# 3.2 EVALUATING THE PERFORMANCE OF DIFFERENT SYNOPTIC REGIME SETTINGS ON THE NCAR AUTO-NOWCASTER

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## 1. Introduction

The NCAR Auto-Nowcaster is a fuzzy logic based automated thunderstorm prediction system that produces routine (6 min) short-term (0-1 hour) nowcasts of thunderstorm initiation, growth and decay (Mueller et al. 2003.) The Auto-Nowcaster is currently running as part of the Forecaster Over The Loop (FOTL) demonstration (Roberts et al. 2005) at the National Weather Service (NWS) Weather Forecast Office (WFO) in Ft. Worth, Texas. The goal of the FOTL demonstration is to show the benefit in performance of an automated nowcast system that incorporates input from human forecasters. As currently designed, the Auto-Nowcaster has three methods in which the human may contribute to the forecast process. First, a user can enter significant convergence features, such as fronts, outflow boundaries and sea breezes. These boundaries are ingested, analyzed and used to create predictor fields which are fed into the fuzzy logic forecast engine to create nowcasts. Nowcasts consist of an initiation likelihood field and a storm growth and decay prediction as shown in Figure 1. Second, forecasters may choose to directly edit the initiation likelihood field using a tool to nudge the entire field toward higher or lower interest, or they can outline a smaller area within the domain and assign an additive value to be applied to that area of the initiation likelihood field. Third, the Auto-Nowcaster has seven unique sets of synoptic regime tailored fuzzy logic rules available for the forecaster on duty to choose from. During FOTL demonstration, the forecaster working the aviation desk would select an appropriate regime based on existing conditions, based on conditions expected to occur while on shift, or in response to atmospheric evolution during the shift.

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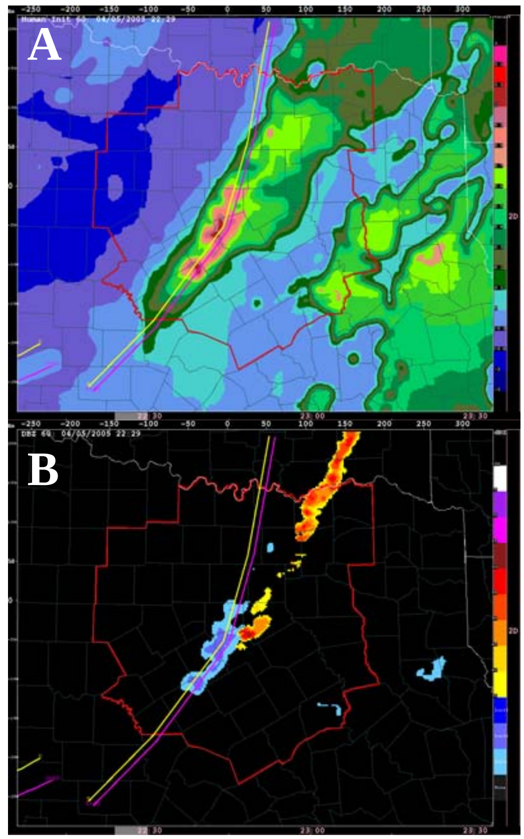


**Figure 1. Auto-Nowcaster Output. a.) shows the initiation likelihood field. Shades of pink and red indicate areas where convection initiation is expected at 60 minutes, with greens and blues indicate lesser likelihoods of initiation. b.) shows the growth and decay nowcasts in the yellows and reds with shades of blue indicating areas of expected initiation.**

In this paper, the new synoptic regime tailored fuzzy logic rule-sets are introduced and the impact of the rule-sets on the end forecasts are examined using cases from the 2007 convective weather season. The FOTL demonstration is the first time user selectable synoptic regime based fuzzy logic rule-sets have been used within the NCAR Auto-Nowcaster.

