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STORM TARGETED RADAR WIND RETRIEVAL SYSTEM

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1. Introduction

In 2004, a storm targeted radar wind retrieval (STWR) system was developed at NSSL and the University of Oklahoma. This system was tested at the Oklahoma Norman Weather Forecast Office to provide additional information for tornado warning in 2004 spring season. Since then, the system has been further upgraded with two new functions: (i) an easy-to-use interface that can control the data selection and retrieval processes, and (ii) vector wind display overlaid with the radar reflectivity (or radial-wind) image on detailed county maps. These functions are designed to target and track critical areas threatened by the storm, to display detailed storm winds in the targeted areas and thus to help the forecasters to make warning decisions with an improved accuracy. The basic design and performances of the upgraded system are presented in this paper.

2. Architecture of STWR system

The STWR system contains two relatively independent components: Warning Decision Support System-Integrate Information (WDSS II) (Hondl 2002) and two-dimensional simple adjoint radar wind retrieval (2dSA) (Xu et al. 1995, 2001). WDSS II provides the capabilities to execute various existing algorithms, such as mesocyclone detection, TVS (Tornadic Vortex Signature) detection (Stumpf et al. 2002), and etc., and to display the results in real time on its interactive interface. The 2dSA can retrieve very-high-resolution storm winds (up to 250 m) from two or more consecutively radar scans. As demonstrated by previous case studies (Xu et al. 1995, 2001), by using the adjoint technique, the critical cross-beam wind information can be extracted effectively from the movements of the reflectivity and/or radial-wind patterns.

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The 2dSA was developed originally for research purpose and written in Fortran 90, while WDSS II was built on object-oriented application code written in C++. To avoid the complexity and difficulties caused by mixed-language programming, the two components are stand-alone and compiled independently. NetCDF (Network Common Data Format) as an emerging standard scientific data format in meteorological society and XML are used for data exchange between the two components.
Designing a real-time system is a challenging task. For operational WSR-88D radar, different VCP (Volume Coverage Pattern) has different time periods to complete a volume scan. In order to utilize the high temporal radar observation as efficiently as possible, the STWR is designed as an event-driven system. This is different from many other meteorological real-time systems that are operated on routine and regular time intervals. First, the STWR system has to deal with irregular data stream and unexpected changes in VCP (Volume Coverage Pattern) and volume scan period. The system has also to provide a sufficiently fast response time that is critical for severe weather monitoring. In the upgraded STWR system, the 2dSA is triggered by the latest available real-time radar scan at the lowest tilt (0.5^o) and the latest outputs of mesocyclone or TVS detection. The RSSD (Remote System Services Daemon, built in WDSS II) is used to manage signal communications in the STWR system. Real-time radar data are collected through LDM (Local Data Manager). The flowchart for the entire STWR system is shown in Fig. 1.

The STWR system is designed to be able to identify and track certain dynamic features. When user selects one feature, such as mesocyclone or TVS, by clicking the feature ID in an interactive table (Fig. 2), the system can automatically and continuously track the feature and perform wind retrieval in a moving frame following that feature until the feature disappears or is unselected by the user. If the feature disappears and user does not reselect a new feature, the system will automatically chose a

