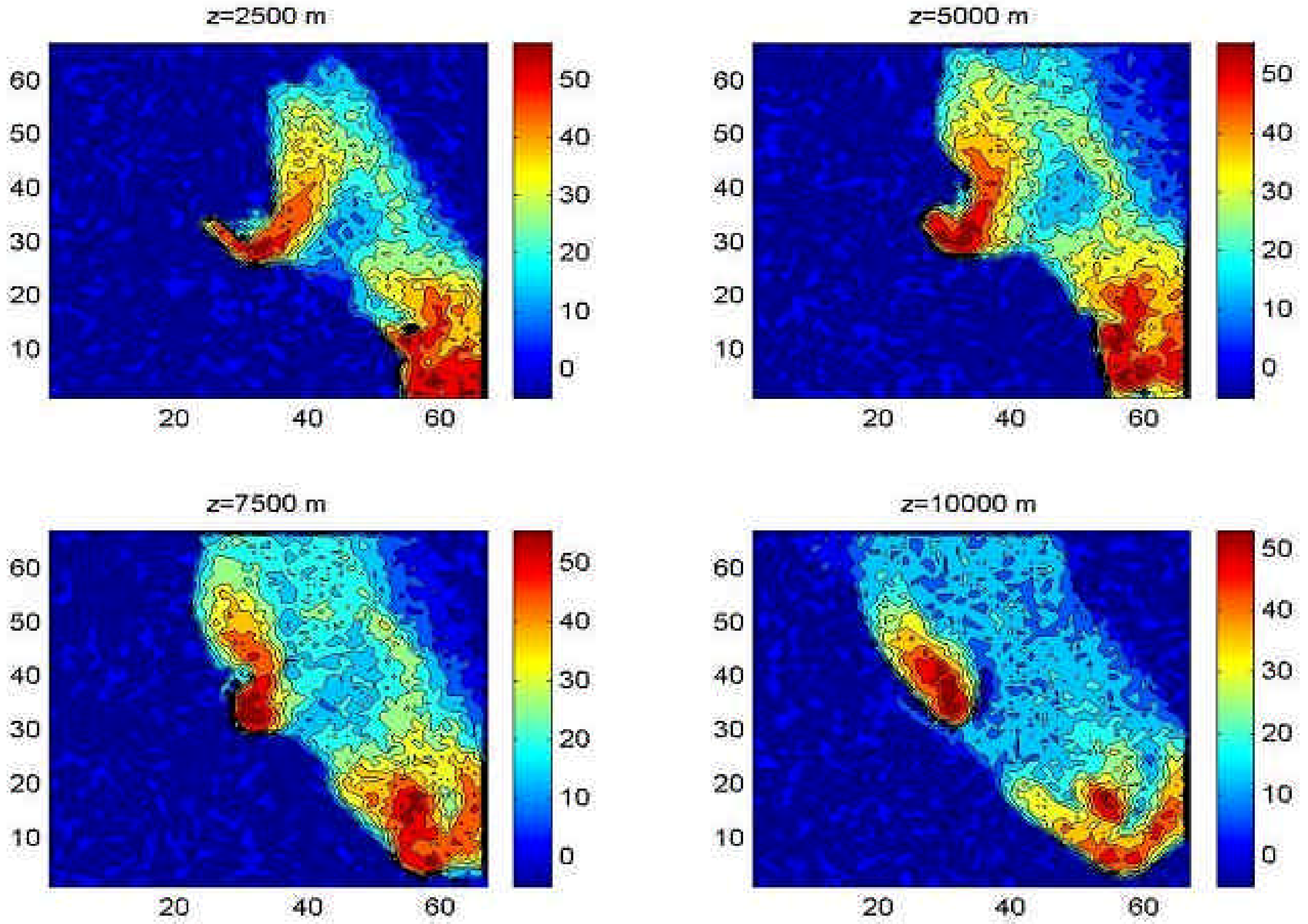
6) If the convergence criterion is not satisfied, steps 2 through 5 are repeated using updated values of (u_m, v_m, w_m, F_m, k_h, and k_v) as the new guess. The iteration process is continued until a suitable converged solution is found.

Reflectivity generated by ARPS (Advanced Regional Prediction System) for tornado in Del City, Oklahoma, 20th May 1977.



