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Neural Networks to identify Tornadic/NonTornadic Circulations based on various radar attributes

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Abstract— Based on various attributes of the circulations, it is perceived that not all the circulations are tornadic. There are two types of circulations based on various attributes –Tornadic and nontornadic circulations. The National Severe Storms Laboratory developed two algorithm for detecting circulations in the atmosphere based on the information constructed from Doppler Radar. Mesocyclone Detection Algorithm is developed is designed for detecting larger, storm-scale circulations while Tornado Detection Algorithm is developed for detecting smaller, but more intense circulations. The aim of this paper is to outline the capability of Neural Network to achieve high Probability of Detection (POD) and reduce False Alarm Ratio (FAR) by incorporating different weather parameters.

Index Terms— False Alarm Ratio(FAR), Heide Skill Score(HSS),), Mesoscale Detection Algorithm, National Storm Environment(NSE), National Severe Storms Laboratory(NSSL), Probability of Detection (POD), Tornado Detection Algorithm(TOD).

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1 INTRODUCTION

Although there is a considerable progress made in the observation, modeling and understanding of tornadoes, warning and forecasting before ahead remains a considerable challenge for the forecasters. The statistics have clearly shown warning probability of detection (POD) and lead time have remained at the same level in recent years with false alarm ratio (FAR) remaining relatively constant(fig.1). This is principally because the existing radars and weather detection methodologies suffer from limitations that allow meteorological quantities and associated features to go undetected. There is a need of new advances in this area if substantial improvements in warning and forecasting accuracy are to take place.

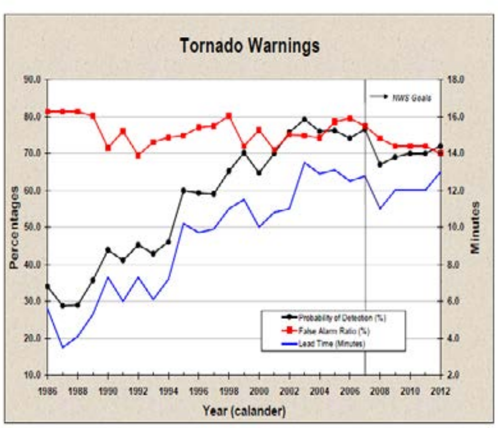

Fig. 1 Nationwide tornado warning verification statistics from 1986-2007 as well as NWS goals for new storm-based warnings beginning in 2008.Probability of Detection,false alarm ratio(FAR), and lead time with future goals.[Data courtesy of B.MacAloney II. National Weather service performance Branch,2008]

Although there are a lot of data mining techniques applied to meteorology to predict the severe weather events. It is the Neural Networks that have had significant success in identifying tornadic circulations in the atmosphere. Neural networks have found wide applicability in meteorology to predict tornadoes. The measures reported in this paper are the Probability of Detection (POD), False Alarm Ratio (FAR) and Heidke Skill Score (HSS). All these are computed on the confusion table:

	non-tornadic	Tornadic
Non-tornadic	null	Fa
Tornadic	miss	Hit

hit=tornadic circulations correctly identified by the neural networks
*n*ull= non-tornadic circulations correctly identified by the neural networks
fa=mesocyclones classified by neural networks as tornadic but verified as non-tornadic
miss=tornadic mesocylones mis-classified by neural networks.
Where hit and null are tornadic and non-tornadic mesocyclones respectively that were correctly identified by the neural network.

$$POD = \frac{hit}{hit+miss} \quad (1)$$

$$FAR = \frac{fa}{hit+fa} \quad (2)$$

$$HSS = \frac{2*(null*hit-miss*fa)}{(fa+hit)*(fa+null)+(null+miss)*(miss+hit)} \quad (3)$$

Where *hit* and *null* are tornadic and non-tornadic mesocyclones respectively that were correctly identified by the neural network.

