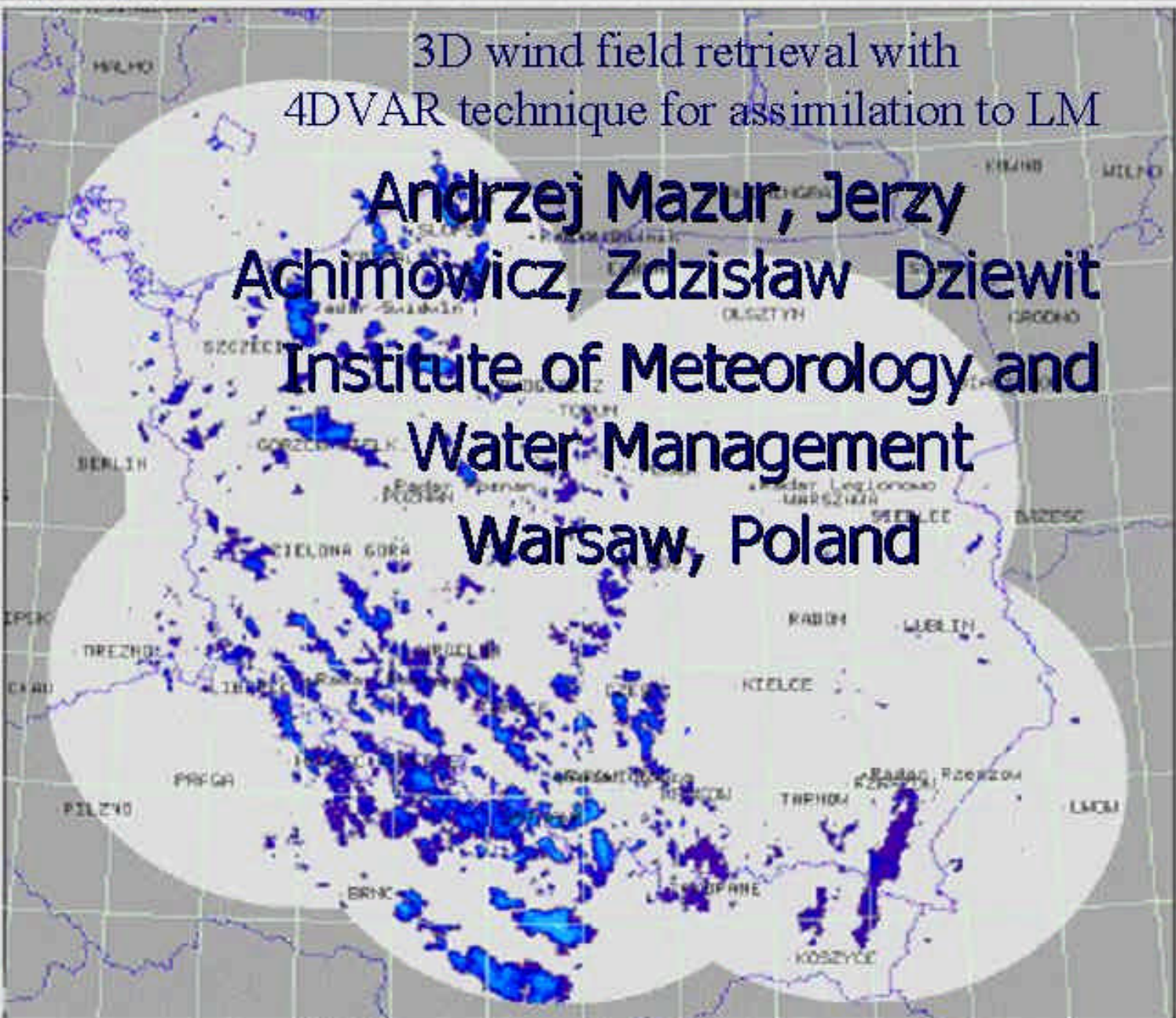


3D wind field retrieval with  
4DVAR technique for assimilation to LM

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Achimowicz, Zdzisław Dziewit**  
**Institute of Meteorology and  
Water Management**  
**Warsaw, Poland**



Projection: RAOB  
Composite Radar:  
PAS  
RWH  
POZ  
RZE  
S41  
LEG

Rainbow (C)  
by GEMETRONIX



# Goals:

- Method for assimilation of radar data that would be alternative to Latent Heat Nudging.
- Verification of "3D Simple Adjoint Velocity Retrievals 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  $\mathbf{Z} = (u_m, v_m, w_m, F_m, k_h, \text{ and } k_v)$  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  $(\partial J/\partial u_m, \partial J/\partial v_m, \partial J/\partial w_m, \partial J/\partial F_m, \partial J/\partial k_h, \text{ and } \partial J/\partial k_v)$  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,

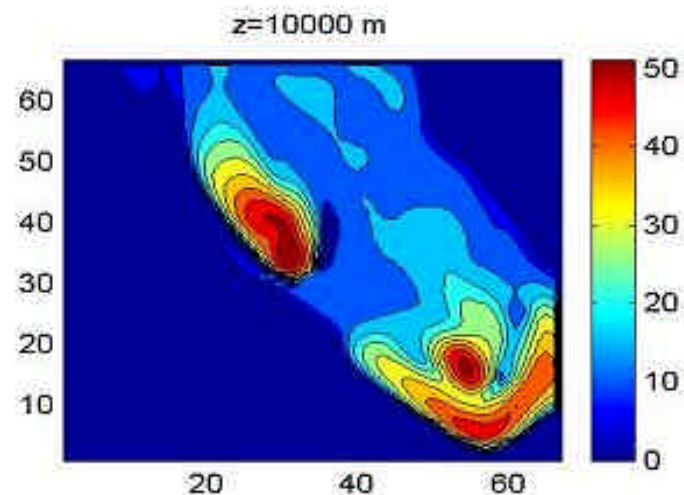
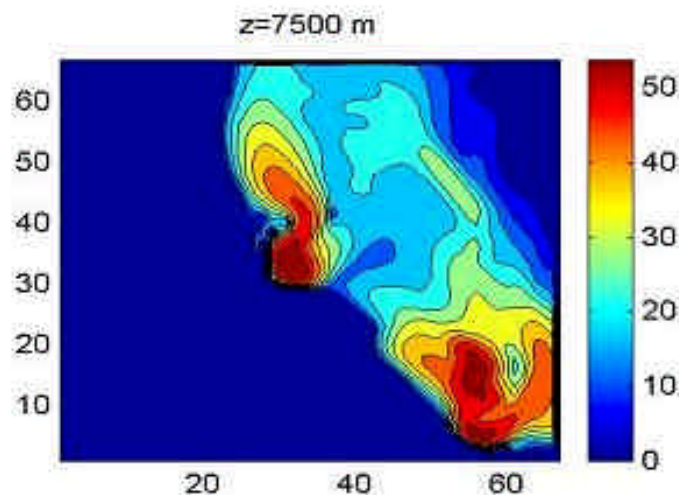
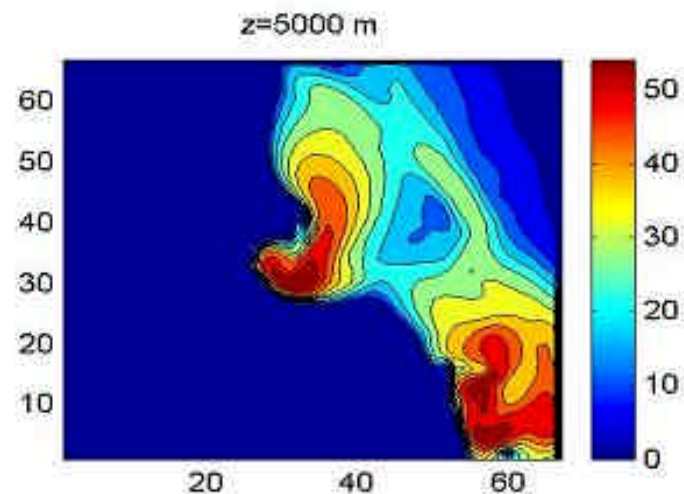
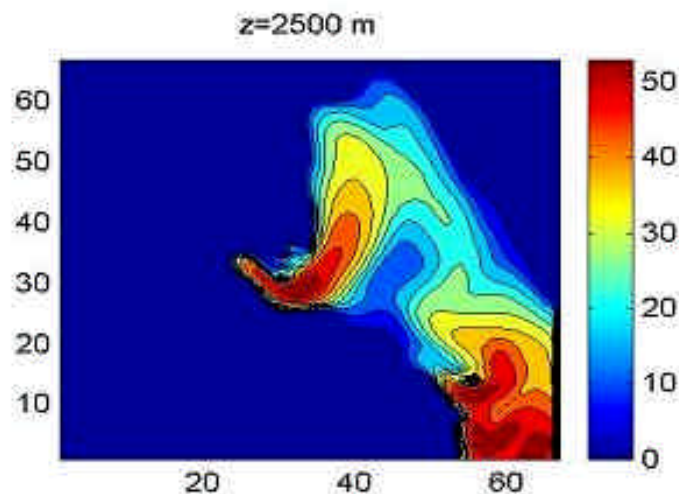
$$Z_{ijk}^{(n)} = Z_{ijk}^{(n-1)} + \alpha f \left( \frac{\partial J}{\partial Z} \right)_{ijk}, \quad (18)$$

where  $n$  is the number of iterations,  $\alpha$  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  $(u_m, v_m, w_m, F_m, k_h, \text{ and } k_v)$ .
- 6) If the convergence criterion is not satisfied, steps 2 through 5 are repeated using updated values of  $(u_m, v_m, w_m, F_m, k_h, \text{ and } k_v)$  as the new guess. The iteration process is continued until a suitable converged solution is found.