Reflectivity [dbZ], referance data

Reflectivity generated by ARPS + 10 dbZ noise



Reflectivity [dbZ] reference data + 10 dbZ noise

Wind V-component retrieved from reference reflectivity

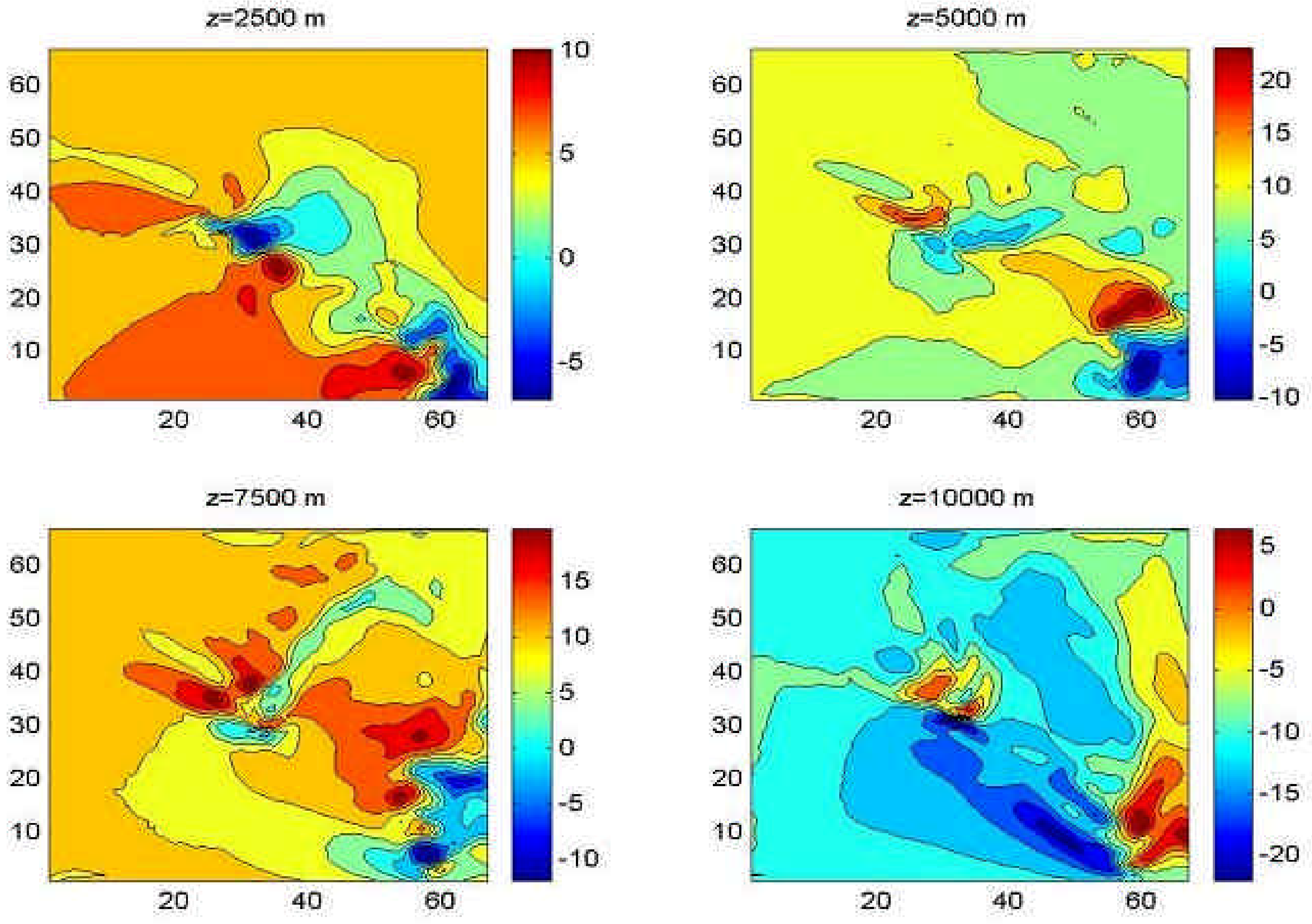


Fig.4. Wind V-component [m/s], reference

Effect of 10dbZ reflectivity noise on retrieved wind V-component

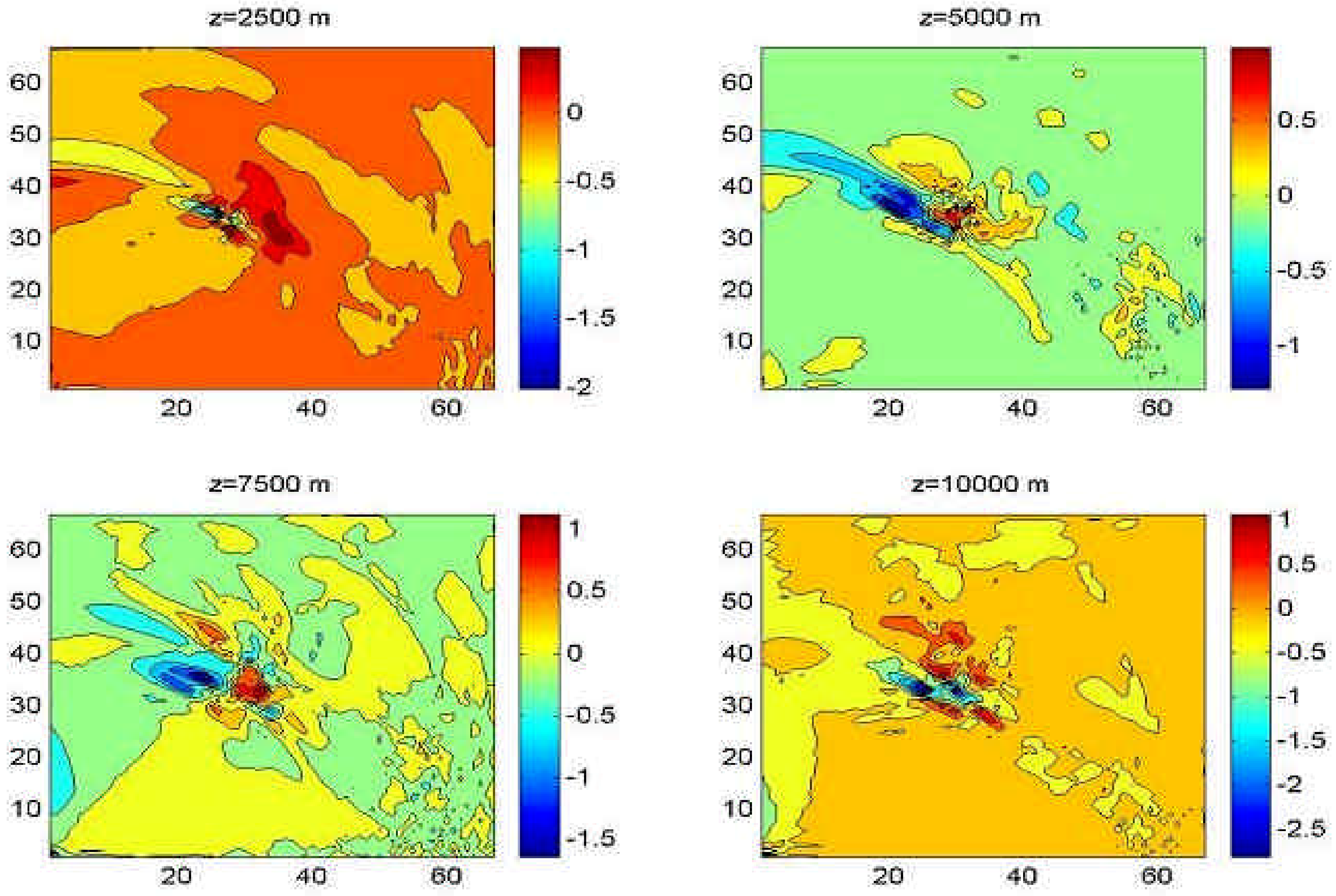


Fig.6. Effect of 10 dbZ refl. noise on V-component [m/s]