## 2. Fuzzy Logic Rule-sets

The Auto-Nowcaster ingests a wide range of data. Radar data, surface observations, radiosonde observations, model output, and other meteorological data are analyzed to produce predictor fields. The fuzzy logic system then applies membership functions to the data to produce interest fields consisting of values of -1 to 1. The interest fields are then weighted and summed to produce the final initiation likelihood nowcast and storm growth and decay nowcast.

### 2.1 Previous Auto-Nowcaster Demonstrations.

Prior to the 2006 FOTL demonstration, the Auto-Nowcaster system had only included at most two sets of forecast logic for the fuzzy engine, though typical installations included only one set of logic. During the 2004 convective season, the Auto-Nowcaster was demonstrated over the Illinois-Indiana region for the FAA's Aviation Weather Research Program (AWRP) using two sets of forecast logic, based on the amount of useful satellite information. One set of forecast logic was configured so that satellite predictor fields used within the Auto-Nowcaster were given less weight when a significant amount of the operational domain was obscured by high-level clouds (Saxen et al. 2004). A simple automated switching system was in place to choose the correct set of fuzzy logic weights based on the areal coverage of clouds in the forecast domain. The forecasters were not given the opportunity to switch the regime themselves.

### 2.2 Fuzzy Logic for the FOTL Demonstration.

For the 2005 convective weather season in Texas, the Auto-Nowcaster was installed using only one set of fuzzy logic rules. After discussions with the forecasters at the Ft. Worth WFO, the Auto-Nowcaster was modified to allow the forecaster on duty to select one of multiple fuzzy logic rule-sets that would be tailored to different synoptic regimes typically experienced in Texas. During late 2005 and early 2006, WFO forecasters and NCAR scientists collaborated on the development of six new fuzzy logic rule-sets. WFO personnel provided NCAR scientists with a list of convective events from 2005 that were then used to develop and test each of the new synoptic regime based fuzzy logic rule-sets. The Auto-Nowcaster user interface (Figure 2) was modified to allow the forecaster on duty to change the active regime rule-set at anytime during a shift. During the 2006 convective season, the regime based rule-sets continued to receive minor adjustments based on qualitative feedback from the WFO forecasters. No changes to the regime based rule-sets have been made since late 2006 in order to provide forecast consistency to the users and to facilitate evaluation of the forecasts produced with the new rule-sets.

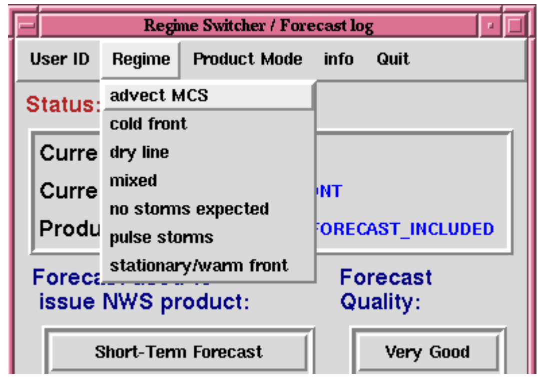


**Figure 2. The user interface used by forecasters at the WFO to change the active set of fuzzy logic rules. Rule-sets are listed in a drop-down regime menu.**

### 2.3 The "Regimes"

Developing the new regime specific rule-sets for the Auto-Nowcaster was a collaborative effort between the WFO Ft. Worth forecasters and NCAR scientists. The NWS forecasters prepared a comprehensive list of regimes that affect Texas during the course of a normal convective season. Working with NCAR scientists, the list was refined down to six new regimes for which there was ample case data already archived with which to develop the new logic. A seventh "Mixed" regime was adapted from the existing default fuzzy logic rules. Test cases were chosen to develop the new regimes and a separate set of test cases were used to qualitatively validate the new regimes. The initial development of the regime rule-sets was focused specifically on improving the storm initiation component of the nowcasts.

***MIXED (MX), the default regime.*** The first regime in the Auto-Nowcaster is referred to as the MIXED regime. This regime is the same default regime that had been deployed with the Auto-Nowcaster in previous demonstrations, except for the addition of model based CIN and vertical velocity predictor fields. This field is intended to be used for events where synoptic evolution is unclear or a variety of convection initiation triggering mechanisms are expected within the operational domain. Predictor fields associated with human entered boundaries are strongly weighted in this regime.