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2 Mesoscale detection algorithm

A Mesocyclone is defined as a three dimensional region in a storm which rotates cyclonically and is usually correlated with severe weather. Mesocyclones are of particular interest since tornadoes, large hail, and damaging winds are collocated with the rotation area. These hazards lead to unnecessary loss of life and destruction of property if people are not adequately warned of the threat. A Mesocyclone detection algorithm was developed in National Weather Service's (NWS) Weather Surveillance Radar-1988 Doppler (WSR-88D) System, and was used as guidance to meteorologists to warn the general public of tornados and other severe weather associated with severe thunderstorms [1]. But the wide spread use of the 88D has discovered various shortcomings in the algorithm, including high false alarm ratio(FAR) in certain severe storm situations such as squall lines and bow echoes. The National Severe Strom Laboratory then developed an enhanced Mesocyclone Detection Algorithm to address these shortcomings. The first version of the new design addressed the false alarm problem by raising existing thresholds and creating new thresholds (including strength, spatial, and time continuity thresholds).But it was found later that some tornado or severe weather events were not reaching any of these thresholds, also some strong vortices occur without a report of a tornado or severe weather [2]. Because of this it became important that new version of the Mesocyclone detection algorithm should be able to entire spectrum of strom-scale vortices (1-10 km in diameter). Then National Severe Storms Laboratory developed an enhanced version of the 88D that addresses these shortcomings. The NSSL MDA attempted to detect all storm-scale vortices (1-10 km diameter) and then diagnosed them to determine if they are significant. Despite many improvements to the MDA it has been found that it is still not perfect. MDA has shown improved diagnostic skills (POD) over the older versions but has problems in high false alarm rate. MDA has shown False Alarm Rate as high as 67.7 to 75.7(Stumpf et al, 1998).Thus there are still several shortcomings in MDA that have to addressed.

3 TORNADO DETECTION ALGORITHM

Another algorithm developed by National Severe Storms Laboratory (NSSL) is Tornado Detection Algorithm (NSSL TDA). Mesocyclone Detection Algorithm is developed is designed for detecting larger, storm-scale circulations while Tornado Detection Algorithm is developed for detecting smaller, but more intense circulations [2]. Tornado Detection algorithm is designed to address the problem of low Probability of Detection and high false alarm ratio of its earlier version Tornado Vortex Signature Algorithm(88D TVS). It has been reported that by applying both the algorithms on an independent dataset of 31 tornadoes, NSSL TDA has shown POD as 43% and FAR of 48% as compared to 88TVS which has shown POD 3% and FAR 0% [6].Performance of the TDA is better than TVS, with a higher probability of detection, some discrimination between tornadic and non-tornadic shear, and a requirement for gate-to-gate shear. Velocity processing is more sophisticated with TDA. Shears must be gate-to-gate, which is more closely re lated to tornadic circulations as compared to strong shear that is not gate-to-gate. The algorithm searches all velocity pairs, not just those within a mesocyclone.

There are more adaptable parameters, allowing fine tuning of the algorithm performance, resulting in a higher probability of detecting important shear regions.The only limitation of the NSSL TDA is that it can not detect tornadoes that are in larger diameter(1-2 km) and are located very close(<20 km) to the radar. This is the limiting case for NSSL TDA since it focuses upon those vortices whose velocity extrema are sampled as gate-to-gate(Mitchell et al, 1998).Thus it has been emphasized that NSSL TDA should be considered as added guiding tool in tornado warning decision process. The WSR-88D and TDA algorithms should be used together to forecast atmospheric conditions.

4 NEURAL NETWORKS TO DETECT TORNADIC/NONTORNADIC CIRCULATIONS

C. Marzban and Stumpf [1],[8],[9] designed a neural network to diagnose which circulations detected by National Severe Storms Laboratory(NSSL) MDA yield tornados. A set of 23 variables are selected as input nodes to the feed-forward neural network. It is shown that the neural network outperforms the rule-based algorithm existing in the MDA, as well as statistical techniques such as Discriminant Analysis and Logistic Regression. C.Marzban examined 29 days of storm circulations which contains N0=5348 nontornadic and N1=512 tornadic circulations [11]. 21 attributes were selected and transformed intp z-scores(i.e mean of zero and a standard deviation of 1).A Multilayered perceptron is developed to predict tornadoes with special emphasis on ,in bootstrapping, of the local minima of the error function. It has been proved that MLP has a higher affinity for the identification of nontornadic circulations. As for the tornadic circulations, the MLP produces a relatively flat distribution.

C. Marzban et al.[12] extended the same work to include 83 storm days and two data sets are included: circulations detected by MDA and circulations detected by TDA. It is clearly shown that a TDA detection is twice likely to be tornadic than an MDA detection.

V Lakshmanan et al.[6] extended the same work to include 83 storm days with some variations that can improve performance of the neural network over that achieved by Stumpf et al. [2]. Near Storm Environment (NSE) parameters are added to check the predictive capability of Neural network. In V Lakshmanan et al.[6], training the neural network has been changed by employing weigh decay as smaller weights tend to generalize better [7], resilient propagation. The results have shown slightly low probability of Detection but low False Alarm Ratio and high HSS (Table 1).