Effect of 2.5m/s radial noise on wind W-component

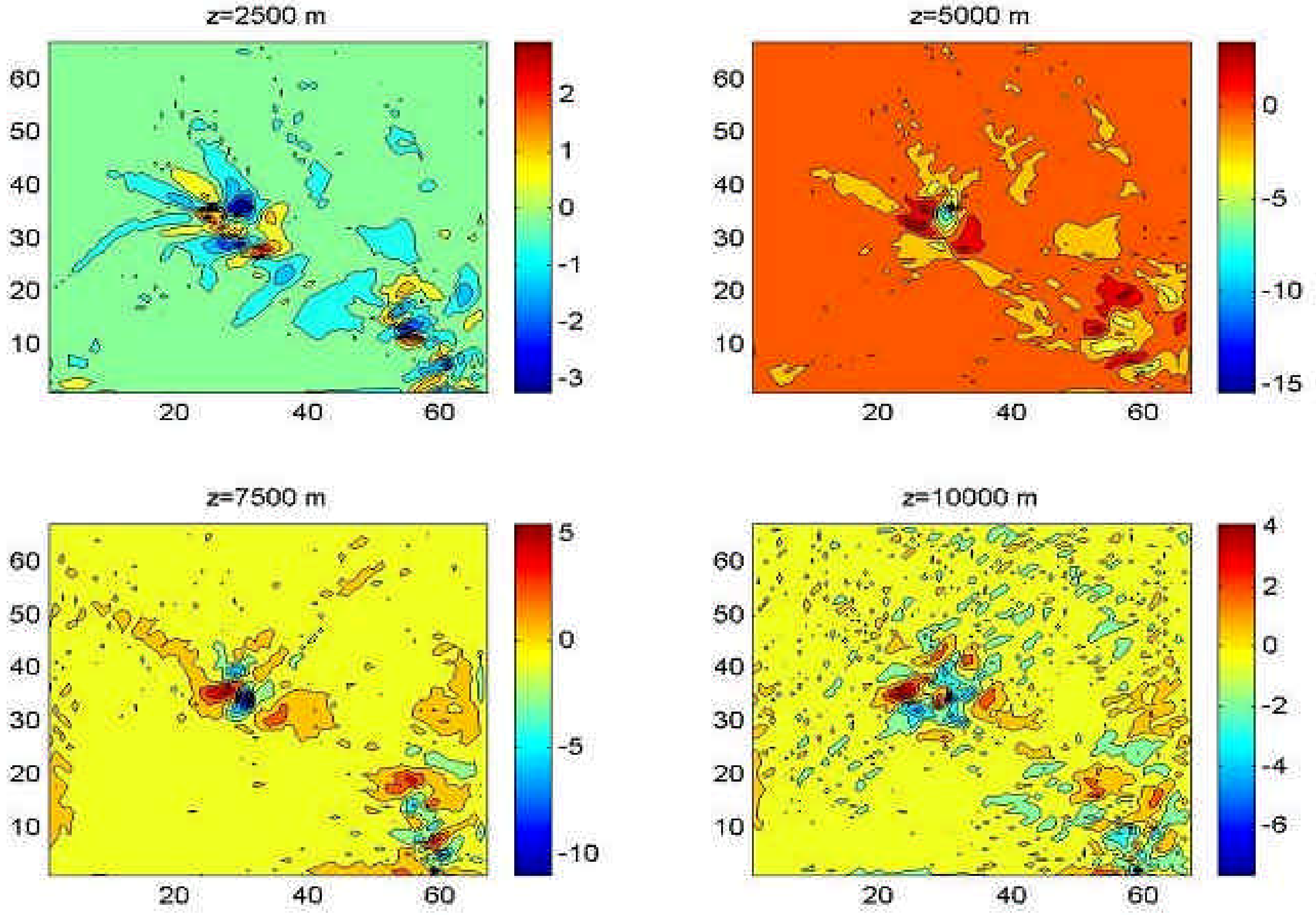


Fig.13 Effect of 2.5 m/s Vr noise on W-component

Effect of 5m/s radial noise on wind W-component

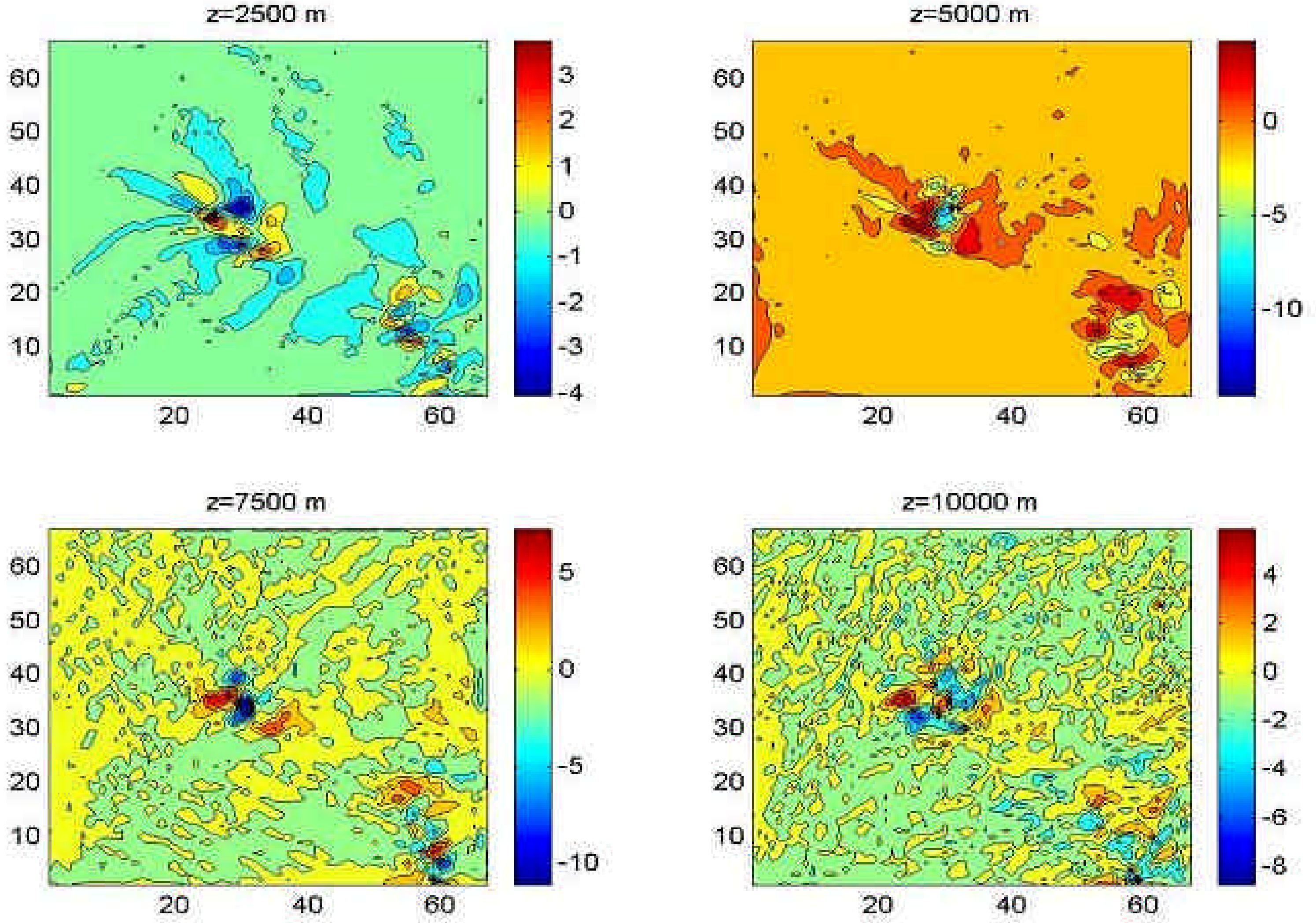
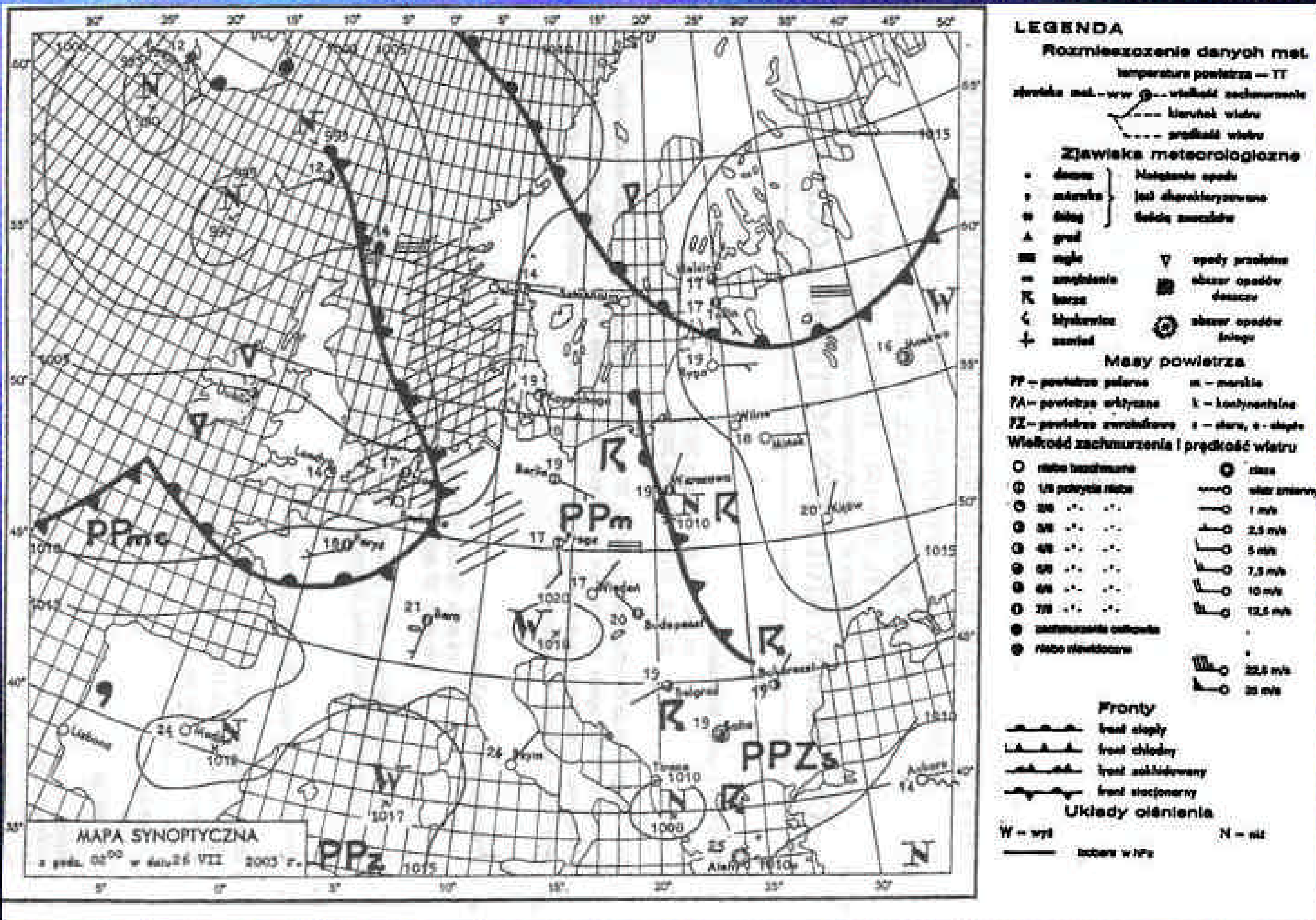
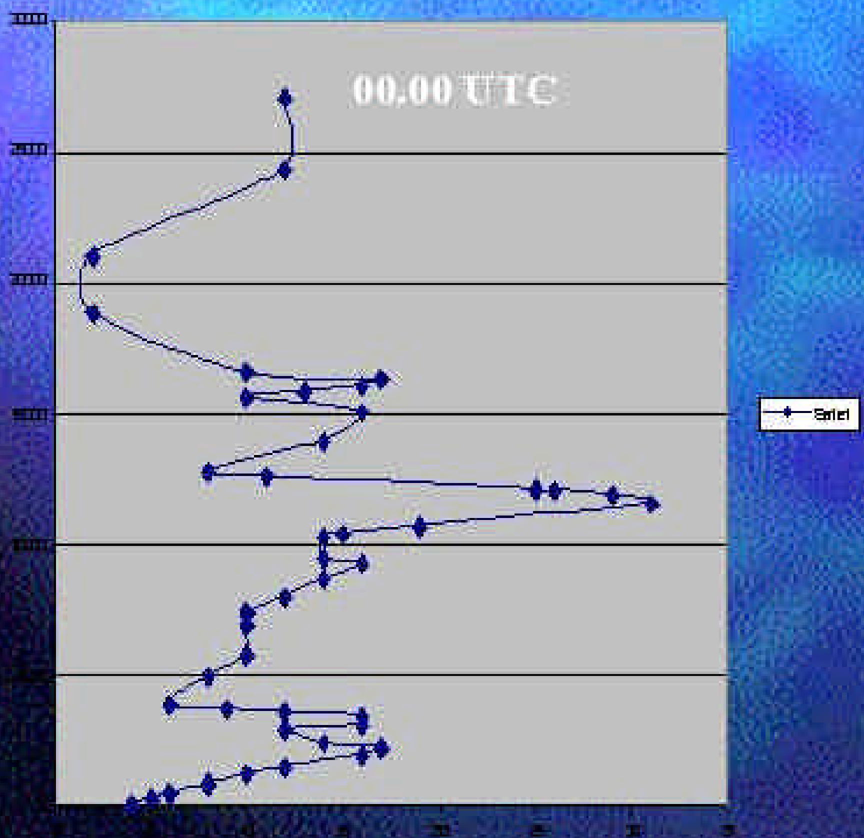


