Experiments in Blending Radar Echo Extrapolation and NWP for Nowcasting Convective Storms

James Wilson[1] and Mei Xu[1]

[1] National Center for Atmospheric Research, Boulder Colorado USA

1 Introduction

Several methods for the very short-term prediction of convection are currently employed throughout the world. They range from systems that automatically detect and extrapolate existing convection (e.g., Dixon and Weiner 1993); to conceptual models that predict the Lagrangian evolution of convection (Pierce and Hardaker 2000, Sleigh and Collier 2004, Mueller et al. 2003); to methods that combine extrapolation with mesoscale numerical weather prediction (NWP) forecasts (Golding 1998, 2000, Lin et al. 2005); to explicit prediction with high resolution NWP models with nudging (e.g., Zou and Kuo 1996; Jones and MacPherson 1997); to NWP using three or four dimensional variational (3DVAR and 4DVAR) data assimilation (Snyder and Zhang 2003, Zhang et al. 2004, Sun 2005); to probabilistic ensemble model approaches (e.g., Weygandt and Benjamin 2004). While observation-based techniques (e.g., extrapolation) perform well in the very short term (e.g., 0-2 hr), their skill decreases rapidly with lead time because of difficulties treating initiation, storm evolution and variations in storm motion (Mueller et al. 2003). The accuracy of NWP models during the first 3 hours typically has been much inferior to extrapolation because of difficulties in initiating the models with the detailed precipitation pattern. It is expected as data assimilation methods improve the NWP forecasts for this period should improve substantially; the biggest challenge will be to improve skill in the 3-6 h period.

This is illustrated in Figure 1 where the skill for extrapolation and NWP forecasts are compared. This conceptual figure which was first presented by Browning (1980), Doswell (1986) and Austin et al. (1987) has been recently confirmed by studies from the United Kingdom, Canada, Japan and United States. The NWP and extrapolation curves cross-over at forecast lengths between 3 and 8 hours. It is believed that this cross-over point is highly dependent on season, meteorological situation and forecast method. It is apparent that a great deal of work remains to be done to improve the nowcasting of convective weather.

A variety of presentations and panel discussions during the recent WWRP Nowcasting and Very Short Period Forecasting Conference in Toulouse, the AMS 32nd Radar Meteorology Conference in Albuquerque and the Quantitative Forecasting Conference in Boulder, suggested that the best way to improve the 1-6 hour forecasting accuracy in the next 5-10 years is through the blending of extrapolation, expert, and numerical weather prediction (NWP) methods.

For the purpose of developing optimal means for blending extrapolation and NWP techniques NCAR assembled and evaluated during the summer of 2005 eight state of the art NWP, extrapolation and expert systems. This experiment called the 2005 Forecast Extravaganza evaluated real-time forecasts of convective storms over the U.S. states of Illinois, Indiana and Ohio; an area of about 350,000 km^2. The evaluation was conducted for the entire month of June 2005 for forecast periods of 1, 2, 4 and 6h. Three studies were preformed: 1) comparison of forecasts when there were existing echoes at forecast issue time, 2) evaluation of NWP initiation forecasts and 3) evaluation of NWP skill in forecasting changes in the size of the convective area (assumed to be the radar echo area > 35 dBZ). Because of the variety of forecast products it was necessary to subjectively evaluate the forecasts. A five level evaluation was used where 1 was a perfect forecast and 5 indicated no skill. (details are not described here).

Fig 2 shows the comparative results for extrapolation and NWP. The extrapolation technique was based on TITAN (Dixon and Wiener, 1993) and NWP was MM5. MM5 used

Correspondence to: Jim Wilson.

jwilson@ucar.edu

a nested grid with an inner domain of 3.3 km, a forecast cycle time of 3 hours with observational nudging and assimilation of the national WSR-88D radar reflectivity.

Similar to the recent results of Lin et al. (2005), the extrapolation method is superior to NWP for forecast periods less than 4-6 h after which time the NWP methods become somewhat better. Unfortunately the quality of the forecasts at 4-6 h is quite low.

The NWP method (MM5) was frequently able to forecast the timing of storm initiation although details of storm location were generally in error. Also MM5 was frequently useful in forecasting the trend in echo area size > 35 dBZ.

The results of the 2005 Forecast Extravaganza suggest 1) for the one hour forecast the best forecast would be with an expert system like the NCAR Auto-nowcaster (Mueller et al 2003) which has the ability forecast initiation, growth and dissipation, 2) for forecast hours beyond one hour if there are no convective echoes present at forecast issue time the best forecast would be with NWP, 3) for forecast hours 2-6 if there is convective echo present the best forecast would be to use the extrapolated echo intensity and position and modify the size of the echo based on the trend in the size of the convective echo forecast by the model.