***COLD FRONT (CF) regime***. The COLD FRONT regime, as the name suggests, is intended for use when the primary focus for convection initiation within the domain is expected to be a cold front. The MX regime served as the basis for the development of the CF regime. The CF regime includes an accumulated precipitation field used to suppress initiation forecasts in areas that have received radar observed precipitation in the past three hours. This helps balance model based environmental stability predictors that may not immediately resolve rapidly developing cold pools and resultant increases in surface based stability. Minor changes were made to some of the predictor field membership functions and most of the predictor field weights. Predictor fields associated with forecaster entered boundaries are strongly weighted.

***DRYLINE (DL) regime.*** The DL regime is expected to be used when the primary focus for convection initiation is along a dryline. Minor changes to predictor field membership functions and weights from the MX regime were implemented. The three hour accumulated precipitation predictor field that is used in the CF regime is used here, in addition to a model derived theta-e gradient predictor field which is used to boost interest along the dryline. This regime relies heavily on the forecaster entered boundaries.

***STATIONARY/WARM FRONT (WF) regime.*** This regime is loosely based on the MX regime. The WF regime is intended to be used when a synoptic stationary or warm front is located in the domain. Tuning of the WF regime was done with the understanding that both surfaced based and elevated convection may occur. As a result, layered environmental stability predictors are given additional weight in this regime and the precipitation accumulation predictor field is not used. Slightly less weight is given to predictor fields associated with forecaster entered boundaries under this regime since convection is often times is not anchored closely to the surface warm front or stationary front position.

***PULSE STORMS (PS) regime.*** The PS regime is designed for days with low vertical shear and sufficient instability present for the threat of convection. This regime uses the fewest number of predictor fields and heavily weights satellite based predictor fields and the objectively analyzed convergence predictor field. Predictor fields associated with forecaster entered boundaries are lightly weighted since it is anticipated that gust front and outflow boundaries are generally small-scale, numerous, fast-moving, but short-lived. This regime should not be used when the areas of interest for convection initiation are obscured by high clouds.

***NO STORMS (NS) regime.*** The NS regime is intended to be used on days when convection initiation is not anticipated. Instability predictors are weighted lighter than regimes associated with synoptic fronts. However, the regime was carefully constructed to allow initiation forecasts to be produced in the absence of forecaster entered boundary predictors and a combination of remaining predictors containing very high interest values.

***ADVECTING MCS (MCS) regime.*** The regime is intended for use while mature mesoscale convective systems are moving or propagating through the domain. This regime was tuned to limit initiation forecasts to forecaster entered gust fronts or smaller areas of extremely favorable likelihood for new non-extrapolated storms.

## 3. Convective Event Reanalysis

The NCAR Auto-Nowcaster was run in post-analysis mode for several cases to facilitate comparison of nowcast performance of each of the regimes, since only one regime is active at any given time in the real-time system. Post analysis mode does not exactly replicate the actual data latencies observed in real-time, rather, latencies are introduced to mimic what was observed, on average, in the real-time system. The results shown are only of reprocessed cases.

### 3.1 Advecting MCS event.

On May 2, 2007, a weak east-west oriented warm front was approaching the Dallas / Ft. Worth metropolitan areas from the south at 1200UTC. At the same time, a cold front was moving Southeast across southern Oklahoma and Northwest Texas. Late in the morning, convection initiated in far West Texas outside of the demonstration domain. This convection organized into an eastward moving MCS. The MCS began to enter the demonstration domain at approximately 1800UTC and continued to move east, affecting the domain through the evening. For this case, the CF, MX, WF, and MCS regimes were used to generate nowcasts between 1200UTC May 2 and 0200UTC May 3. Figure 3 shows results from the reruns. Probability of detection scores (not shown) show very little variance between the different regimes but an improvement over extrapolation. Fig. 3A highlights a significant improvement in false alarm ratio for nowcasts being generated using the MCS regime vs. those generated using other regimes. Similarly, CSI scores for the MCS regime are generally equal or superior to that of the other regimes, and an improvement over extrapolation for all but the first couple of nowcasts when the MCS is entering the domain.