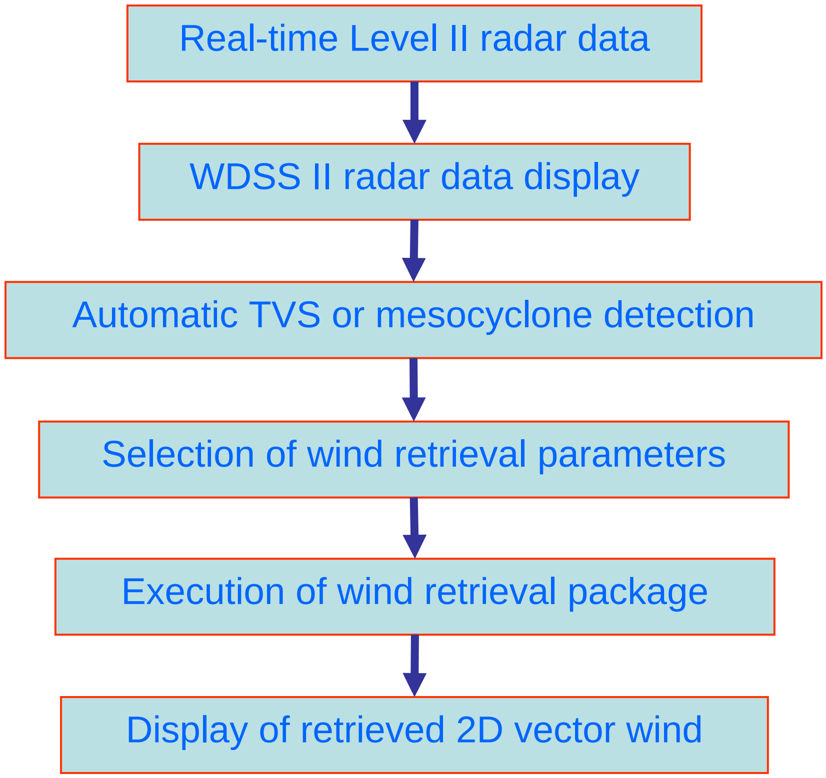


Fig.1 Flowchart of STWR system.

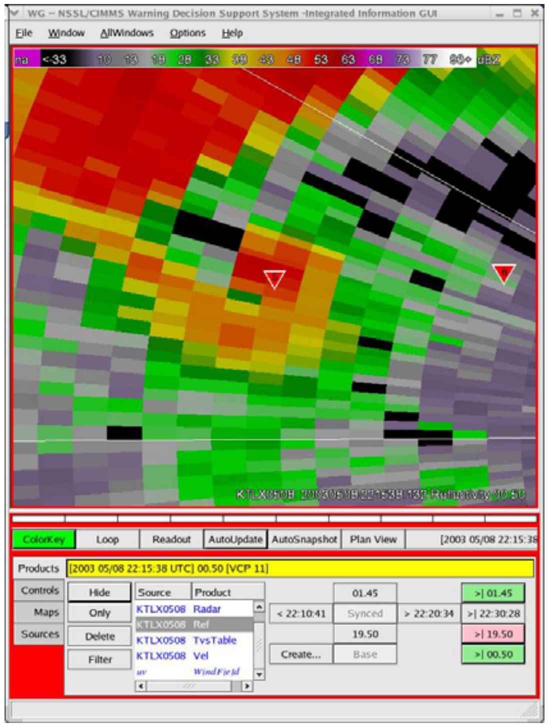
similar feature in closest distance to the previous one to track. This distinguish function lets users focus on the evolution of wind field around specified feature rather than manually search and reselect the feature time after time when new radar data become available. In addition, as feature ID is clicked, the feature will be automatically displayed in the center of its browser (Fig. 2).

To make the STWR easy to use, a user-friendly interface is developed. The parameters for 2dSA (such as the retrieval location, spatial resolution, number of grid points and etc) can be easily set and edited in a pop-up table (Fig. 3). Then by clicking “Apply” button, user can let the system starts listening to the signals from RSSD and then triggers wind retrieval. The retrieved 2D wind field will be displayed in the WDSS II browser that has capability to overlap the wind field onto multi-sensor observations, model outputs and other products.

STWR also gives user the option of running archived cases. Using real-time simulator built in WDSS II, user can easily reproduce a real-time data flow and perform wind retrieval for either research purpose or improvement of the system itself.

3. Tests with real cases

On 8 May 2003, KTLX radar observed a server thunderstorm at close range (~20 km) (Fig. 4). It provides a good case to test STWR system. Real-time simulator and TVS detection algorithm are turned on to simulate a real-time dataflow environment. The TVS marked 2 as its feature ID is selected as targeted feature. In the period between 22:11UTC and 22:21UTC, STWR follows the targeted TVS and continuously performs wind retrieval for three times. The TVS moves from 277^{o}, 20.6 km (azimuth, range) to 295^{o}, 15.3 km in radar coordinates. Time series of KTLX observations and retrievals are shown in Fig. 5. The retrieval regions at different scans are highlighted by the yellow boxes. The retrieved wind field at 22:16UTC is displayed in detail in Fig. 6. A vortex is evidently exhibited at the center of retrieval domain where TVS locates. It demonstrates the capability of STWR system. Meanwhile, the overlapping display function