Summer 2006 experiment

Partially based on the results from the 2005 Forecast Extravaganza a nowcasting system to blend echo extrapolation and NWP is under development and testing. This system is called NIWOT. Presently NIWOT has three modes 1) automated area blending, 2) automated trending and blending and 3) human modification of 1) and 2).

The first mode (area blending) is similar to the English system called NIMROD (Golding 1998). This was the first system to address the question of how to blend NWP and extrapolation; Figs 3a and b illustrate the blending problem for a 3 h forecast. Similar to Figs 3a and b seldom do the extrapolation and NWP forecasts overlap significantly. The NIWOT area blending mode gives full weight to extrapolation for the first hour and then continually decreased the weight for each succeeding hour while increasing the weight for NWP until it was given full weight by the sixth hour. The reflectivity values at each grid point for each forecast method is multiplied by the specified weight for the given forecast period and then the two weighed fields are summed. Examples of this technique are not discussed further in this paper.

The second mode (trending and blending) automatically blends radar echo extrapolation and NWP. If no radar echo >35 dBZ is present at forecast issue time and NWP forecasts initiation the NWP forecast is used as the forecast. If radar echo >35 dBZ is present at forecast issue time the forecast is based on the extrapolated radar echo and the area of the extrapolated echo is increased or decreased based on the forecast change in the area size of the NWP forecast area > 35 dBZ. To simplify the process for growing or decreasing the echo size the extrapolated echo is expanded or decreased a specified number of grid points depending on the model forecast change in the size of the area > 35 dBZ. Initial experiments arbitrarily increases/decrease the area 1 grid square in all directions if the model forecast area increases/decreases at least 10,000 km^2. The increase/decrease is 2 grid points when the forecast area change is at least 20,000 km^2. On average the model forecast area > 35 dBZ is roughly 3 times larger than actual. This bias is partially accounted for in this procedure. Fig 3c shows the blended/trend method has increased the area size 1 grid square in all directions (compare Figs 3a and 3c) since the model forecast the >35dBZ precipitation area to increase by 11,520 km^2.

Mode 3 provides a capability for the human forecaster to easily modify the automated trend/blend forecast products. Based on two separate experiments taking place during the summer of 2006 at NCAR there is growing evidence that in particular situations the human forecaster can significantly improve the automated forecasts in the 1-6h time period. Mode 3 of NIWOT allows the human to enter polygons on the trend/blend forecast product. Within these polygons the human can request initiation, dissipation or growth. The initiation is for 35 dBZ within the entire polygon. A specified number of grid points can be specified for growth or dissipation within a polygon. Fig 3d illustrates this process. Initiation has been specified for the more northern polygon and growth of 3 grid points for the southern polygon. The human can modify each forecast period independently. Presently a new set of forecast products are prepared each hour. The human is allowed 5 min to modify the automated forecast before it is automatically sent.

At this writing the trending experiment is underway and preliminary results will be presented at the conference. The intent will be to compare the accuracy of the extrapolation only, NWP only, automated NIWOT blended forecasts and the human assisted NIWOT forecasts.

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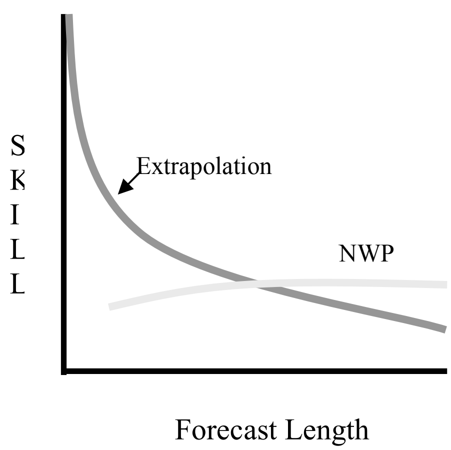

Fig 1. Conceptual comparison of forecast skill as a function of forecast length for extrapolation and numerical weather prediction

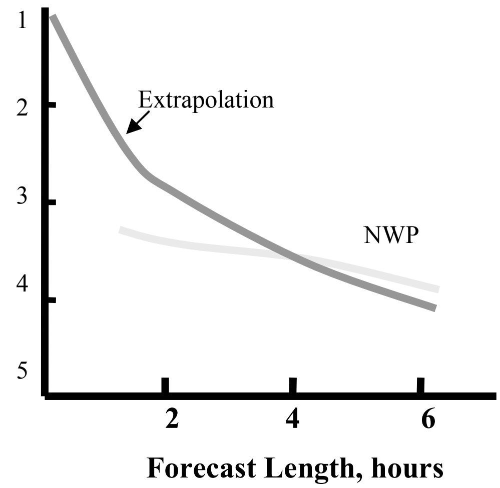

Fig 2. Comparison of extrapolation and NWP forecast skill as a function of forecast length for the 2005 Forecast Extravaganza. The ordinate is forecast skill based on a subjective evaluation scheme where 1 is perfect skill and 5 is no skill