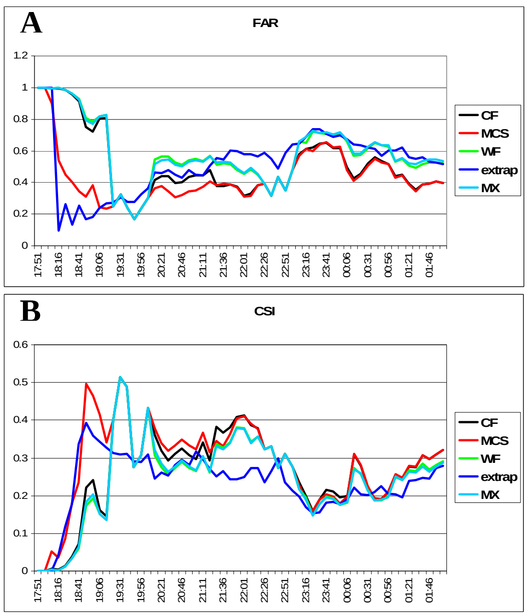


**Figure 3. Plots of False Alarm Rate (FAR) and Critical Success Index (CSI) for the afternoon and evening of 2 May 2007. a.) Shows the FAR for the Cold Front (black), MCS (red), Warm Front (green), Mixed (cyan) regimes and extrapolation (blue). b.) shows the CSI scores for four regimes and extrapolation.**

### 3.2 Pulse storms event.

On May 12 2007, the FOTL domain was just down stream of an upper-level ridge axis that stretched from New Mexico to eastern Montana. Morning and evening soundings from Ft. Worth observed weak winds through the depth of the troposphere. At the surface, high pressure was in control, with dew points in the low to mid-60's across the FOTL domain. Surface winds were weak out of the north, and no significant frontal features were analyzed in the domain. From late morning through the afternoon, scattered, disorganized convection initiated over a majority of the domain. The PS, NS, and MX regimes were rerun for the period between 1200UTC and 0100UTC on May 13th.

In Figure 4, the storm initiation likelihood field from both the MX and PS regime for 2138UTC is shown. The initiation likelihood field produced by the MX regime has a single elongated initiation zone. This is a result of a gust front that was entered into the system by the forecaster on duty. The initiation likelihood field produced by the PS regime exhibits a completely different character and distribution of initiation zones. The PS regime produces initiation zones that are smaller, more numerous and have considerable spatial separation.