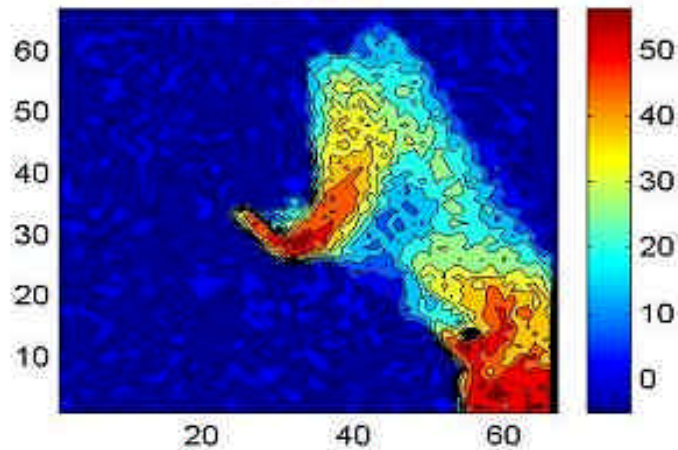


# Reflectivity generated by ARPS (Advanced Regional Prediction System) for tornado in Del City, Oklahoma, 20th May 1977.

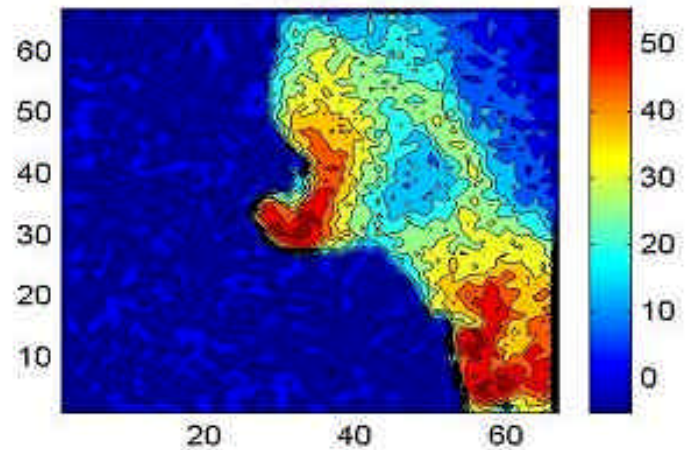


# Reflectivity generated by ARPS + 10 dbZ noise

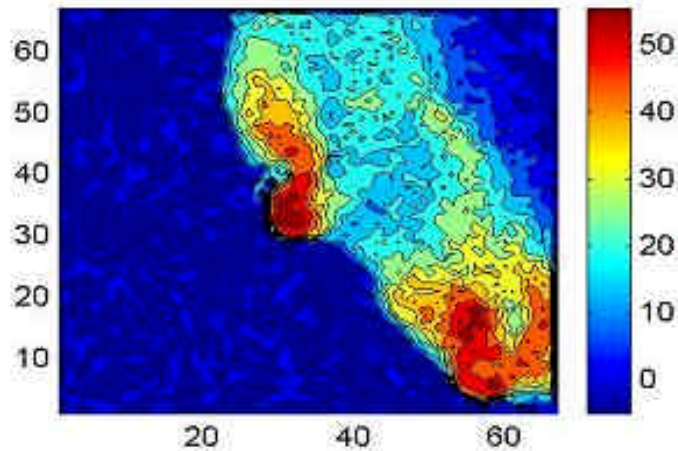
z=2500 m



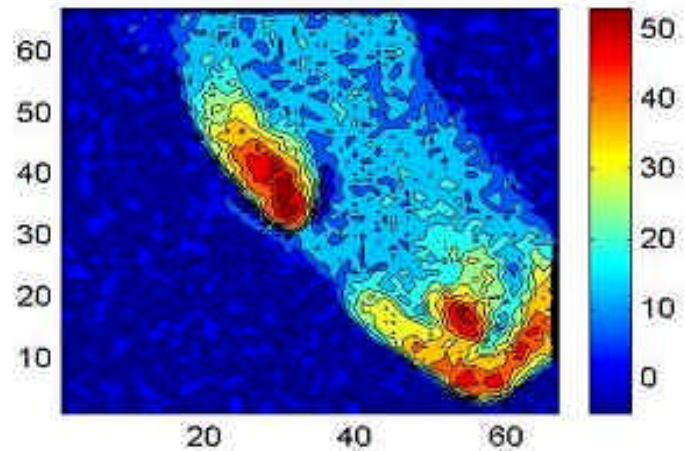
z=5000 m



z=7500 m



z=10000 m



Reflectivity [dbZ] reference data + 10 dbZ noise



# Wind V-component retrieved from reference reflectivity

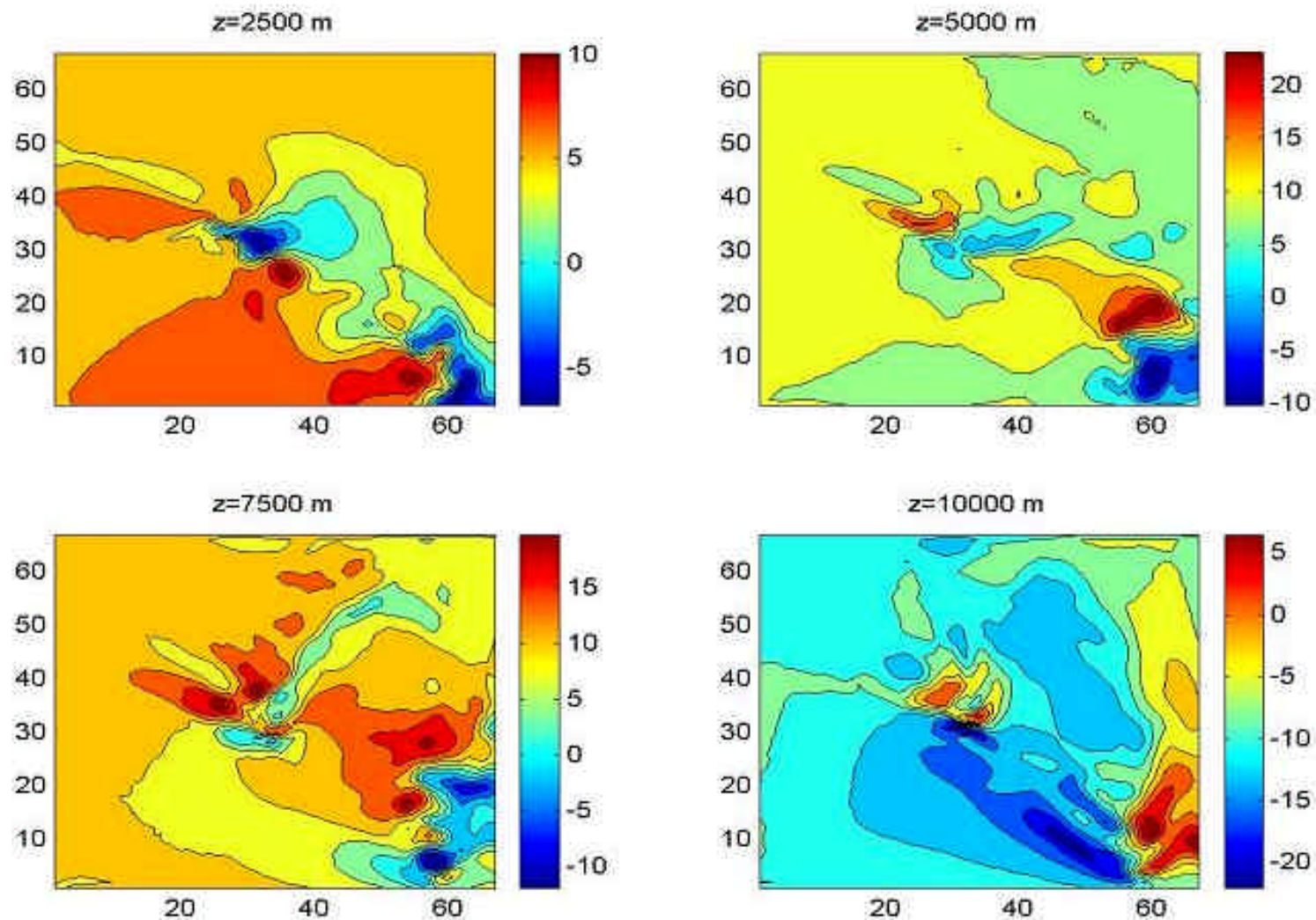