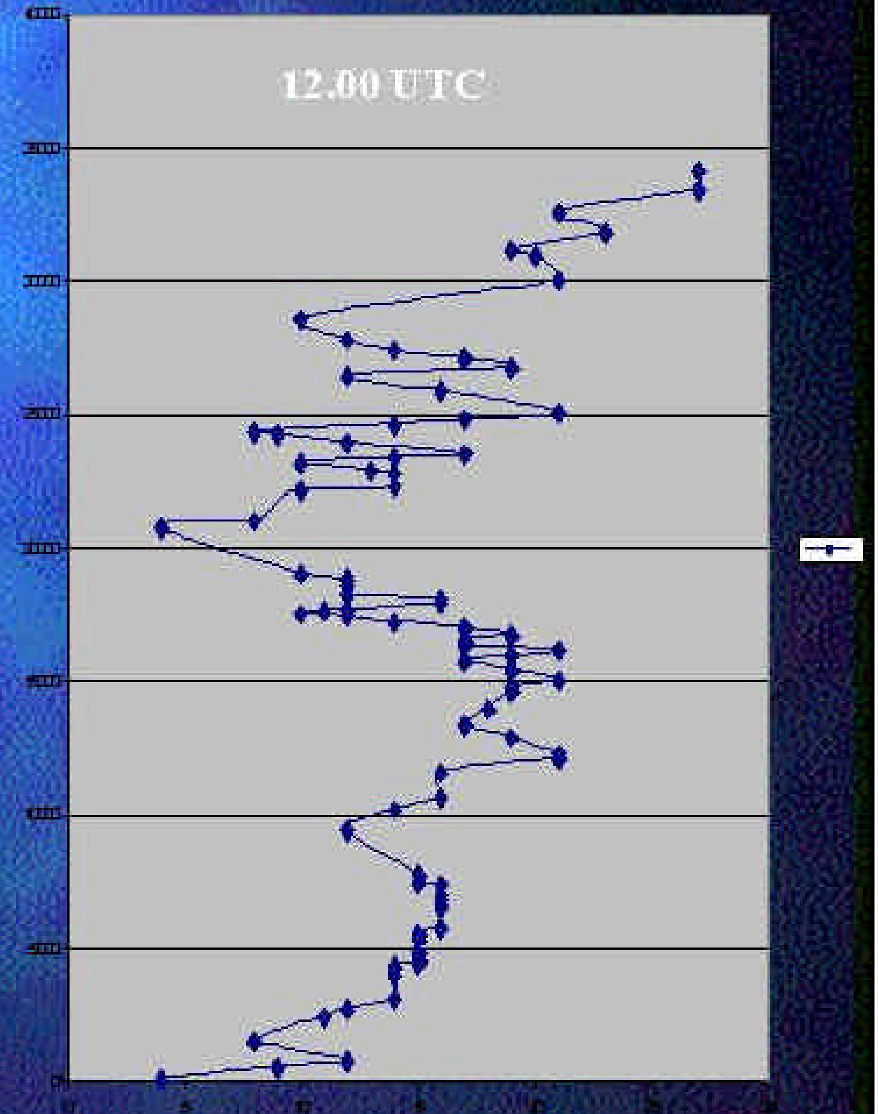
Fig.11. Effect of 5 m/s noise on wind W-component

Synoptic situation, 26 July 2003 02.00 UTC

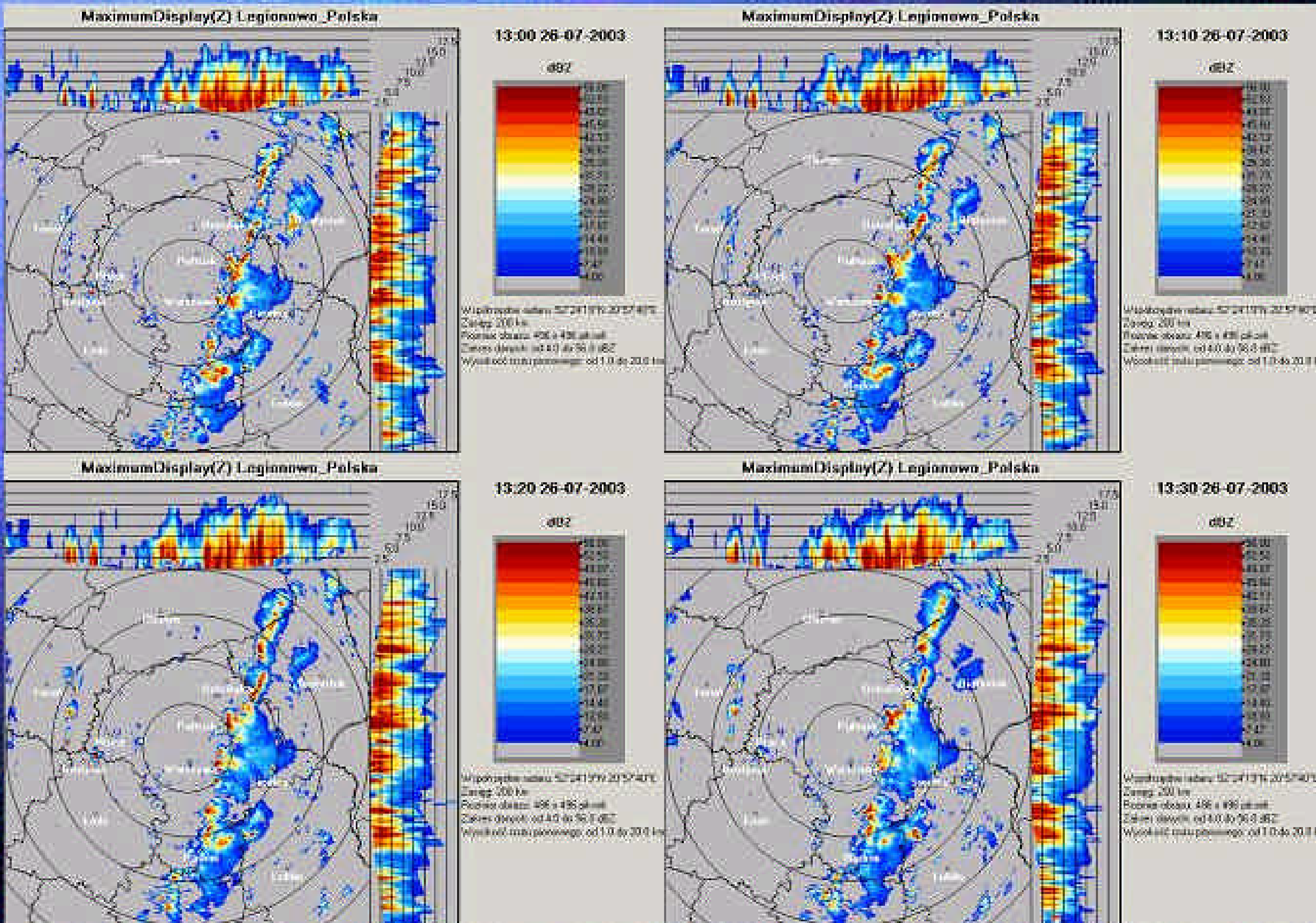


Wind velocity (knots) - vertical profile at Legionowo, 26.07.2003 r.



