JP4.6 # A Variational Method for Dual-Doppler Radar Retrievals of Wind and Thermodynamic Fields

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1.Introduction

In this paper, a new scheme is developed based on MANDOP analysis (Scialom 1990; Protat et al. 1997). This scheme produces two wind fields at two time levels: the beginning of the first volume scan and the ending of the second volume scan, and retrieves the perturbation pressure and temperature fields at the middle time of the two volume scans. Compared with previous methods, the new scheme considers the exact time of each beam position of the radar scan and uses the three momentum equations as weak constraints for the retrievals.

2.Method formulations

As in MANDOP analysis (Scialom1990), all retrieved variables are expressed by three-dimensional expansions of Legendre polynomials, which include two 3D wind fields and thermodynamic fields. The three momentum equations, continue equation, and boundary conditions are used as weak constraints in the cost function. This scheme uses two volume scans from each of the two radars to derive the wind fields at the beginning and ending times and to retrieve the perturbation pressure π' and temperature $\theta c'$ fields at the middle time of the volume scans in three-dimensional space. The costfunction contains four terms, that is,

$$J = J^O + J^M + J^{con} + J^B \qquad (1)$$

Here, the first term is

$$J^O = (HB - V_r^{obs})^T (HB - V_r^{obs}) \qquad (2)$$

which defines the distance between analytical and observed radial winds. During the retrieval period, the retrieved wind field is linearly interpolated in time to fit the observed radial winds at the time of each beam position. This treatment is found to be useful in improving the accuracy of the retrievals. Here, **H** is a matrix that transforms the retrieved wind in Cartesian space into radial wind in Legendre space, **B** the expansion coefficients of wind components, and $\mathbf{V_r^{obs}}$ the observed radial winds.

The second term contains three weak constrains:

$$J^M = \sum_{i,j,k}(c_p\theta_{0c}\frac{\partial\pi'}{\partial x} - A)^2 + \sum_{i,j,k}(c_p\theta_{0c}\frac{\partial\pi'}{\partial y} - B)^2 + \sum_{i,j,k}(c_p\theta_{0c}\frac{\partial\pi'}{\partial z} - g\frac{\theta_c'}{\theta_{0c}} - C)^2 \qquad (3)$$

where *A, B* and *C* are, respectively, the right-hand sides of the following three momentum equations:

$$c_p\theta_{0c}\frac{\partial\pi'}{\partial x} = -\{\frac{Du}{Dt} - fv - S_x\} = A \qquad (4)$$

$$c_p\theta_{0c}\frac{\partial\pi'}{\partial y} = -\{\frac{Dv}{Dt} + fu - S_y\} = B \qquad (5)$$

$$c_p\theta_{0c}\frac{\partial\pi'}{\partial z} - g\frac{\theta_c'}{\theta_{0c}} = -\{\frac{Dw}{Dt} - S_z\} = C \qquad (6)$$

There are five retrieval variables: π' the nondimensional perturbations pressure, $\theta c'$ the potential temperature perturbations, and (u, v, w) the three wind components. Here, c_p is the specific heat at constant pressure, θ_{0c} the potential temperature of the reference state (given by a sounding profile), and the three *S*-terms represent the effects of turbulent diffusion.

J^{CON} is the weak constrains of continue equation and J^B is the boundary constrains. These two terms are expressed directly by three-dimensional extensions of Legendre polynomials. Using the standard conjugate gradient algorithm, the coefficients in the Legendre polynomial expansions of (u, v, w, π', $\theta c'$) are searched to minimize J and then substituted into the expansions to give the wind and thermodynamic fields.

3. Tests with simulated radar data

The tornadic supercell storm simulated by ARPS (Gao et 1999) on 20 May 1977 near Del city of Oklahoma is used to test the new scheme. Two volume scans of radial

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velocity are generated by projecting the model simulated 3D winds onto the directions of radar beams, similarly to NEXRAD scans, for the time period between 6600 and 7200 s. The simulated winds at 6900 s are used to evaluate the performance of the method. The accuracy and quality of the retrievals are measured by the following statistics, rms, relative rms (rre) and correlation coefficients (cc). The results are listed in Table 1.