Fig.4. Wind V-component [m/s], reference

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

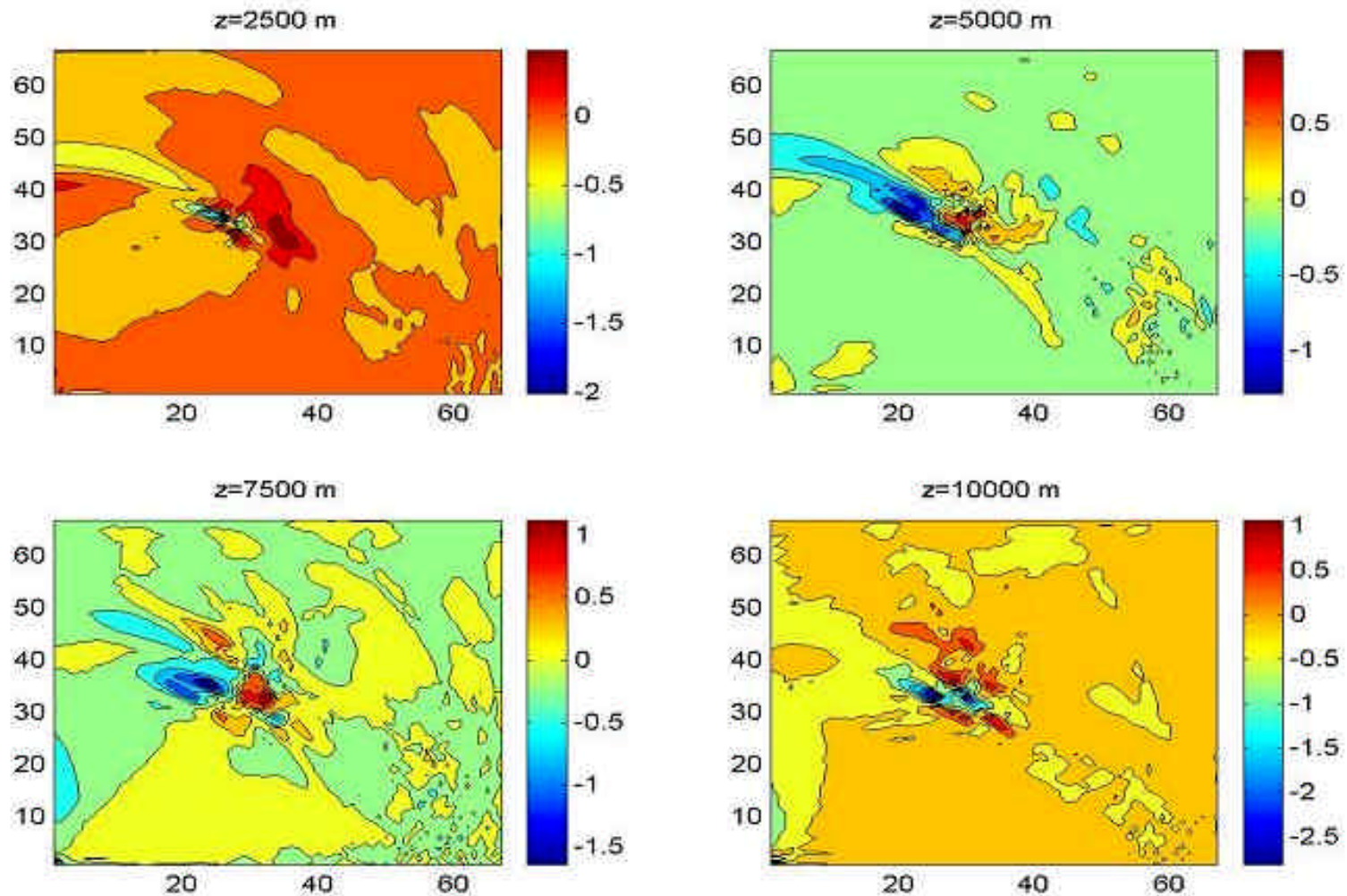


Fig.6. Effect of 10 dbZ refl. noise on V-component [m/s]



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

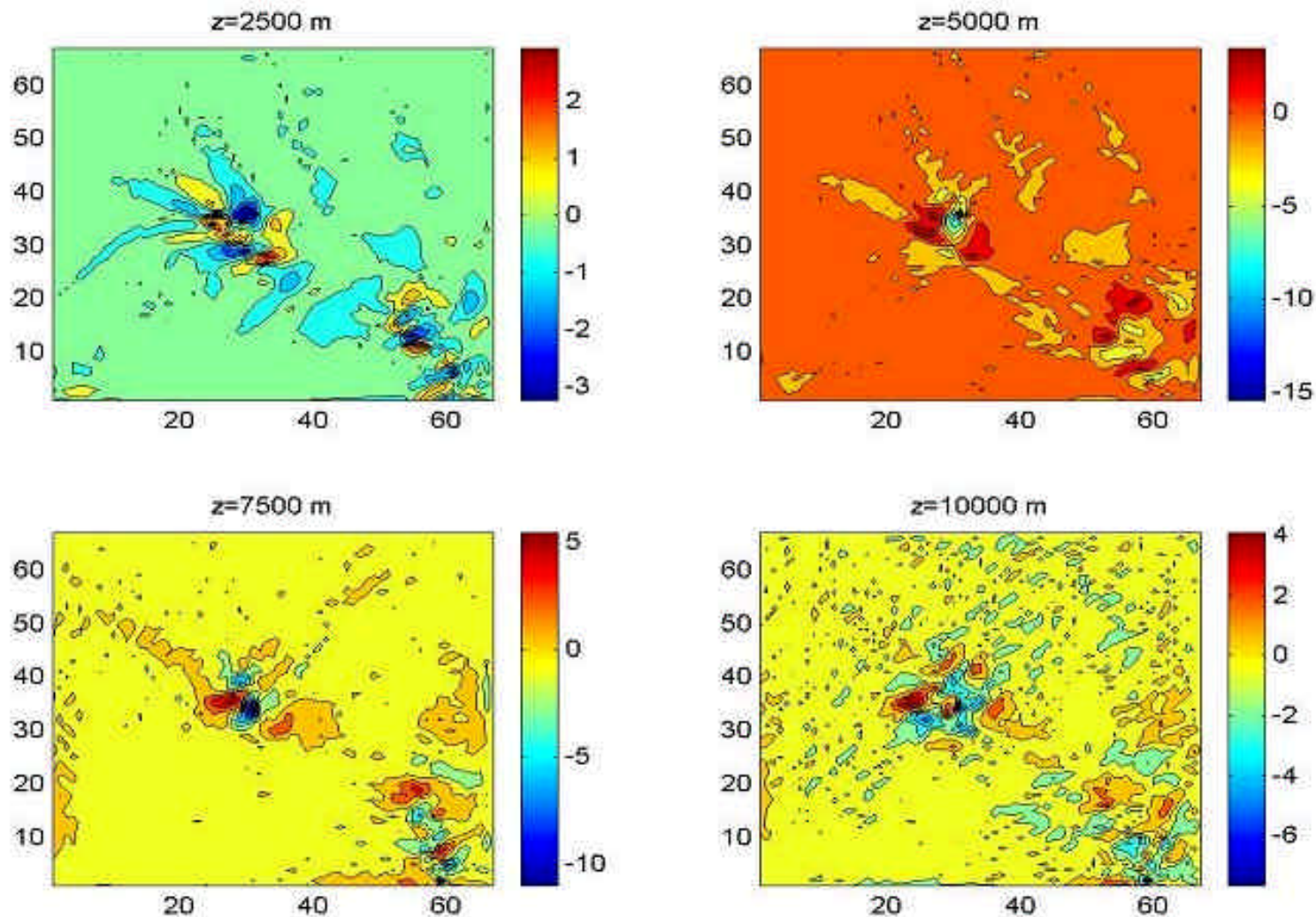


Fig.13 Effect of 2.5 m/s Vr noise on W-component

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

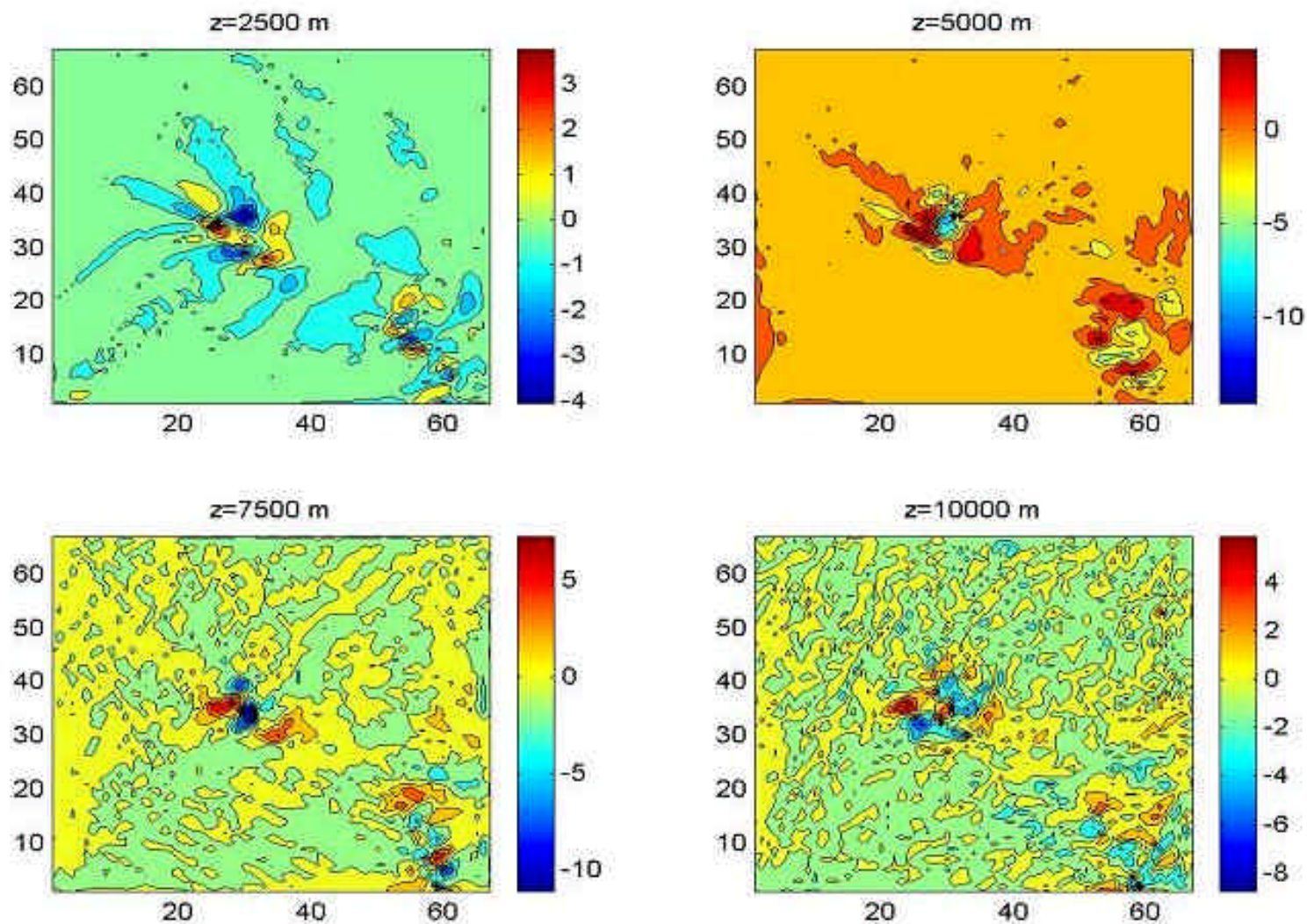
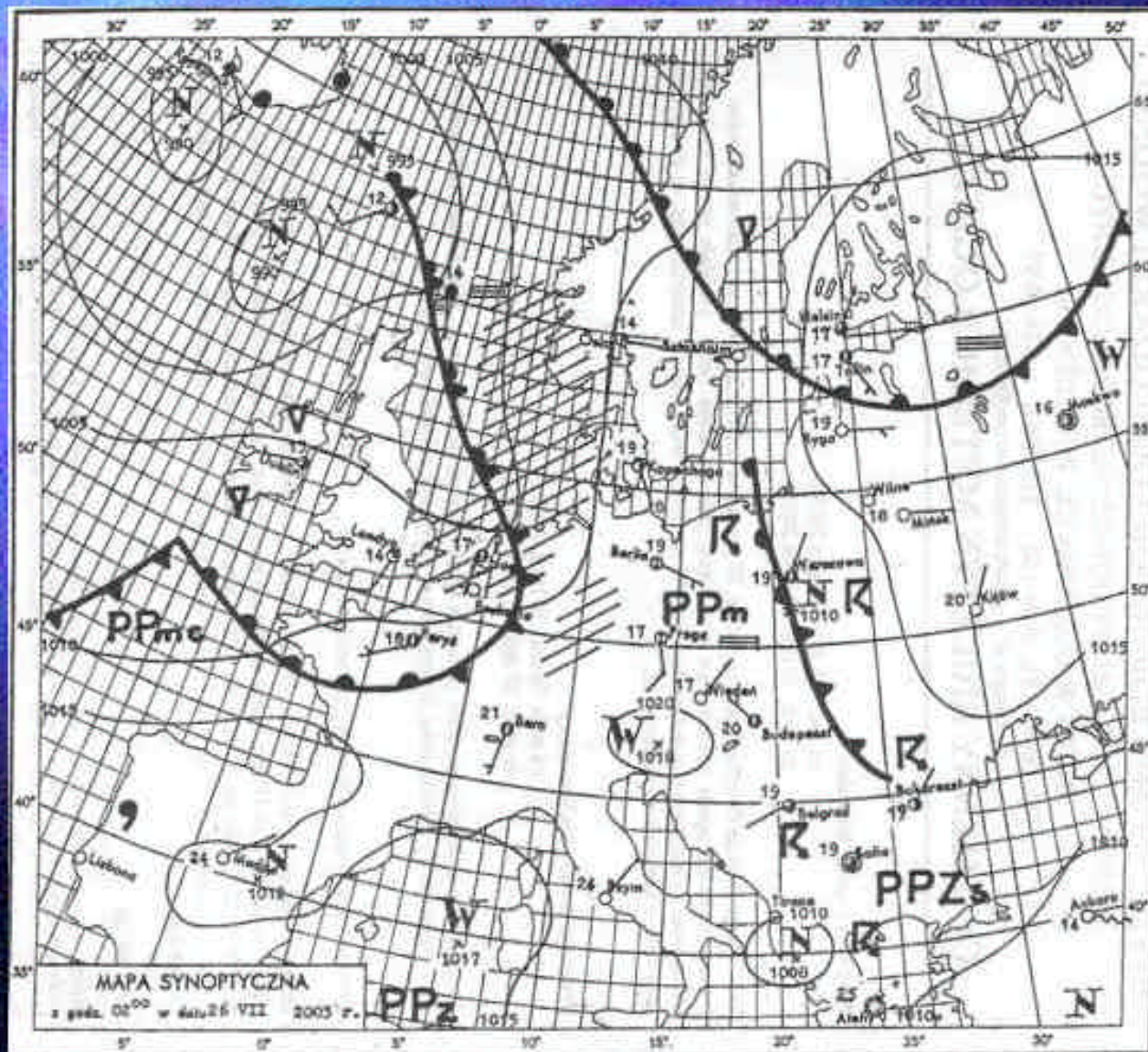