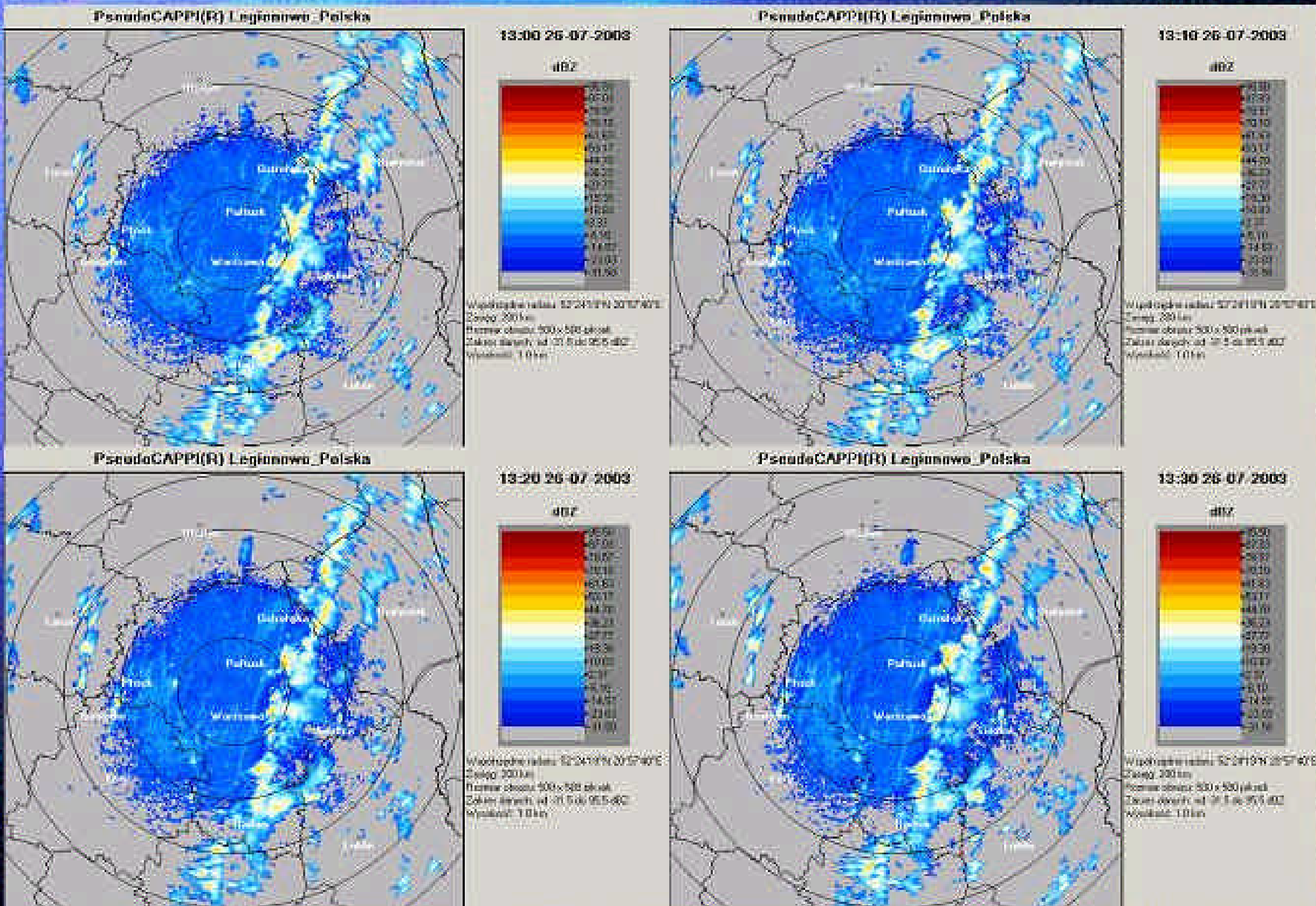


Projection of 3D maximum reflectivity, Legionowo 26.07.2003-13.00-13.30 UTC

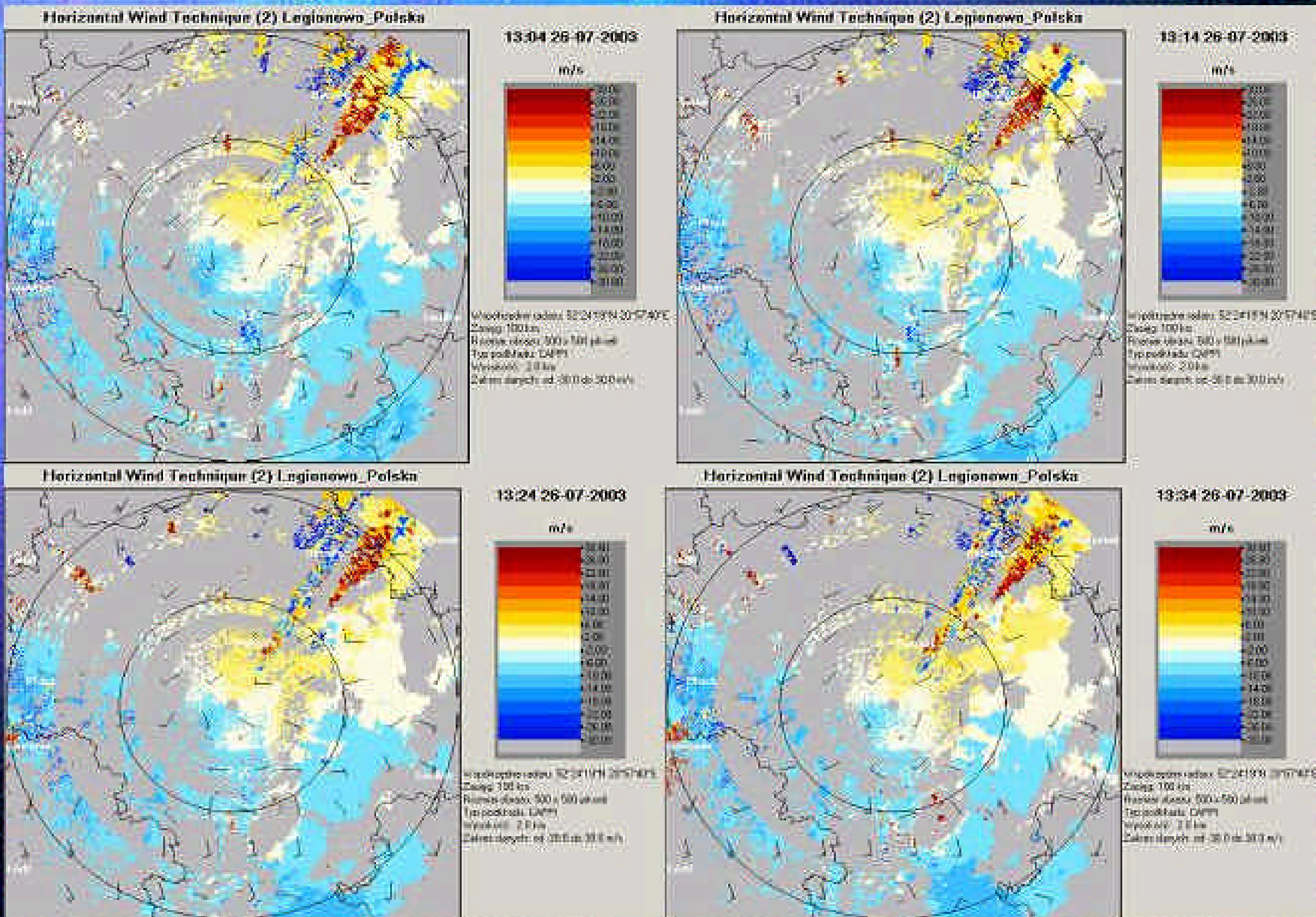


Horizontal cross-section of reflectivity at 1000m Legionowo

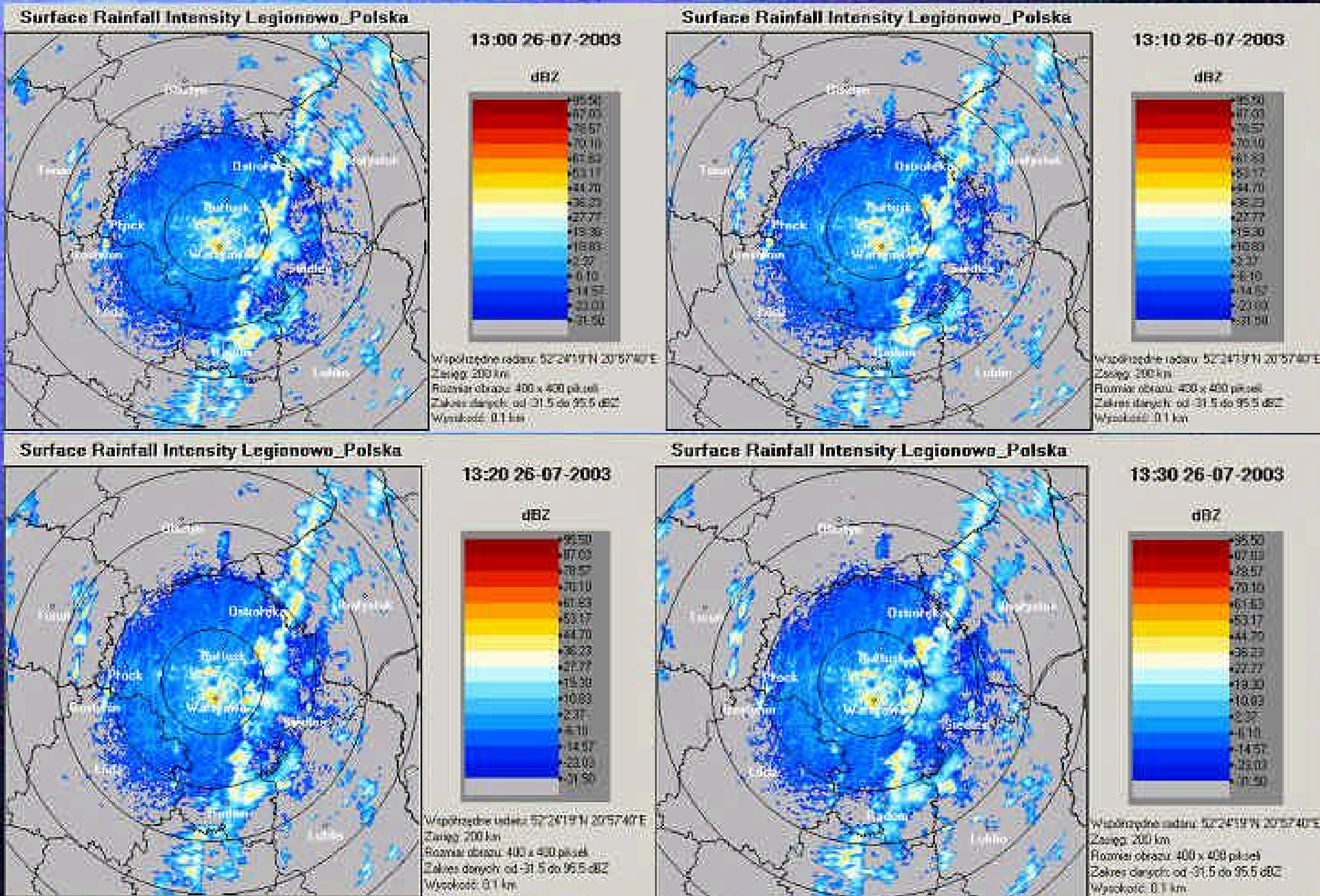
26.07.2003- 13.00-13.30 UTC - PCAPPI



