VERY SHORT PERIOD (0-6) FORECASTS OF THUNDERSTORMS

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1. Introduction

This paper briefly describes some of the motivation and history for the development of nowcasting systems. It then briefly describes nowcasting systems that have been developed and are under development at the National Center for Atmospheric Research (NCAR).

Improvements in short term (0-6h) forecasts of high impact weather should have significant societal and economic benefits. The 0-6h forecast period is typically refereed to as the nowcast period. The societal and economic benefits include: (1) reduced fatalities and injuries due to weather hazards, (2) reduced private, public, and industrial, property damage, and (3) improved efficiency and savings for industry, transportation, and agriculture. Although few quantitative studies exist on the incremental benefits of *improved* short term weather forecasts in the U.S. the number of injuries from tornadoes, thunderstorms, and lightning exceed 2000, while the damage caused by these events is of the order of 10 billion[1]. Estimates of the sensitivity of the US economy to weather reach upwards of a trillion dollars, Dutton (2002). The unanswered question, is how much of these impacts can be mitigated by improved short-term weather forecasts.

Extrapolating precipitation radar echoes has been the mainstay of very short period forecasting of precipitation ever since it was first advanced by Ligda (1953). During the 1980s the Met Office in the UK introduced the FRONTIERS (Browning and Collier 1989), and then the Nimrod operational nowcasting systems (Golding 1998). The major innovation of the latter of these systems was the combination of radar extrapolation techniques with NWP model precipitation products to produce an extended short-period forecast that was consistent with larger scale and longer period forecasts (Golding 2000). At about the same time satellite cloud imagery and radar clear air observations of the boundary layer showed

[1] Statistics derived from a number of studies including, Pielke et al., 1999 and Ashley and Mote, 2004.

that thunderstorm initiation and evolution was often controlled by boundary layer convergence lines. This lead to the development of heuristic thunderstorm nowcasting methods based on the monitoring convergence lines and their characteristics.

A major stimulus for future development of very short-period forecast techniques was the WMO indorsed Sydney 2000 FDP (Keenan et al. 2003). This demonstration brought together 'nowcast' systems from a number of countries, designed for both severe weather and precipitation forecasts. The timing of this project was ideal as it exploited the most recent advances in radar technology, as well as computing power and programming techniques. The interaction of the developers of the various systems and their interactions with operational forecasters and users coupled with extensive dissemination of the results of the project (see special issue of Weather and Forecasting Feb. 2004), has led to a rejuvenation of activity in the very short-period forecasting of high impact weather.

2. NCAR Auto-Nowcaster

The NCAR Auto-Nowcaster (Mueller et. al 2003) is an expert system, sometimes referred to as a heuristic system or an observation based nowcast system. It automatically provides time and place specific 30 and 60 min forecasts of thunderstorms. It ingests and integrates data from Doppler radar, satellite, surface stations, upper-air soundings, lightning sensors and numerical models.

Thunderstorm initiation, growth and dissipation are forecast by considering stability, storm motion relative to convergence lines, low-level shear relative to convergence lines, storm characteristics, and the presence of cumulus clouds in the vicinity of convergence lines. The above data are converted into fields of forecast parameters which are then operated on through a combination of conceptual model forecast rules and fuzzy logic techniques.

Central to the forecast logic is the presence of boundary layer convergence lines. For storm initiation they are a requirement. Convergent lines are identified in three ways; 1) automated algorithms identifying radar reflectivity and Doppler velocity signatures known to be associated with convergence lines, 2) human identification utilizing all types of data sets (such as radar, satellite, surface stations) and 3) automated analysis of numerical model analyses of temperature, pressure and vorticity gradients.

Figure 1 is an example of a 60 min nowcast that includes storm initiation. In this case storm initiation was successfully forecast to occur along boundary layer convergence lines.