Fig. 11. Effect of 5 m/s noise on wind W-component



# Synoptic situation, 26 July 2003 02.00 UTC



## LEGENDA

### Rozmieszczenie danych met.

- temperatura powietrza — TT
- znaczniki met.-ww — wielkość zachmurzenia
- — — — — kierunek wiatru
- — — — — prędkość wiatru

### Zjawiska meteorologiczne

- deszcz } Najczęściej opady
- mgła } jest charakterystyczne
- śnieg } śnieg zasneżony
- ▲ grad
- ☼ mgła
- ☼ opady prosiące
- = zamglenie
- ☼ obszar opadów
- ☼ śnieg
- ☼ obszar opadów
- ☼ śnieg
- ☼ śnieg
- ☼ śnieg

### Masy powietrza

- PP — powietrze polarno
- m — morskie
- FA — powietrze arktyczne
- k — kontynentalne
- FZ — powietrze zwrotnikowe
- s — suche, e — ciepłe

### Wielkość zachmurzenia i prędkość wiatru

- niebo bezchmurne
- klasa
- 1/8 pokrycia nieba
- nieb zmierzny
- 2/8 .. ..
- 1 m/s
- 3/8 .. ..
- 2,5 m/s
- 4/8 .. ..
- 5 m/s
- 5/8 .. ..
- 7,5 m/s
- 6/8 .. ..
- 10 m/s
- 7/8 .. ..
- 12,5 m/s
- zachmurzenie całkowite
- niebo niewidoczne
- 22,5 m/s
- 25 m/s

### Fronty

- — — — — front ciepły
- — — — — front chłodny
- — — — — front zachodzący
- — — — — front stacjonarny