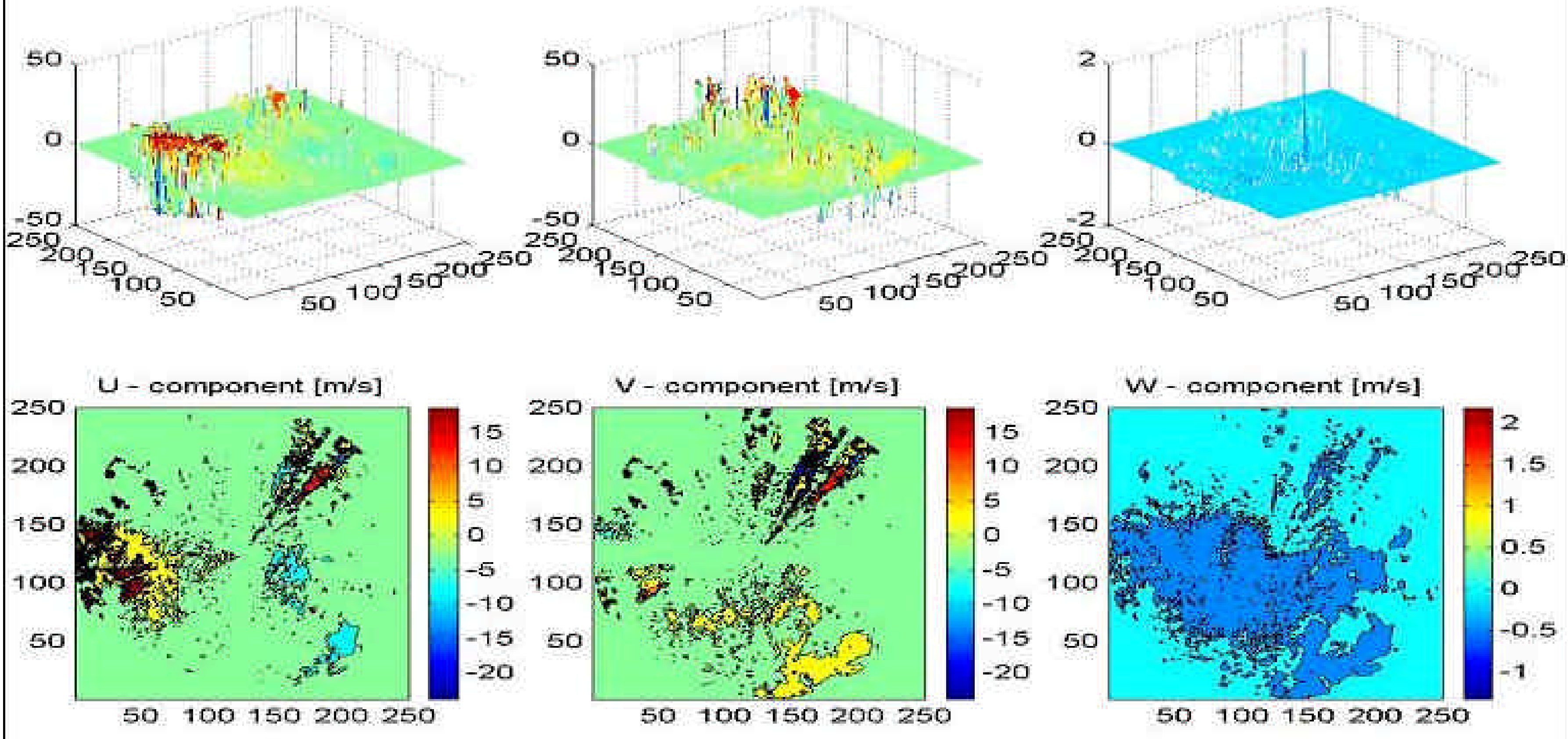
Horizontal wind vectors on the background of amplitude of radial wind -CAPPI (uniform wind technique) Legionowo 26.07.2003- 13.00-13.30 UTC



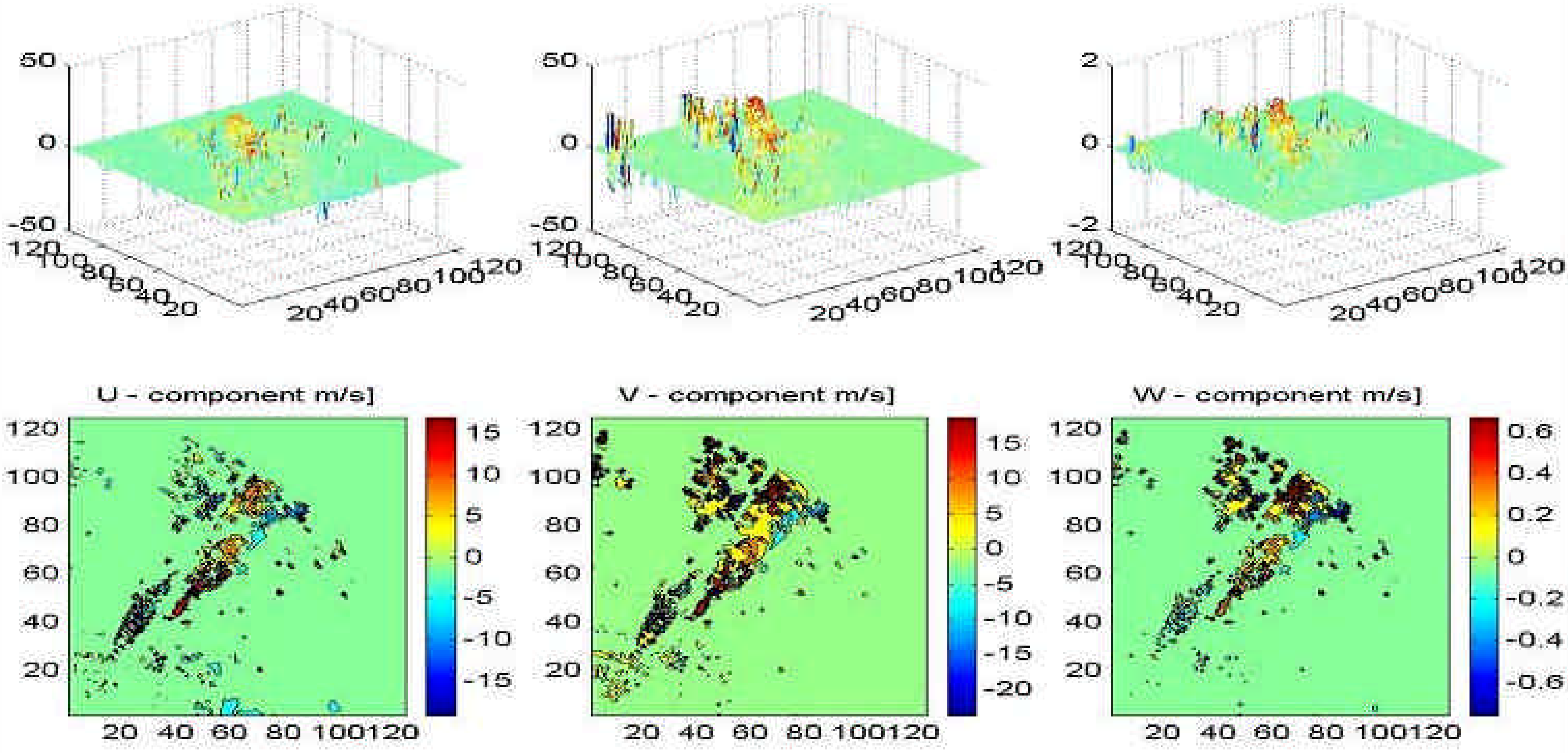
Precipitation intensity at the surface (SRI) Legionowo
26.07.2003- 13.00-13.30 UTC