KTLX0508 TvsTable [2003 05/08 22:15:38 UTC]													
ID	Circ	Az	Ran	CellID	MesoId	Base	Depth	LLgtg	MXgtg	Dir	Speed	AlgRank
5	TVS	285	18.8	29	389	0	5	52	70	241	14	1
8	TVS	293	12.5	29	0	0	4	26	26	238	17	2

Plot Trend | Plot Time Height | Delete current plot | Show Plots

Fig. 2. WDSS II browser and its interactive TVS table. The first column in the table is feature ID. The red triangles in the browser indicate the locations of TVS on the relevant reflectivity field.

Filter Selector

3DGrid | AzShear | Contour | Cressman | Dealias | Dilate | Erode | Gauss | LLSD | LocalAverage | Make360 | MedianFilter | Oriented | Percent | SAWR

Description	Letter	Value
Height of bottom right corner	d	0
number of sweeps	n	2
dx(m)	p	250
dy(m)	q	250
reflectivity	r	false
Char. Speed	s	0
Height of top left corner	u	0
velocity	v	true
nx	x	40
ny	y	40

Apply | Reset | Close

Fig. 3. Interactive table for wind retrieval parameters.

provides a useful tool for users to evaluate and then improve the retrieval algorithm.

The other purpose to perform real-time simulation is that user can test if the system is efficient enough to operate real-time on a certain computer. Our simulations are conducted on a 2 CPU PC version workstation (Dell Precision 530) with Linux operation system. The test results show the current version of STWR can be smoothly operated on real-time on this Linux workstation. Other cases, such as 3 May 1999, have been used to test this system and shown similar performance.

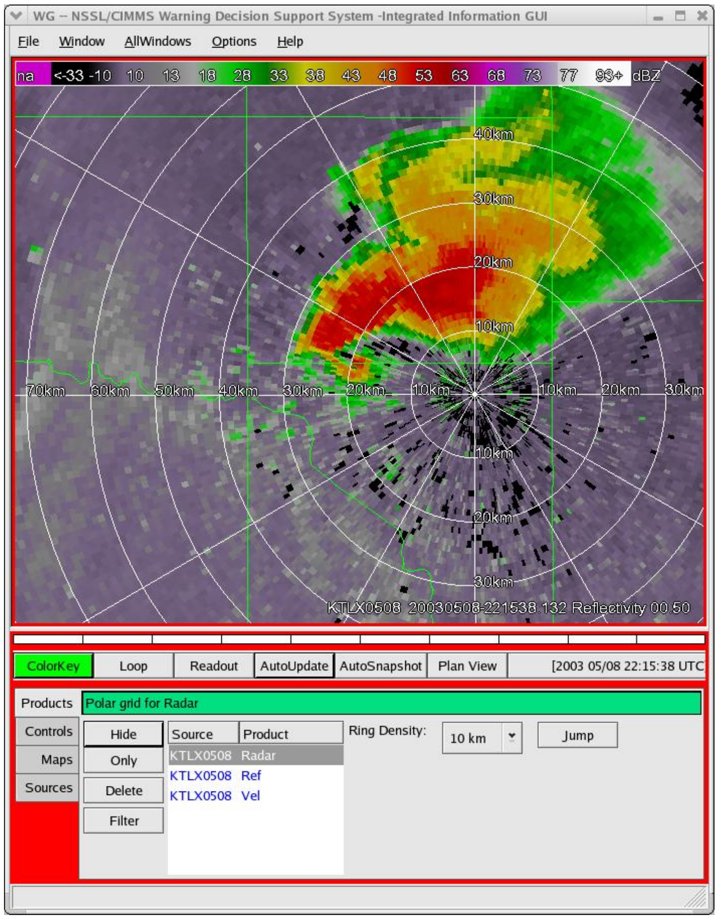


Fig. 4 The reflectivity field of a tornadic thunderstorm observed by KTLX radar on 8 May 2003.