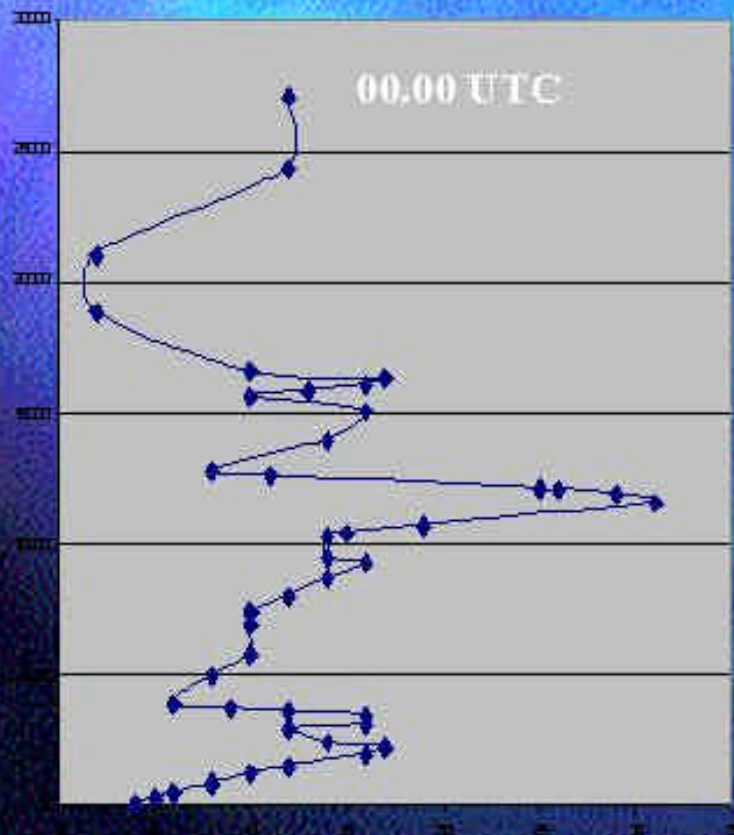
### Układy ciśnienia

- W — wyż
- N — niż
- — — — — izobary w hPa

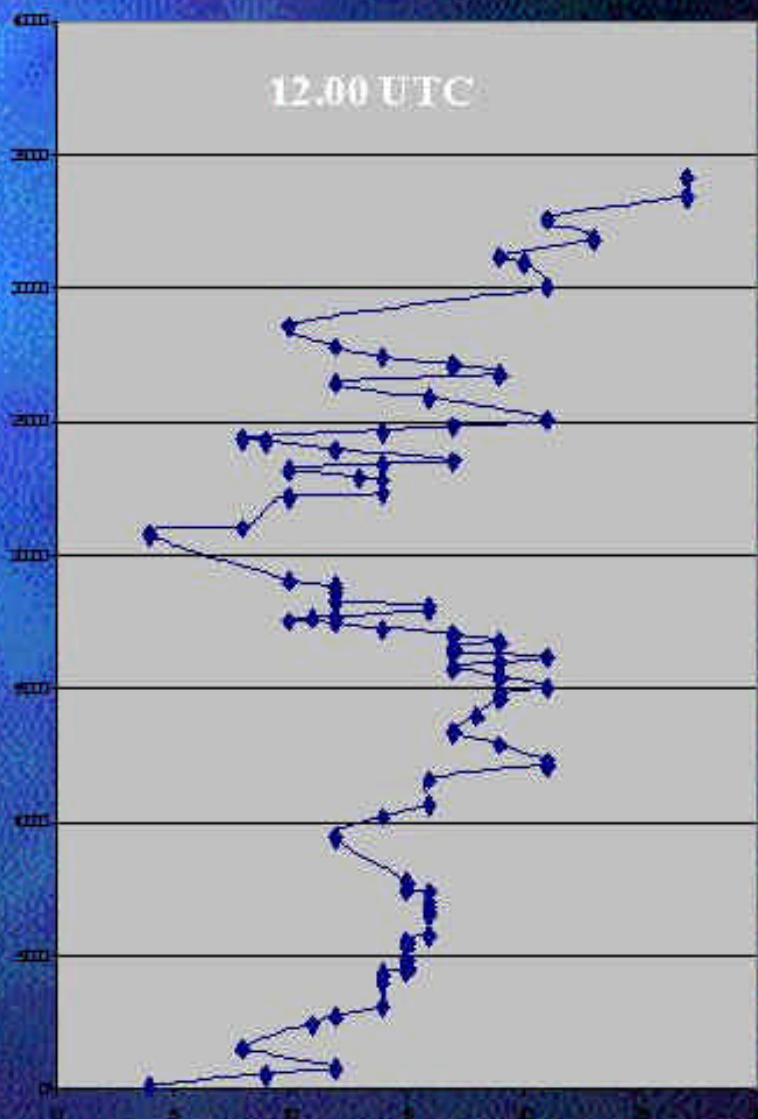


# Wind velocity (knots) - vertical profile at Legionowo, 26.07.2003 r.

Profil wiatru Legionowo 26 lipca 2002

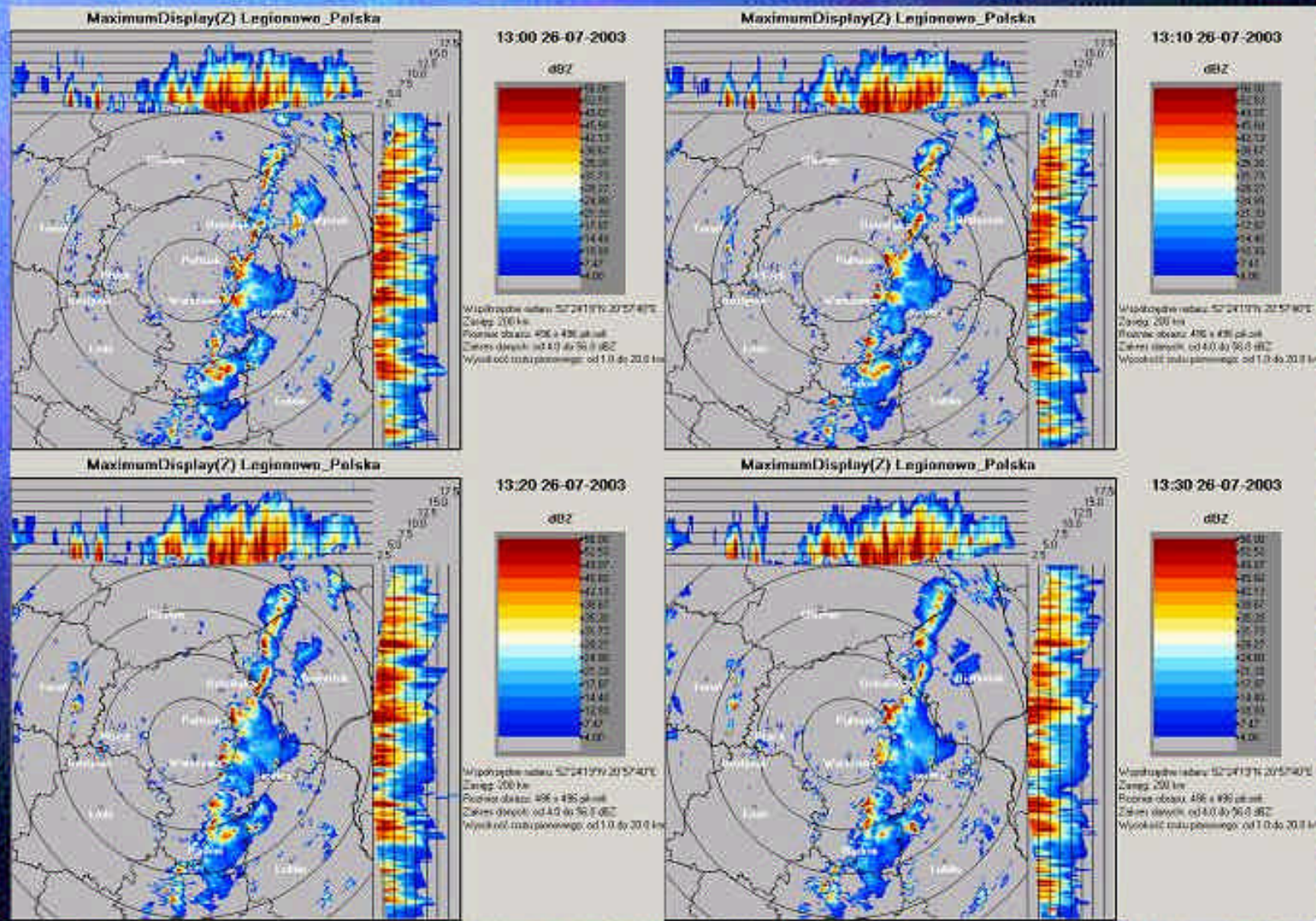


◆ Siret





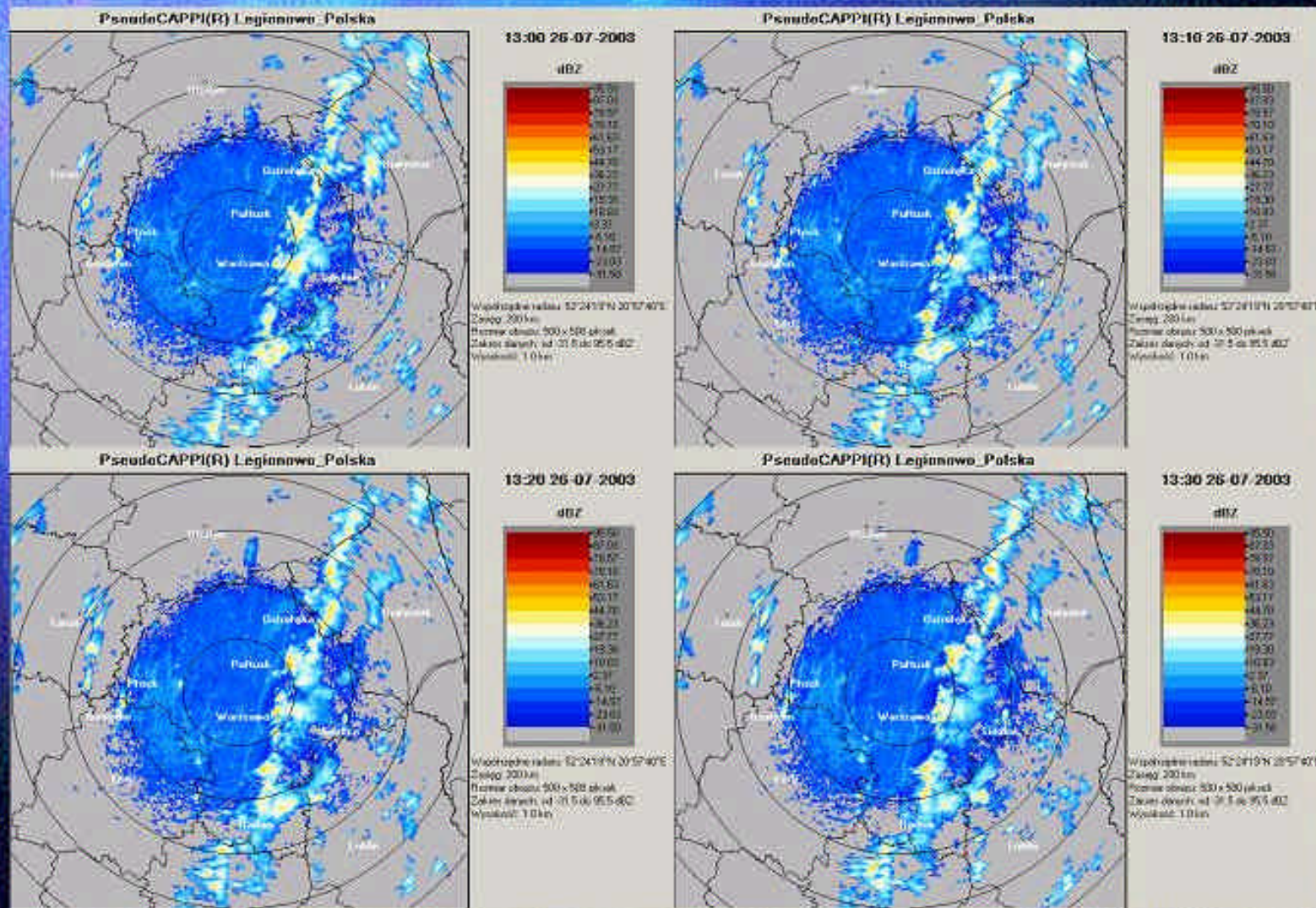
# Projection of 3D maximum reflectivity, Legionowo 26.07.2003-13.00-13.30 UTC





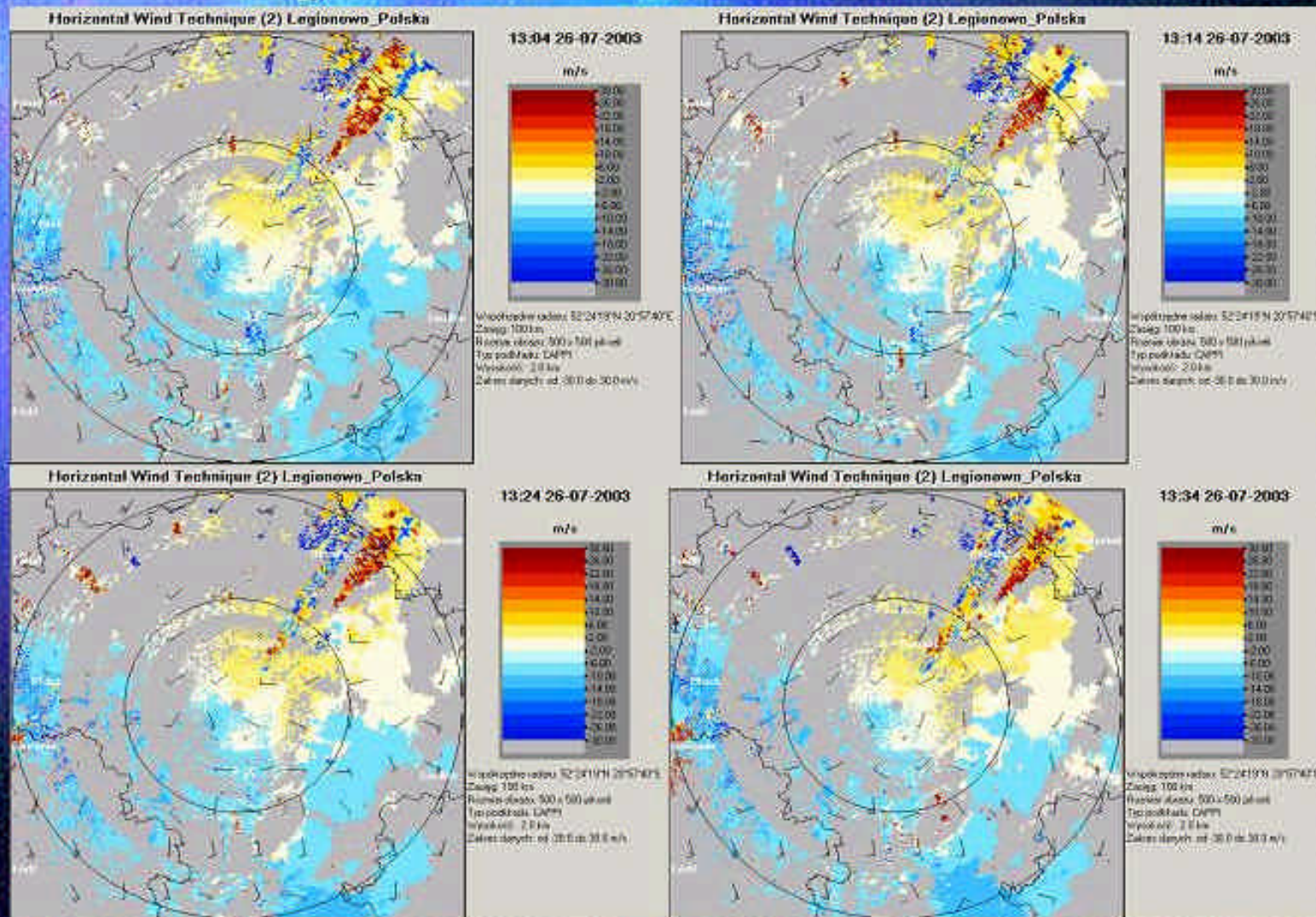
# Horizontal cross-section of reflectivity at 1000m Legionowo