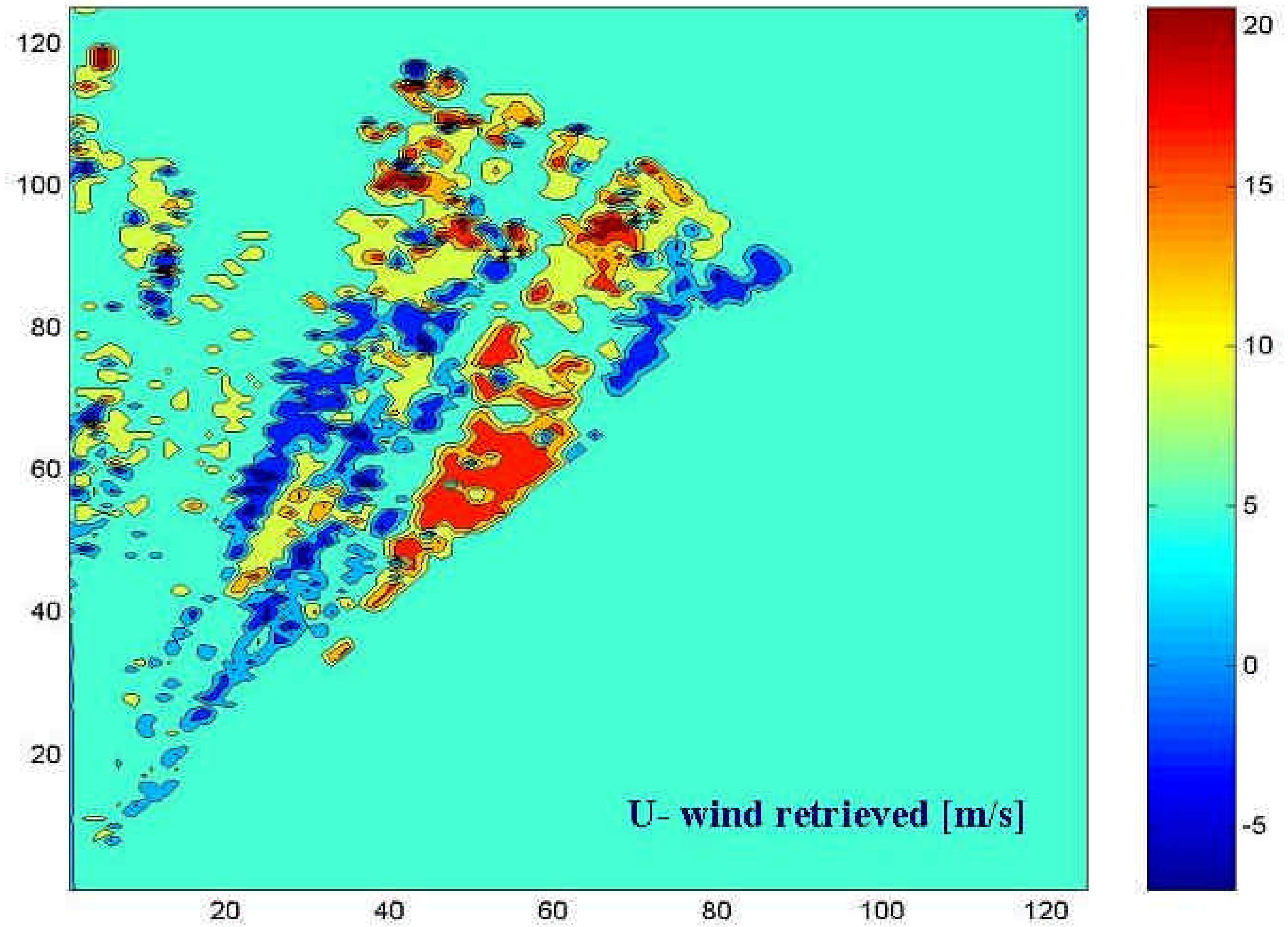


Decomposition of radial wind component into Cartesian
Legionowo 26.07.2003, 13.14 UTC- level 1000 m - PCAPPI

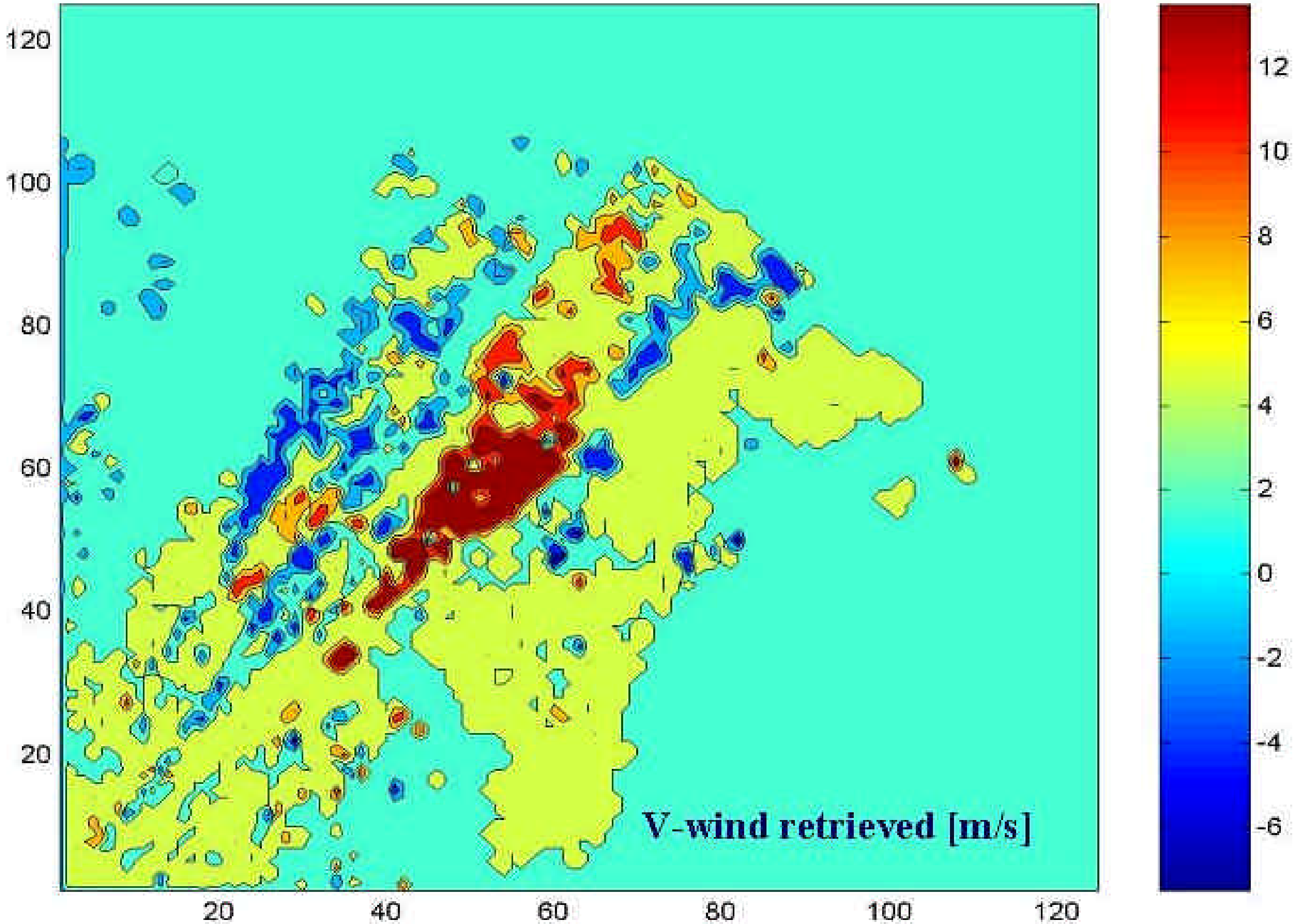


Decomposition of radial wind component into Cartesian
Legionowo 26.07.2003, 13.14 UTC- level 2000 m- PCAPPI