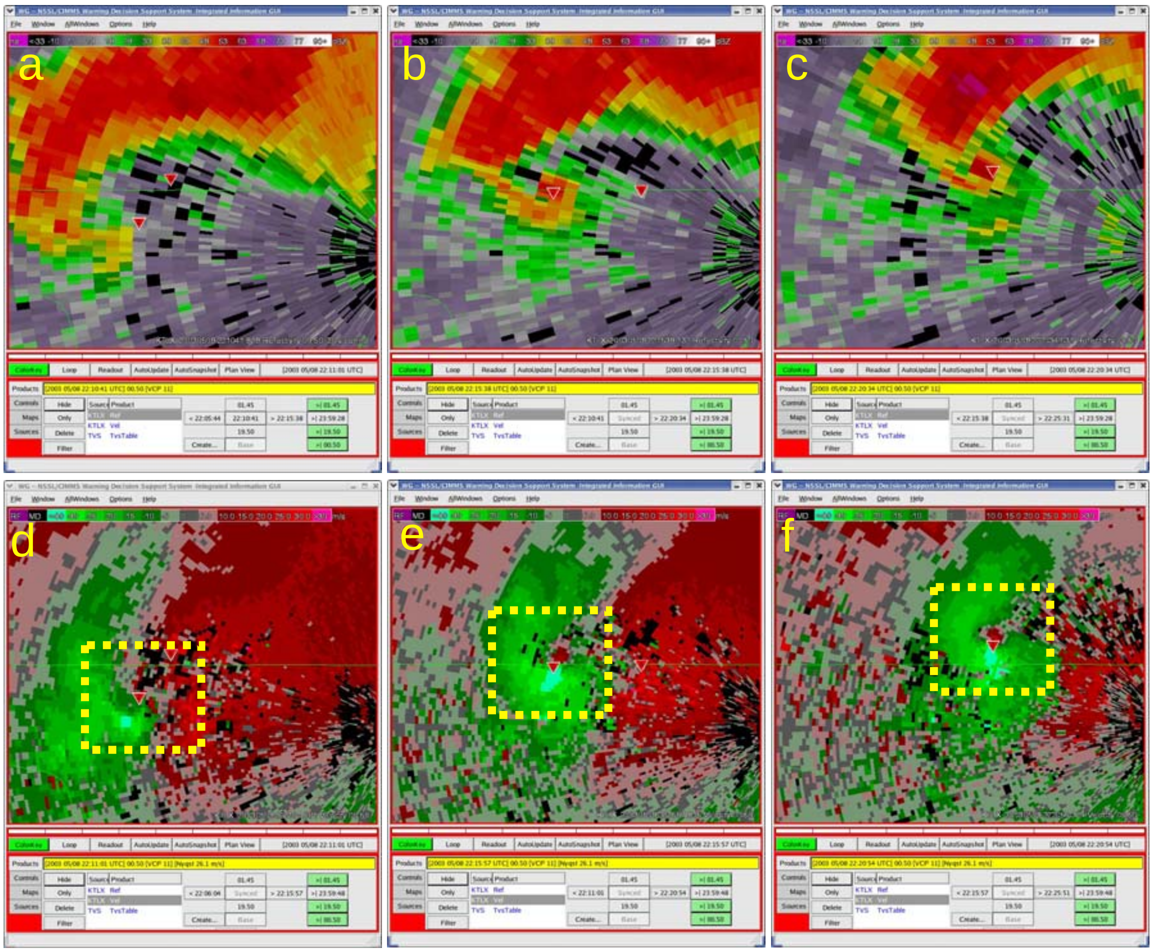


Fig. 5 Reflectivity fields (a, b, and c) and Doppler velocity fields overlapped by retrieved wind vectors (c, d, and f) at 22:11 UTC (a and d), 22:16UTC (b and e), and 22:21 UTC (c and f) on 8 May 2003. The storm-target wind retrieval regions are highlighted by the yellow boxes.