## 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

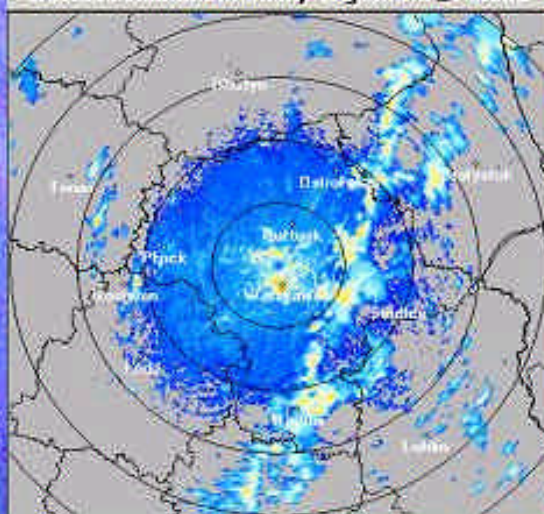




# Precipitation intensity at the surface (SRI) Legionowo 26.07.2003- 13.00-13.30 UTC

Surface Rainfall Intensity Legionowo\_Polska

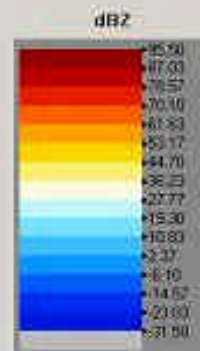
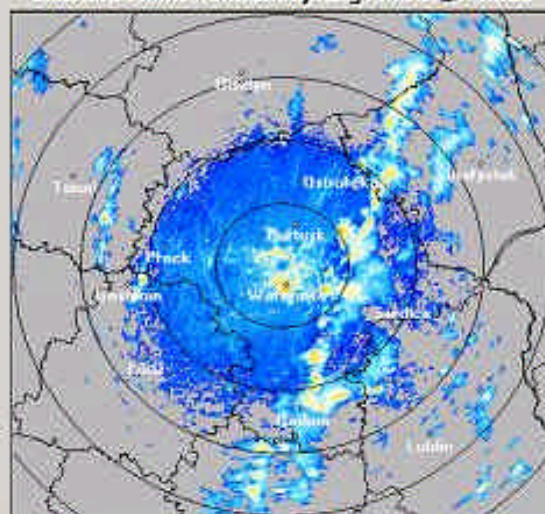
13:00 26-07-2003



Współrzędne radaru: 52°24'19"N 20°57'40"E  
Zasięg: 200 km  
Rozmiar obrazu: 400 x 400 pikseli  
Zakres danych: od -31.5 do 95.5 dBZ  
Wysokość: 0.1 km

Surface Rainfall Intensity Legionowo\_Polska

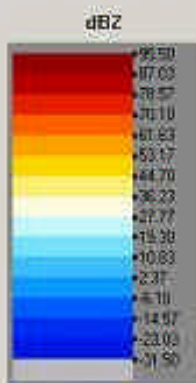
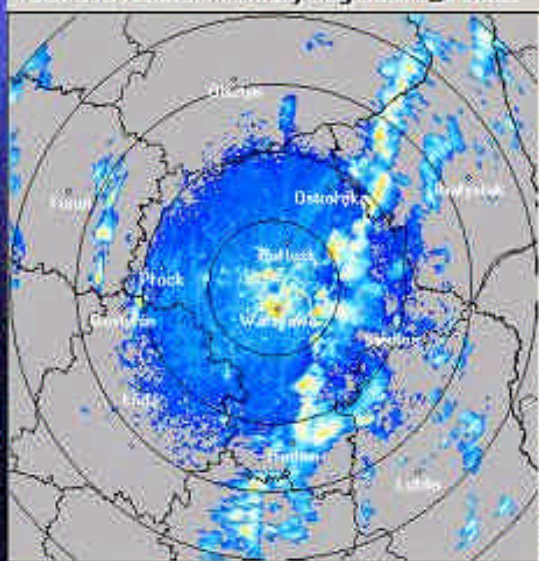
13:10 26-07-2003



Współrzędne radaru: 52°24'19"N 20°57'40"E  
Zasięg: 200 km  
Rozmiar obrazu: 400 x 400 pikseli  
Zakres danych: od -31.5 do 95.5 dBZ  
Wysokość: 0.1 km

Surface Rainfall Intensity Legionowo\_Polska

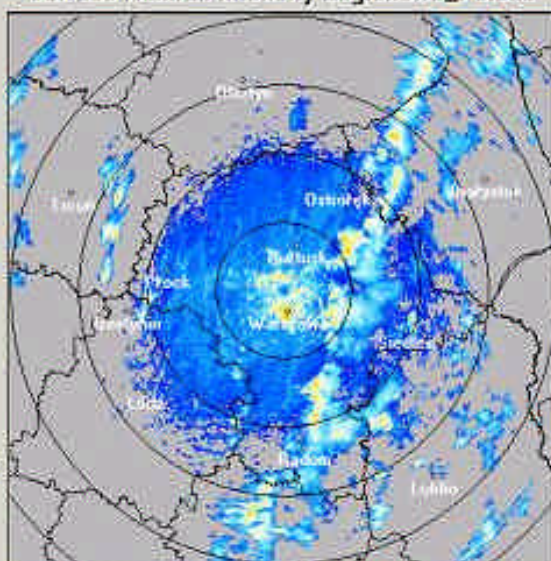
13:20 26-07-2003



Współrzędne radaru: 52°24'19"N 20°57'40"E  
Zasięg: 200 km  
Rozmiar obrazu: 400 x 400 pikseli  
Zakres danych: od -31.5 do 95.5 dBZ  
Wysokość: 0.1 km

Surface Rainfall Intensity Legionowo\_Polska

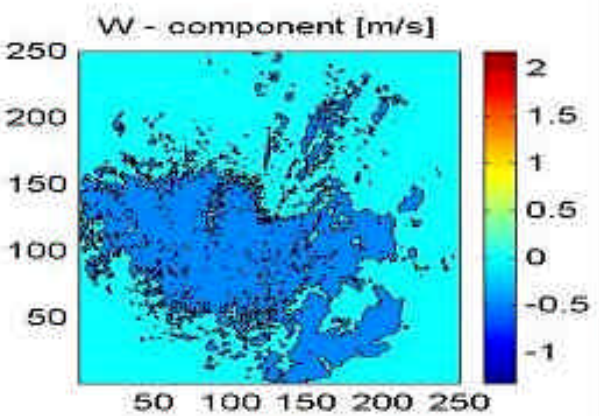
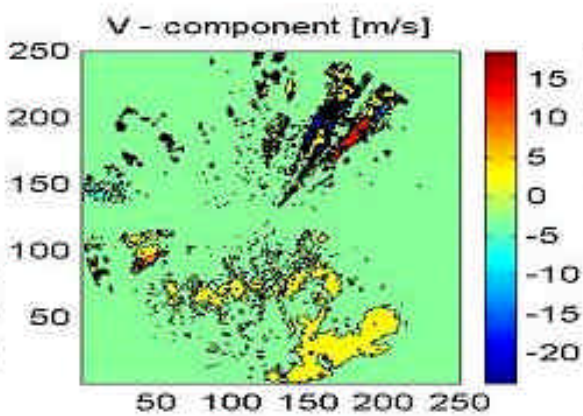
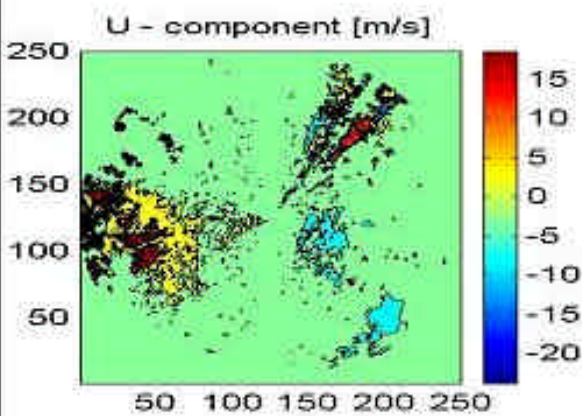
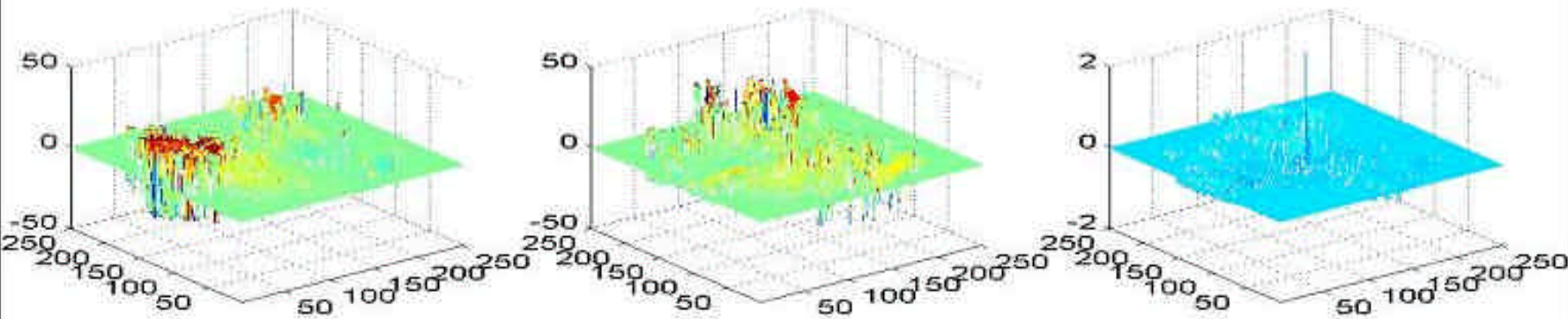
13:30 26-07-2003