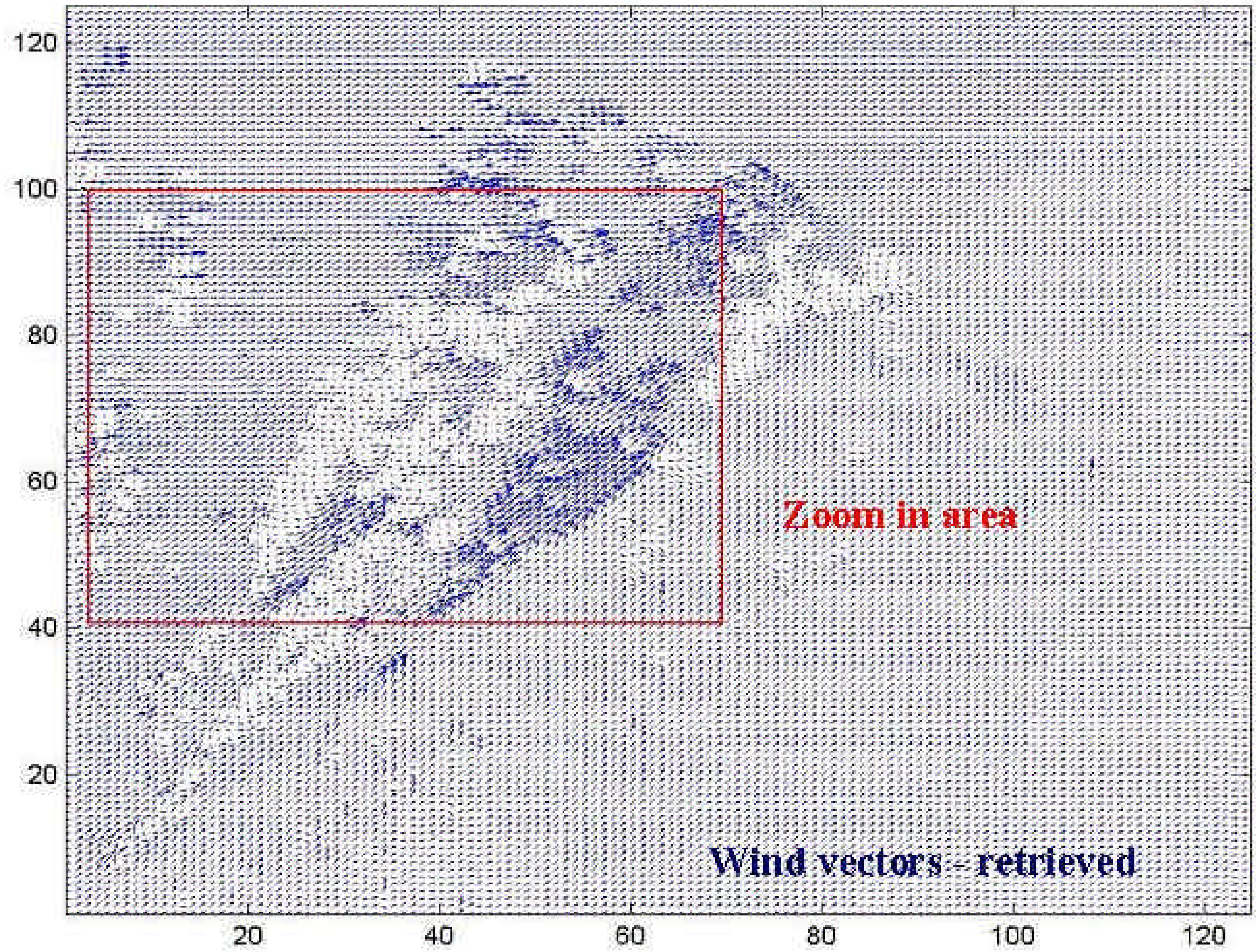




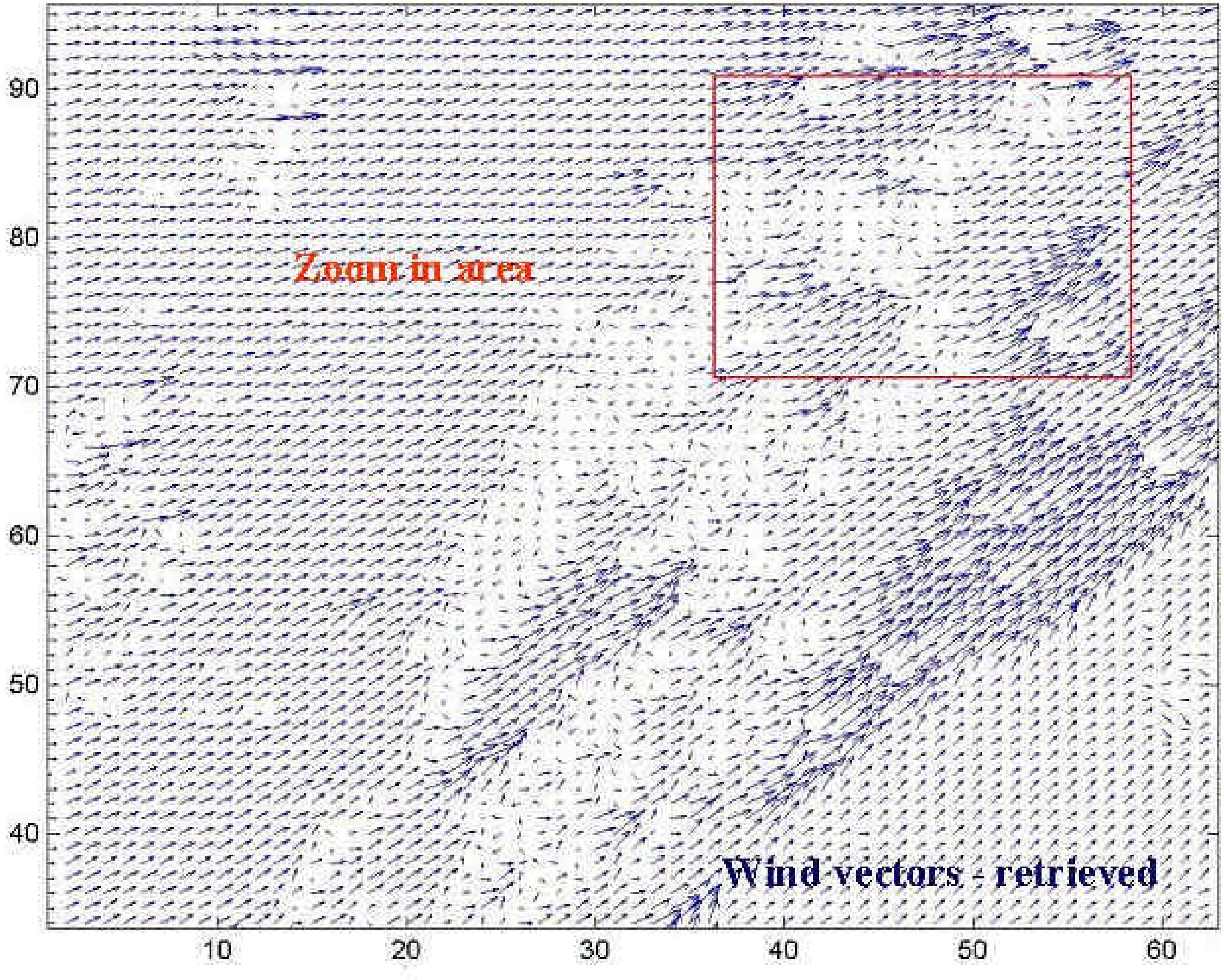
120
100
80
60
40
20
20
40
60
80
100
120
20
15
10
5
0
-5
U- wind retrieved [m/s]



V-wind retrieved [m/s]
120
100
80
60
40
20
20
40
60
80
100
120
12
10
8
6
4
2
0
-2
-4
-6



120
100
80
60
40
20
20
40
60
80
100
120
Zoom in area
Wind vectors - retrieved



Zoom in area
Wind vectors - retrieved
90
80
70
60
50
40
10
20
30
40
50
60

Conclusions

- Variational method of reconstruction of 3D wind field (Gao *et al.*) based on the radar data (reflectivity and/or radial component) gives good results for input data produced in model ARPS.
- Method seems to be stable with respect to reflectivity errors (eg. Noise) significantly more than to radial component errors.
- It pertains especially to wind W-component. This is very important in case of description of convection.
- For Polish radars (PolRad) this method requires also additional filters and/or interpolation techniques to establish continuity of analyzed fields
- Both CAPPI and PCAPPI cannot establish an optimum input data for reconstruction due to interpolation to Cartesian coordinates.