Figure 1 compares the retrieved fields with the simulated. As shown, the retrieved fields match the simulated quite well. In particular, the simulation shows a strong updraft with positive temperature perturbation within the updraft at the middle levels. The pressure perturbation is negative (positive) in the rear (front) of the storm. These structures are favorable to the intensification of the storm and are all well captured by the retrievals.

4. Summary

In this paper, a new scheme is developed to retrieve 3D wind and thermodynamic fields from dual-Doppler radar observations. The scheme is tested with simulated radar data for a supercell storm and the results are very encouraging. The scheme is currently being tested with NEXRAD data and the results will be presented at the conference.

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Table1 List of retrieved result unit (velocity: m/s, π': 10^{-4}, $\theta c'$: K)

	6600			7200			6900	
	u	v	w	u	v	w	π'	θ'
cc	0.9674	0.9502	0.6903	0.9600	0.9355	0.7605	0.8490	0.6200
rre	0.2126	0.3136	0.7272	0.2432	0.3611	0.6549	0.5790	0.8124
rms	3.6123	3.5113	3.9474	4.1053	4.1671	4.1664	2.1923	1.6521

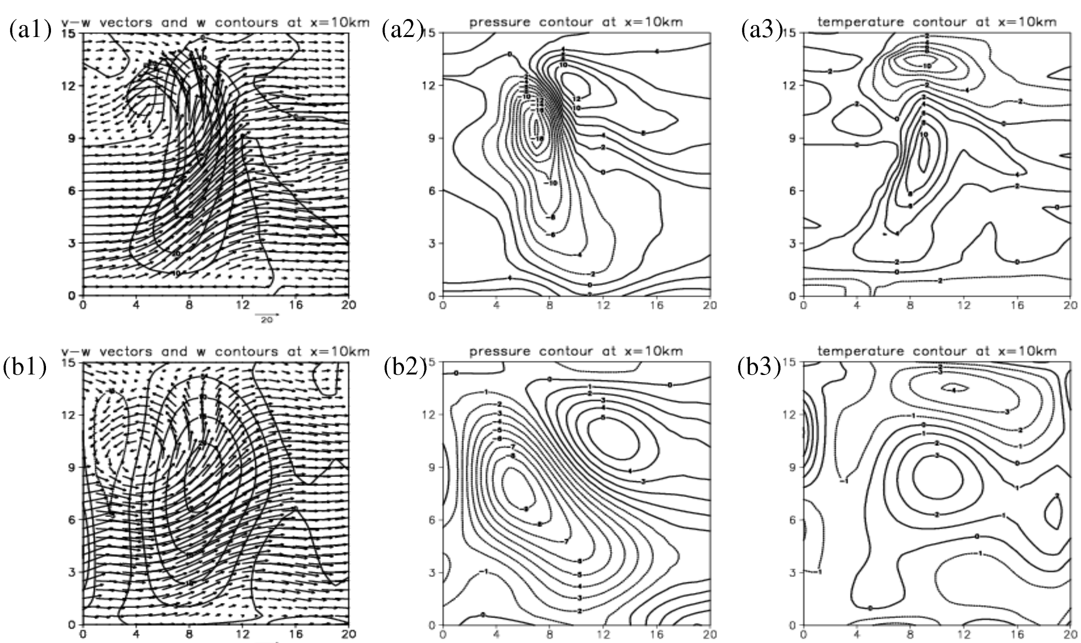

Fig. 1. Upper panel: Vertical cross-sections at x =10 km of the simulated vertical velocity, w contours (a1), perturbation temperature (a2), pressure (a3) at t = 6900s. Lower panel: As in the upper panel but for the retrievals.