Współrzędne radaru: 52°24'19"N 20°57'40"E  
Zasięg: 200 km  
Rozmiar obrazu: 400 x 400 pikseli  
Zakres danych: od -31.5 do 95.5 dBZ  
Wysokość: 0.1 km

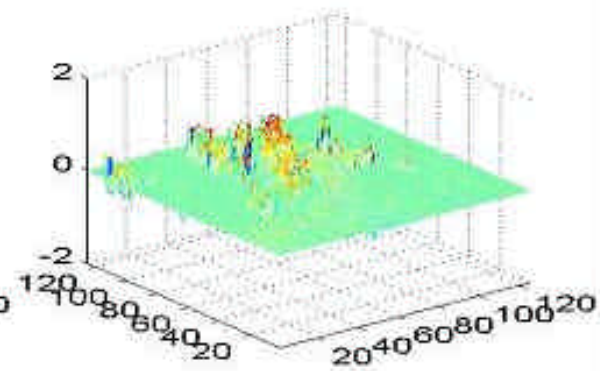
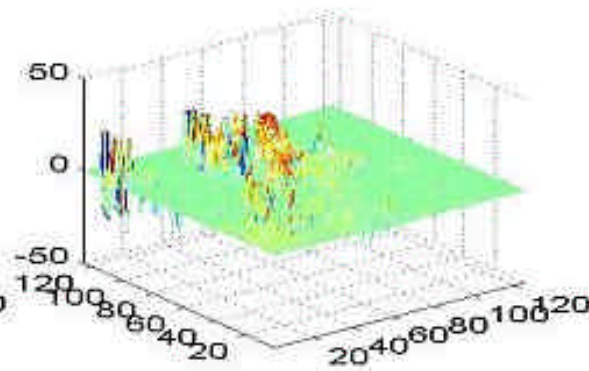
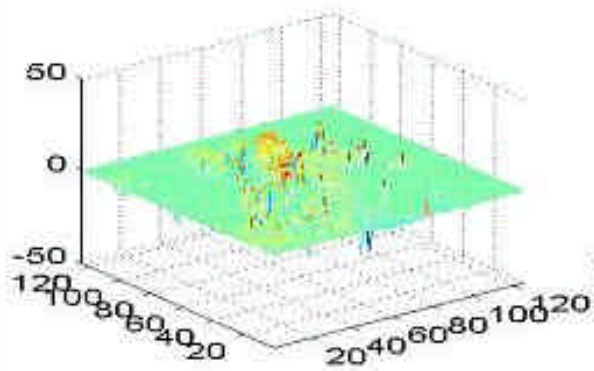


# Decomposition of radial wind component into Cartesian Legionowo 26.07.2003, 13.14 UTC- level 1000 m - PCAPPI

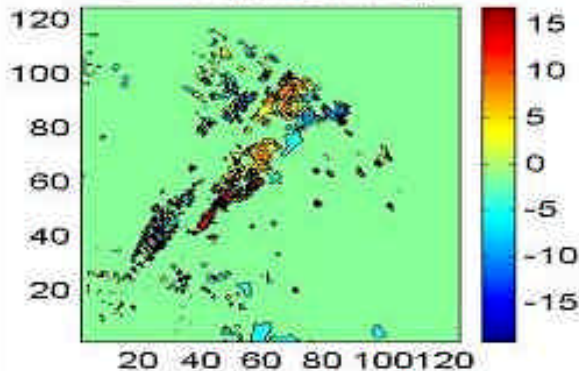




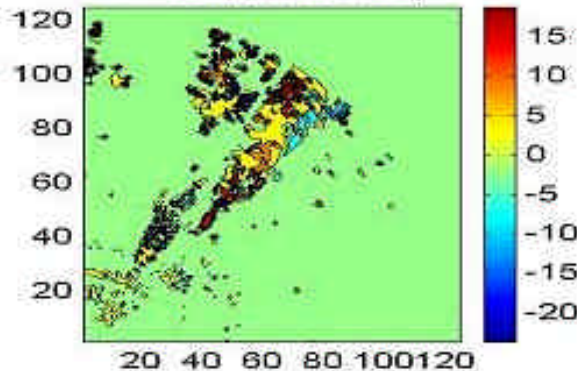
# Decomposition of radial wind component into Cartesian Legionowo 26.07.2003, 13.14 UTC- level 2000 m- PCAPPI



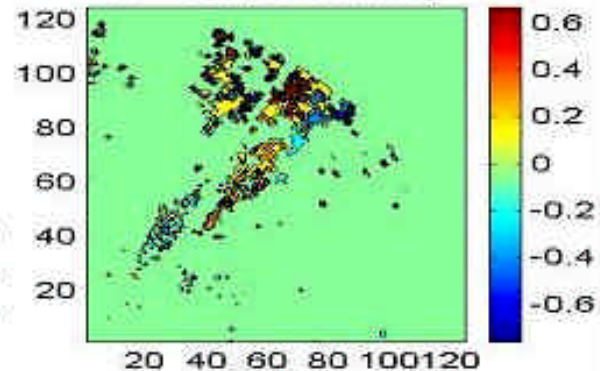
U - component m/s]



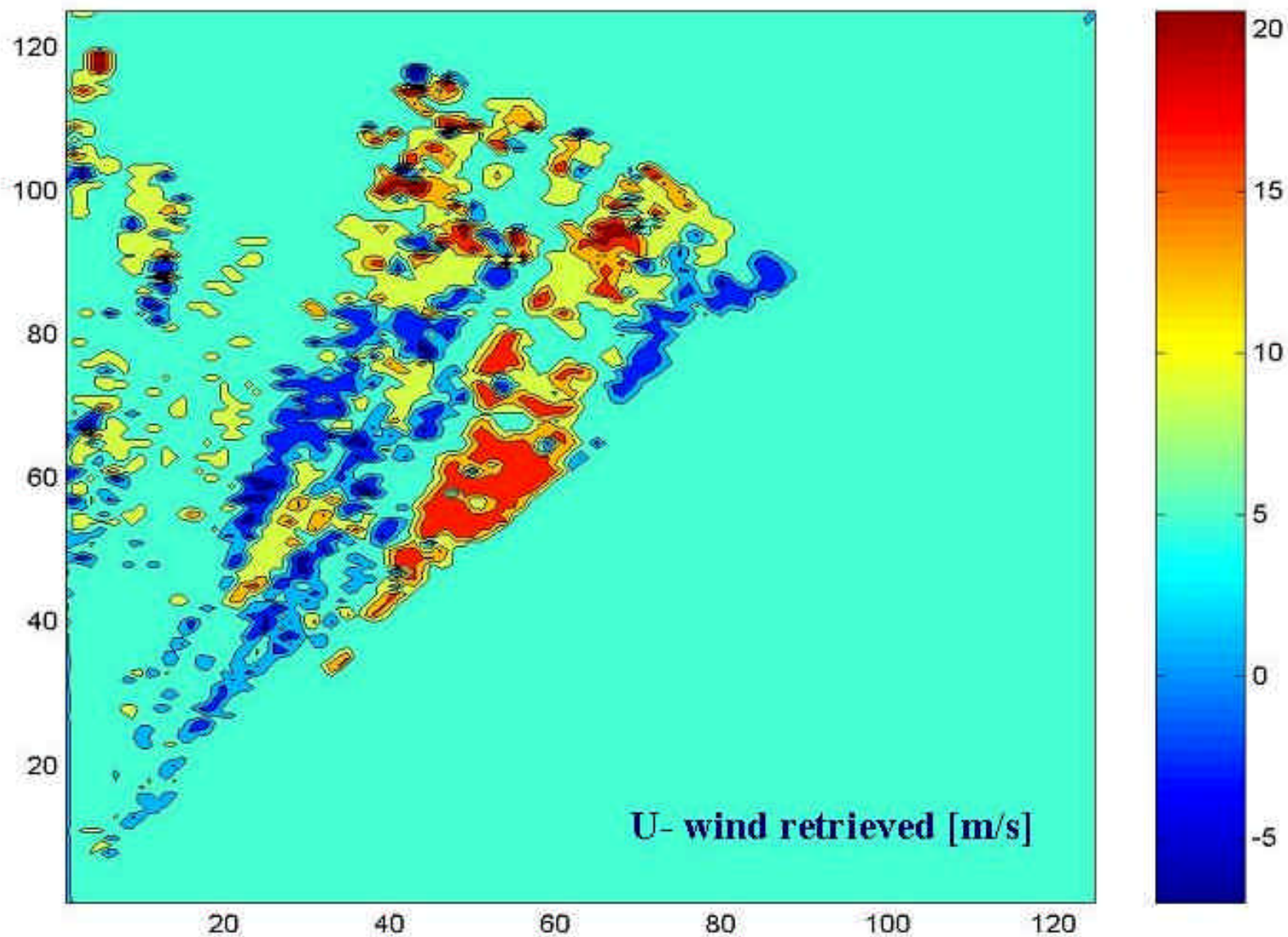
V - component m/s]