60 min forecast **Verification of 60 min**

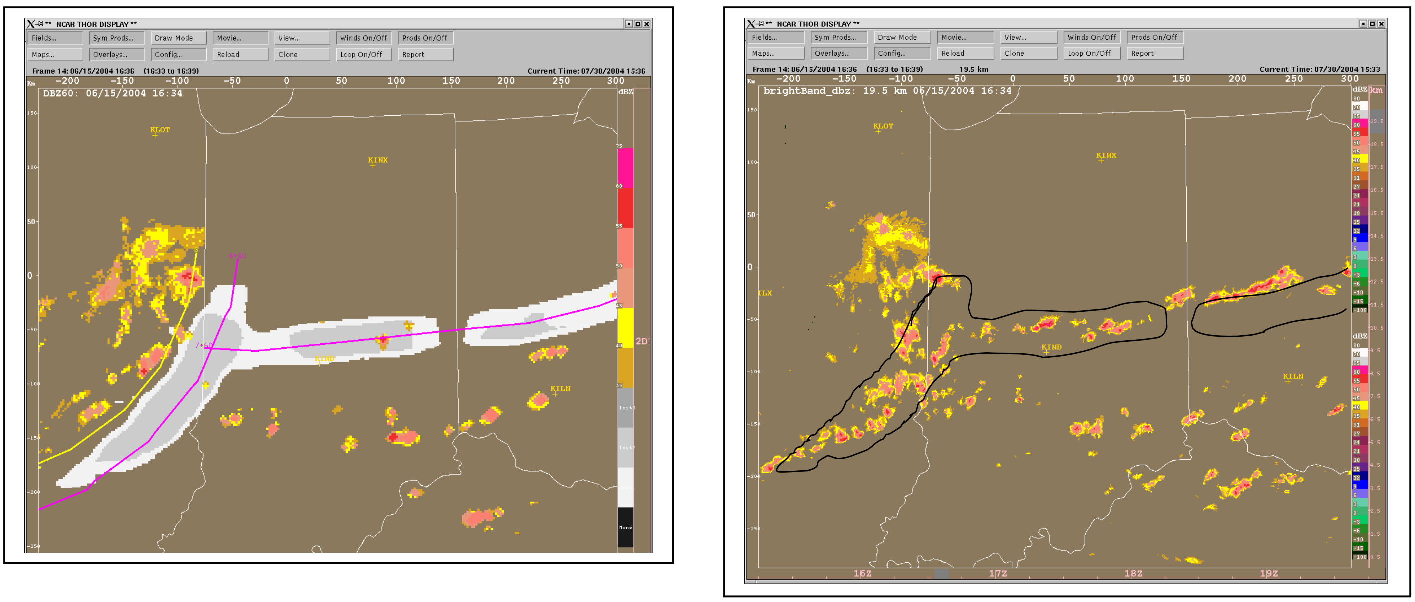

Fig. 1 Example of a 60 min forecast and verification produced by the NCAR Auto-Nowcaster. The gray areas on the left image are areas where initiation is forecast. The brown, yellow and reds are extrapolation forecasts of radar reflectivity. The right image shows the actual radar reflectivity at verification time. The black outline reproduces where initiation was forecast in the left image. The purple lines in the left image are the 60 min forecast location of boundary layer convergence lines. It can be seen that there was considerable amount of initiation within and very near the forecast

3. National Convective Weather Forecast (NCWF)

NCWF is a 0-2 hour nowcasting system which is being operationally demonstrated for the aviation community. It provides a nowcast which is updated every 15 min for the entire USA. It is primarily based on the extrapolation of a national mosaic of radar echo, and lightning cloud-ground frequency data. The analysis fields associated with the operational Rapid Update Cycle (RUC) numerical forecast is used to define frontal regions, Cape and CIN fields. Its unique feature is to identify frontal regions and then grow the size of convective cells that satellite or radar detect.

4. Niwot

Niwot is a nowcasting system to blend echo extrapolation and NWP which is under development and testing at NCAR. 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). NIMROD was the first system to address the question of how to blend NWP and extrapolation. Seldom do the extrapolation and NWP forecasts overlap significantly thus the nature of the problem. The Niwot area blending mode gives full weight to extrapolation for the first hour and then decreasing weight for each succeeding hour while increasing the weight for NWP until it is given full weight by the sixth hour. The reflectivity values at each grid point for each forecast method are 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.

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 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 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.

5. Conclusions

The 0-6 hour forecast period warrants particular scientific focus since it is the primary forecast period where there is the potential to produce forecasts that are sufficiently accurate to warrant users of the forecasts to take cost effective actions to improve safety and mitigate property loss.

For the foreseeable future it is felt that forecast techniques that blend NWP, observational based techniques and forecaster input have the most promise. While promising, NWP techniques for this very short period are not expected to improve over extrapolation in the first 3 hours for many years. These techniques require the assimilation of high resolution observation on a dense grid with a rapid update cycle as well as new and improved science to properly produce boundary layer convergence lines and initiate second generation convection.

There is good evidence that the forecaster can play a significant role in improving the nowcast through his use of conceptual models, identification of bad data and identifying boundary layer convergence lines.

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