Table 1

Method	POD	FAR	HSS
Marzban,Stumpf(2002)	36%	69%	29%
V. Lakshmanan(2005)	34%	**38%**	**38%**

It has been proved thus incorporating NSE parameters into the training of neural network improved the ability of the network to classify which circulations are tornadic.Although Probability of Detection is decreased marginally yet False Alarm Ratio and Heide Skill Score have shown noticeable improvement.

4 Conclusion

A Comparison study is done based on different atmosphereic parameters viz. MDA/TDA/NSE.It has been outlined that how Neural Network can be trained and may yield promising results by incorporating NSE parameters.

References

[1] Marzban, C. and G. Stumpf, 1996: A neural network for tornado prediction. *J. App. Meteo.*, **35**, 617.

[2] Stumpf, G. and C. Marzban, 2002: Tornado warning guidance. Technical report, Warning Decision Training Branch, National Weather Service, http://www.wdtb.noaa.gov/resources/PAPERS/twg02/.

[3] Riedmiller, M. and H. Braun: 1993, A direct adaptive method for faster backpropagation learning: The RPROP algorithm. Proc. IEEE Conf. on Neural Networks.

[4] Caruana, R., S. Lawrence, and C. Lee Giles: 2001, Overfitting in neural networks: Backpropagation, conjugate gradient, and early stopping. Neural Information Processing Systems (Proceedings of NIPS*2000), MIT Press,volume 13.

[5] Stumpf, G., A. Witt, E. D. Mitchell, P. Spencer, J. Johnson, M. Eilts, K. Thomas, and D. Burgess, 1998: The national severe storms laboratory mesocyclone detection algorithm for the WSR-88D. Weather and Forecasting, 13, 304–326.

[6] V Lakshmanan, J. Stumpf.(2005) J5.2 A Neural Network for Detecting and Diagnosing Tornadic Circulations using the Mesocyclone Detection and Near Storm Environment Algorithms.

[7] A. Krogh and J. Hertz, "A simple weight decay can improve generalization," in Advances In Neural Information Processing Systems (S. H. Moody, J. and R. Lippman, eds.),vol. 4, pp. 950–957, Morgan Kaufmann, 1992.

[8] Marzban, C., G. J. Stumpf, 1998: A Neural Network for Tornado and/or Damaging Wind Prediction Based on Doppler Radar-derived Attributes. Microcomputer Applications, Vol. 17, 21-28.

[9] Marzban, C., G. J. Stumpf, 1996: A neural network for tornado prediction ..., Journal of Applied Meteorology, Vol. 35, 617.

[10] Marzban, C., G. J. Stumpf, 1998: A Neural Network for Tornado and/or Damaging Wind Prediction Based on Doppler Radar-derived Attributes. Microcomputer Applications, Vol. 17, 21-28.

[11] Marzban, C., E. D. Mitchell, G. Stumpf, 1999: The notion of ``best predictors:'' An application to tornado prediction. Weather and Forecasting, Vol. 14, No. 6, 1007-1016.

[12] Marzban, C. 2000: A neural network for tornado diagnosis. Neural Computing and Applications, Vol. 9 (2), 133-141.

[13] G. Stumpf, C. Marzban, and E. Rasmussen, "The newNSSL mesocyclone detection algorithm: a paradigm shift in the understanding of storm-scale circulation detection," in 27th Conference on Radar Meteorology, 1995.

[14] R. J. Donaldson Jr., and P. R. Desrochers, 1993: Tornado detection and warning by radar. *The Tornado: Its Structure, Dynamics,Prediction, and Hazards*, *Geophys. Monogr.*, No. 79, Amer. Geophys. Union, 203–221.

[15] Mitchell, E. D., 1995: An enhanced NSSL tornado detection algorithm.Preprints, *27th Conf. on Radar Meteorology*, Vail, CO, Amer. Meteor. Soc., 406–408.

[16] Lakshmanan, V., Stumpf, G. and Witt, A. (2005), „Neural Network for Detecting and Diagnosing Tornadic Circulations using the Mesocyclone Detection and Near Storm Environment Algorithms", 21st Int'l Conference on Information Processing Systems, Amer. Meteo. Soc., San Diego, CD-ROM, pp. J5.2.