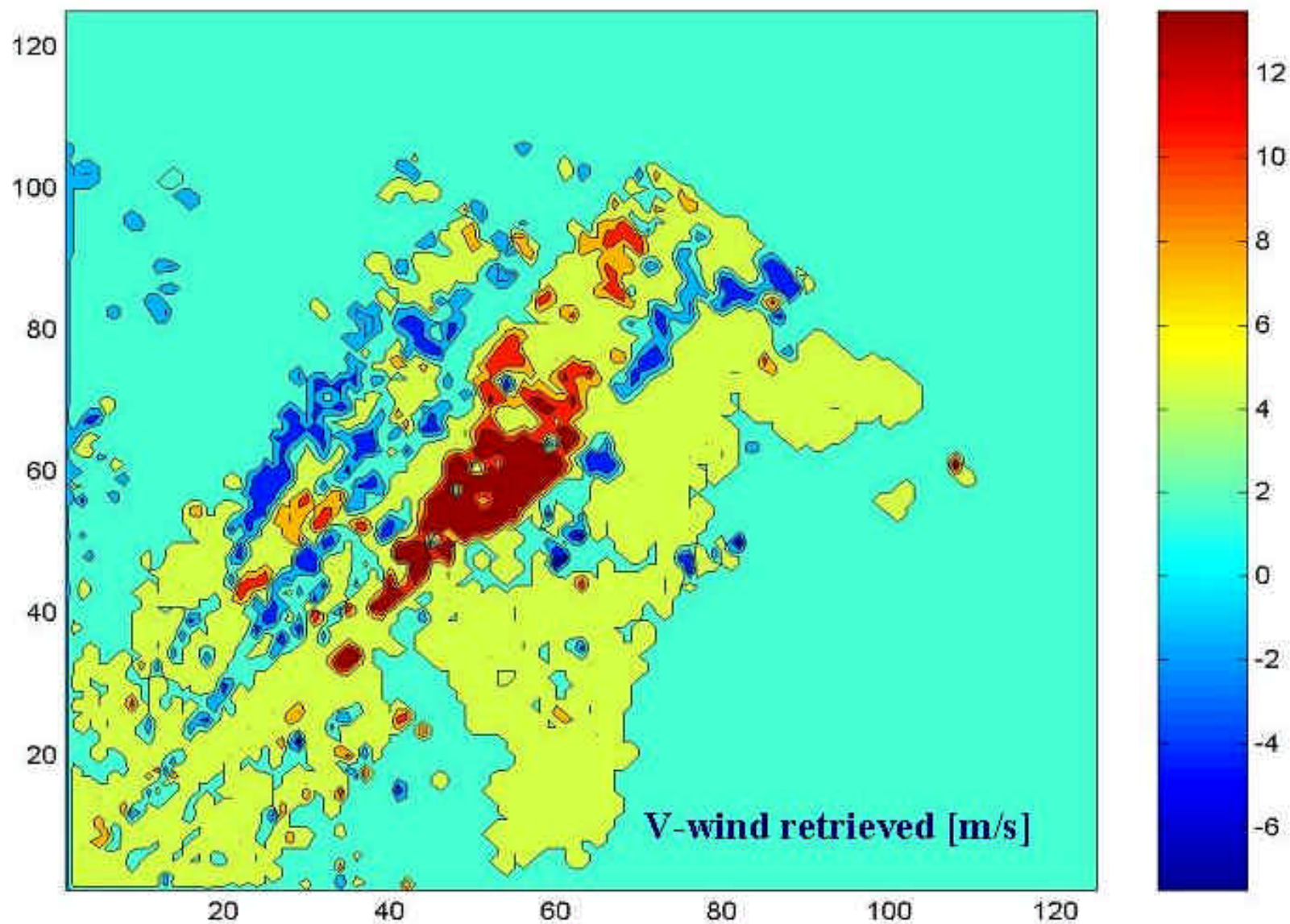
W - component m/s]



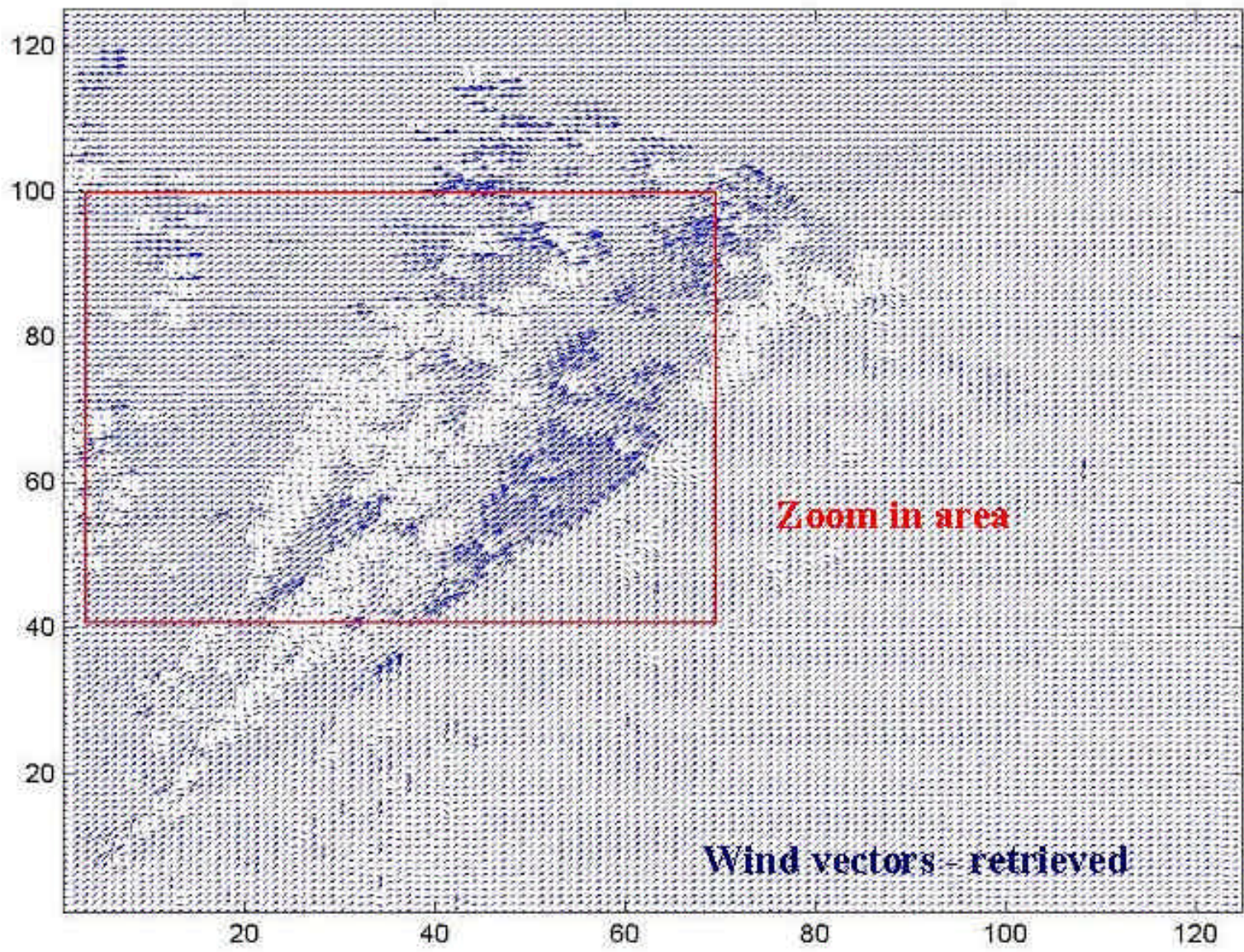








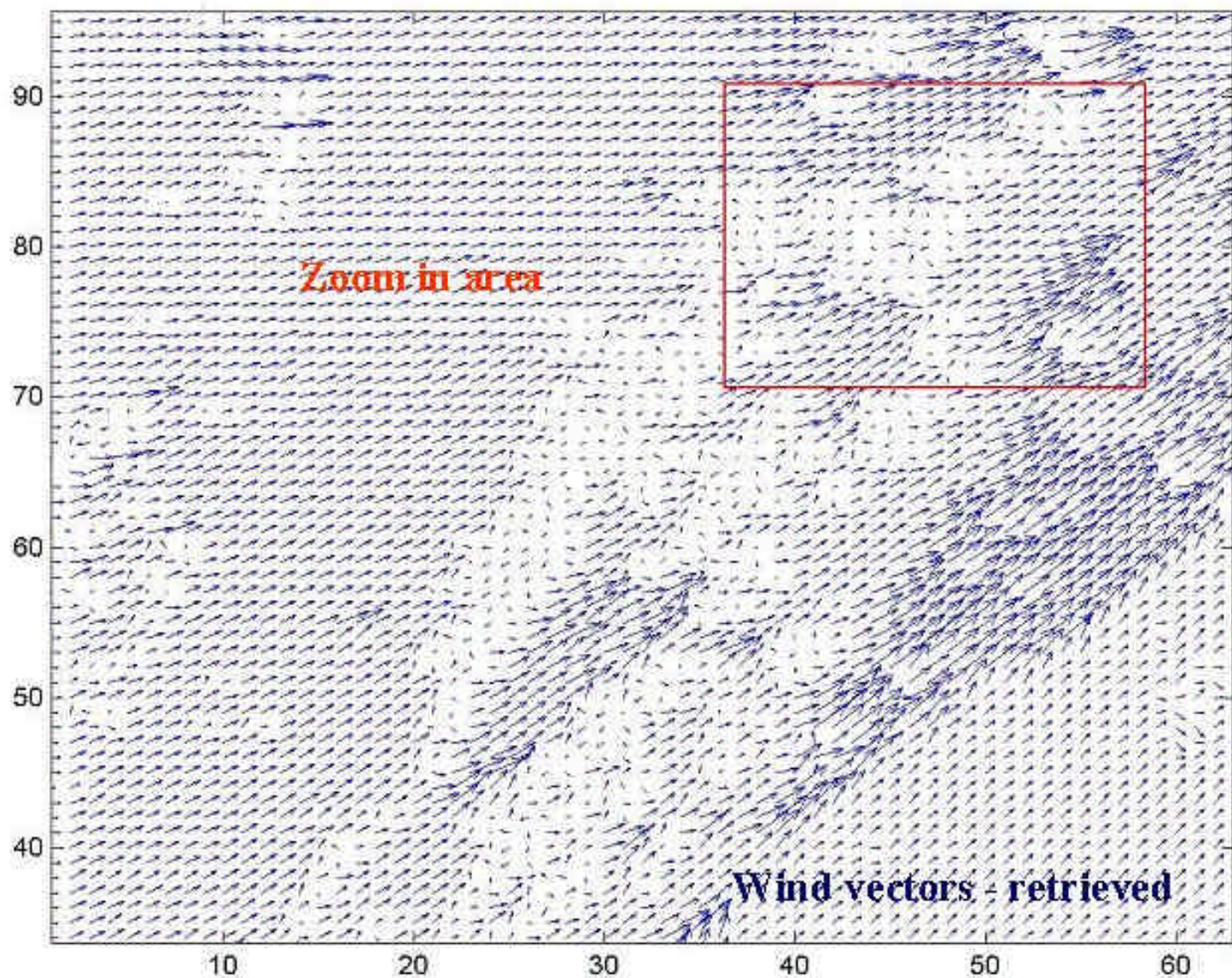




**Zoom in area**

**Wind vectors - retrieved**







# 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.