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

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Goals:

- 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 ($\partial J/\partial u_m$, $\partial J/\partial v_m$, $\partial J/\partial w_m$, $\partial J/\partial F_m$, $\partial J/\partial k_h$, 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,

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

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

00.00 UTC

12.00 UTC
Horizontal cross-section of reflectivity at 1000m Legionowo
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
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 (e.g., 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.