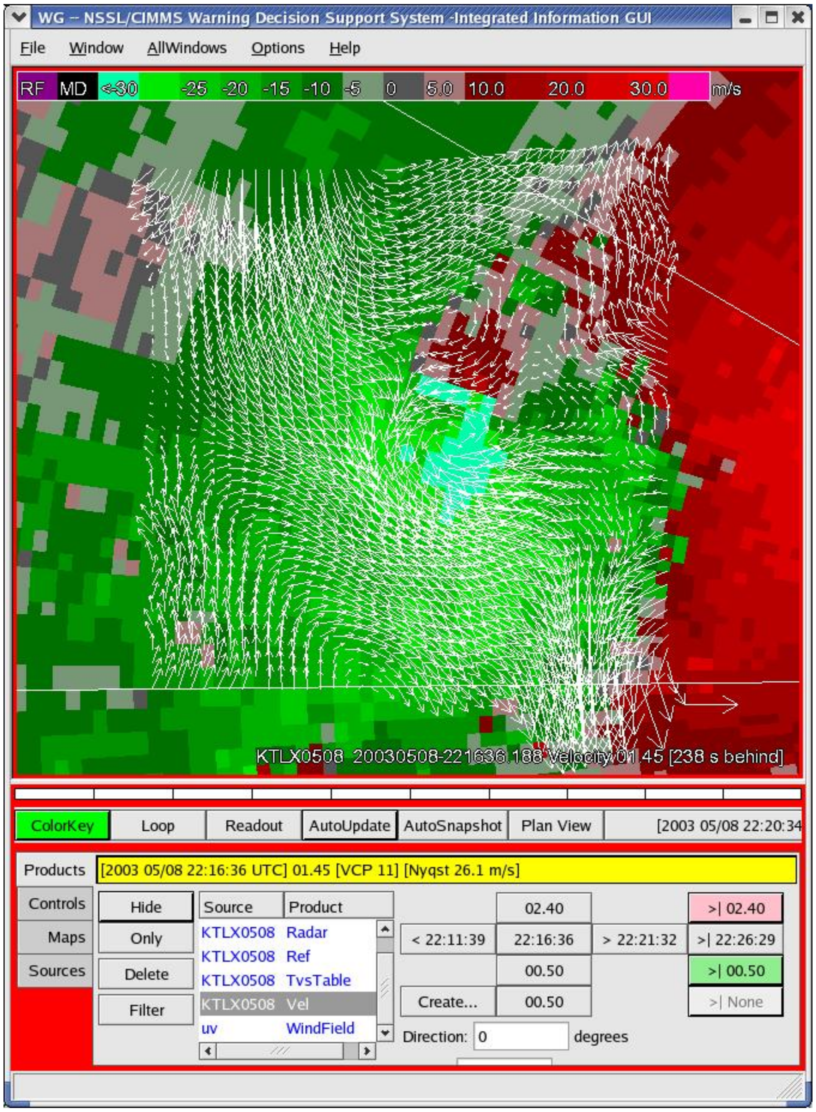


Fig. 6 Enlarged Doppler velocity field with overlapped retrieved wind field around selected TVS at 22:16UTC on 8 May 2003. Warm colors denote velocities away from radar. Cool colors denote velocities toward to radar. The radar is on the cross-point of two solid white lines outside of this image.

4. Summary

Building on the achievements of WDSS II and on the success of Collaborative Radar Acquisition Field Test (CRAFT) project, we have successfully converted research algorithms to an operation-oriented application system. The STWR functions and features can be summarized as follow: 1) real-time level II data display; 2) automatic estimate of moving speed and direction of user-selected feature; 3) user-friendly interface; 4) dynamic feature following wind retrieval; 5) automatic and interactive display of retrieved wind field. The accomplishment of STWR system also provides a prototype framework for converting other algorithms written in different programming language rather than C++ to a real-time operation-oriented application through WDSS II system in the future.

Acknowledgments

This work was supported by the ONR Grants N000140310822 and N000140410312 to the University of Oklahoma and by the NOAA High Performance Computing and Communications (HPCC) program. The authors would like to thank the NSSL WDSSII and SWAT groups for their technical support and collaboration.

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