Improving dual-Doppler retrieval of the vertical wind using a vertical vorticity constraint

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MOTIVATION

- Vertical wind w is poorly sampled by quasi-horizontally scanning radars
- Must therefore use mass conservation constraint and boundary condition(s) to retrieve w from horizontal divergence field
- Unfortunately, divergence often unobserved near surface due to earth curvature, ground clutter, and rough terrain, and in low-SNR regions
- Leads to locally severe errors in retrieved w (analysis underdetermined)
- Seek to improve w retrieval by imposing vertical vorticity equation as an additional dynamical constraint

MESOSCALE VERTICAL VORTICITY EQUATION

$$\frac{\partial \zeta}{\partial t} + u\frac{\partial \zeta}{\partial x} + v\frac{\partial \zeta}{\partial y} + w\frac{\partial \zeta}{\partial z} = \left(\frac{\partial u}{\partial z}\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\frac{\partial w}{\partial x}\right) - \zeta\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$$

Local tendency | Advection | Tilting | Stretching

TECHNIQUE OVERVIEW

- 3D-VAR formulation (cost function minimization problem)
- Weakly satisfies radial winds from both radars, anelastic mass conservation equation, smoothness constraint, and (optionally) the vertical vorticity equation
- Impermeability condition exactly satisfied at surface
- Provision made for spatially-variable advection and evolution of wind field

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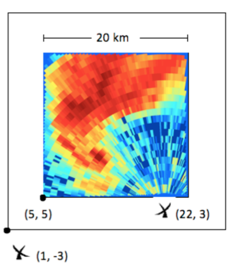
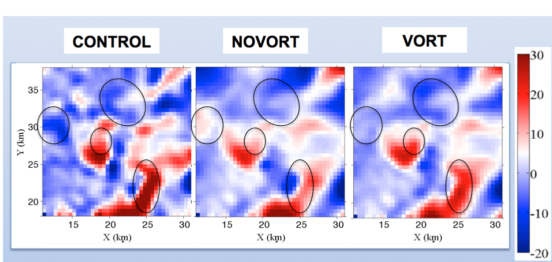
REAL-DATA EXPERIMENTS



- 8 May 2003 Oklahoma tornadic supercell
- Observed by KTLX (WSR-88D), KOKC (TDWR)
- $\Delta\Phi = 1$, $\Delta R = 250$ m/150 m, $\Delta T = 5$ min/4 min
- Retrievals performed over 20 km analysis domain (see figure) with 500 m grid spacing
- Improvement similar to ARPS ΔT=5 min experiments



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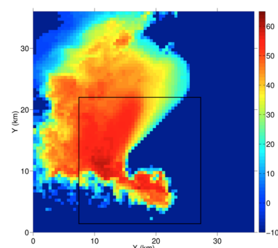
OSS EXPERIMENTS WITH SIMULATED SUPERCELL

- Supercell simulated using Advanced Regional Prediction System (ARPS)
- Emulated radars positioned ~35 km from analysis domain center
- Pseudo-observations computed every 200 m in range, 1° in azimuth, elevation
- Dual-Doppler retrievals performed over 20 km analysis domain (box in figure)
- Volume scan time ΔT varied between 30 s and 5 min



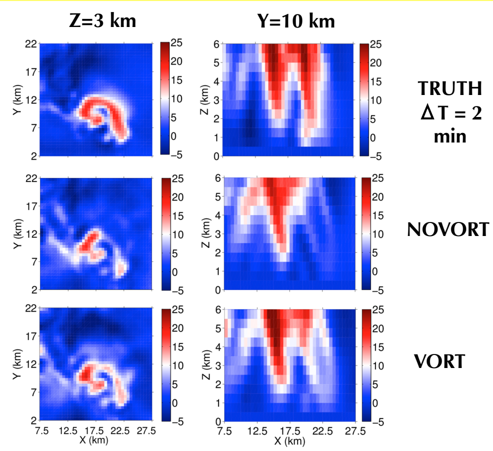
THREE MAIN EXPERIMENTS

CONTROL: all pseudo-observations used in analysis, vorticity constraint OFF

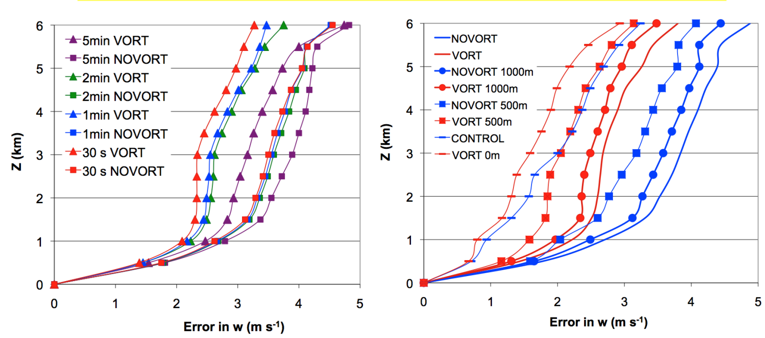
NOVORT: pseudo-observations only used above 1.5 km AGL, vorticity constraint OFF

VORT: pseudo-observations only used above 1.5 km AGL, vorticity constraint ON

Vorticity constraint substantially improves retrieved *w* in main updrafts/downdrafts:



Improvement from vorticity constraint increases as ΔT decreases or data rejection level increases:



Accounting for flow advection, evolution in calculation of $\partial\zeta/\partial t$ substantially improved the retrievals; best method for doing so varied with ΔT.