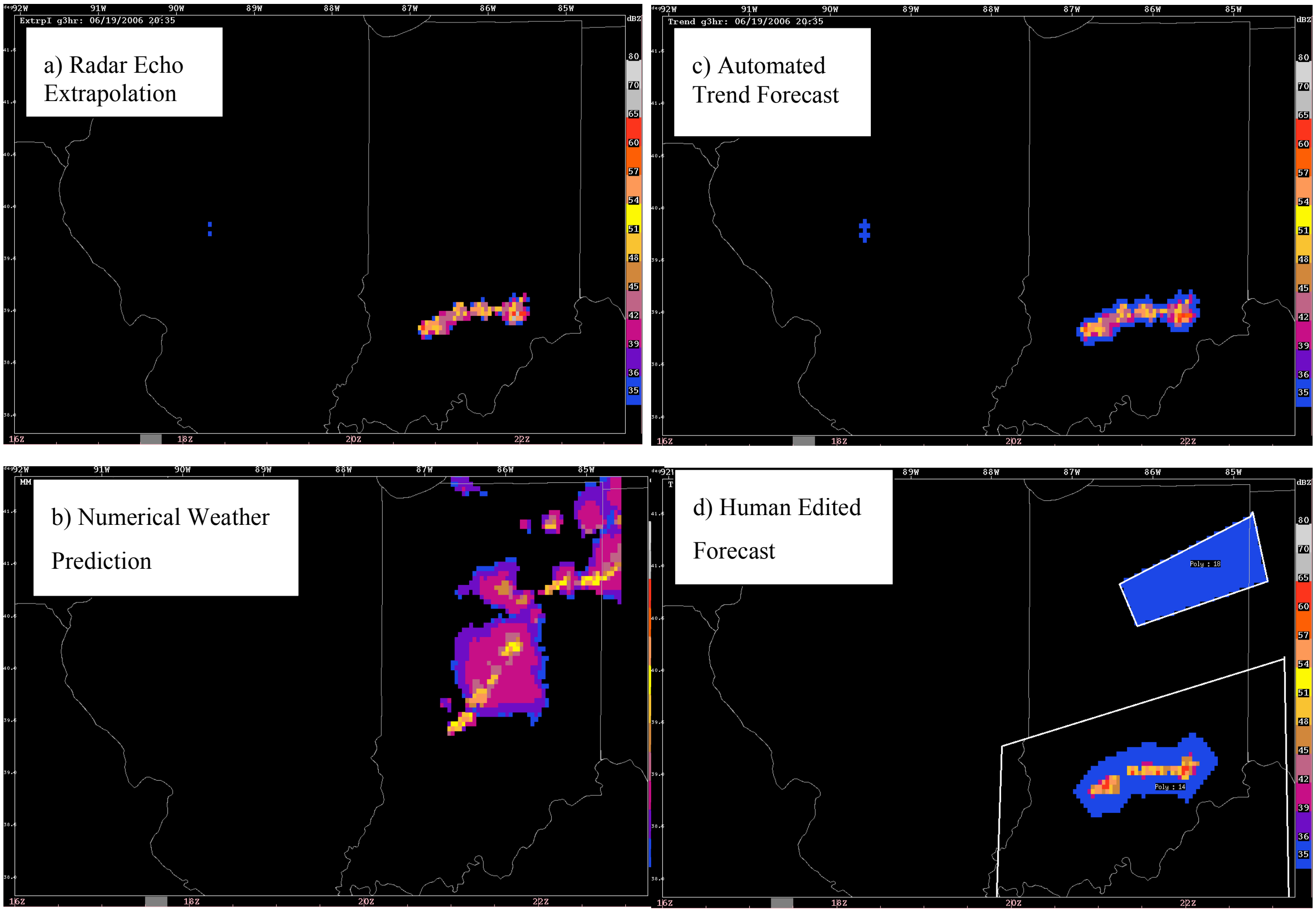

Fig 3 Example of 3 hour NIWOT forecast. a) radar echo extrapolation forecast, b) NWP forecast, c) trend/blend forecast and d) human edited forecast. extrapolation. The forecasts are for equivalent precipitation intensities >35 dBZ. The intensity scale is given on the right side of each image. The first gray shade is 35 dBZ.