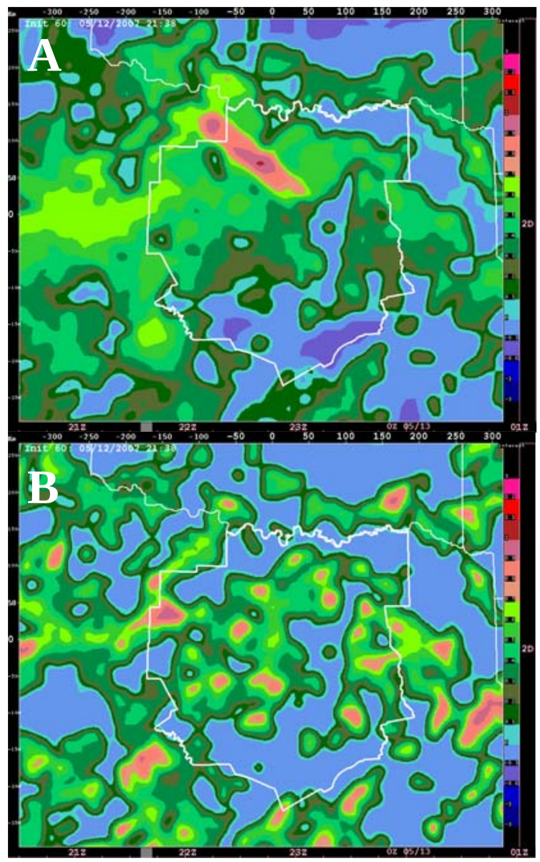


**Figure 4 Initiation likelihood nowcasts. a.) is the output from the Mixed regime, while b.) is output from the Pulse Storms regime. In both "a" and "b", pink and red shades represent areas of expected convection initiation at 60 minutes, while green and blues shade areas not expected to initiate convection. The white polyline outlines the extent of the NWS Ft. Worth county warning area (CWA).**

The PS regime relies heavily on the satellite predictor fields, particularly the IR rate-of-change field and the cumulus and cumulus congestus cloud type predictor fields. The pattern from the PS regime initiation likelihood field resembles what would be expected for capturing small, spatially isolated cells in the absence of a larger synoptic convergence feature to serve as a focus for convection initiation.

In Figure 5, plots of POD and CSI show the advantage of using the PS regime over either the MX or the NS regime. The PS regime shows improvement in POD over the other regimes most of the afternoon and improvement over extrapolation most of the afternoon as well. Similar to the POD graph, the PS regime shows improvement over the other regimes most of the afternoon, but still has stretches of time that do not show any improvement over extrapolation.

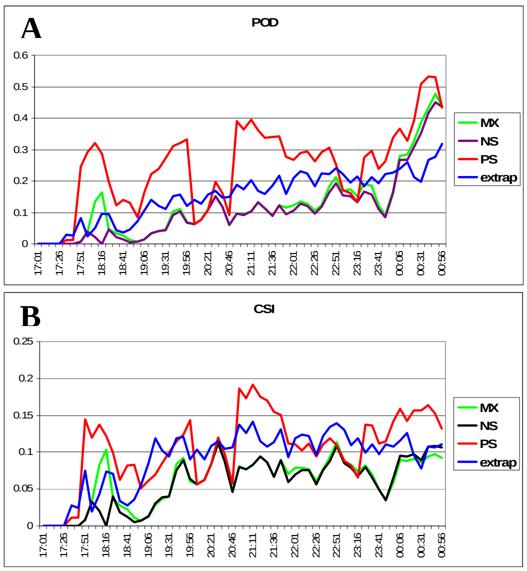


**Figure 5. Plots of Probability of Detection (POD) and Critical Success Index (CSI) for the time period of 1700UTC to 0100UTC on May 13. a.) plots the POD for the Pulse Storms (red), No Storms (black), Mixed (green) regimes and extrapolation (blue). b.) is the CSI for each of the regimes in a.)**

## 4. Summary and Future Direction

The cases shown in this paper highlight the benefits of having multiple user-selectable regime-based, fuzzy logic rule-sets. Not every predictor field is useful in all environments, so the regimes have been tuned in a way that attempts to optimize the use of predictor fields that play especially important roles for some situations but not others. For example, the theta-e gradient predictor is used only in the dryline regime, and predictor fields derived from human entered boundaries are given less weight in favor of satellite predictors in the Pulse Storms regime. The cases above highlight that the choice of regime can have an impact on the performance of the Auto-Nowcaster. At times, the improvement over the default set of rules can be significant, and improvement over extrapolation can be demonstrated.

The current configuration of the Auto-Nowcaster is enables the of running of only one regime. Since regimes can significantly impact the nowcasts, forecasters at the WFO have suggested modifying the Auto-Nowcaster to produce and display likelihood fields from all the available regimes. This would allow the forecaster to see all of the possible nowcast solutions, and allow the forecaster to select the most appropriate regime based on their subjective assessment of recent performance. NCAR scientist and engineers will explore the feasibility of modifying the system to produce output from all the regimes simultaneously.

The regimes described in this paper were all developed and tested to improve the initiation component of the Auto-Nowcaster, while the growth and decay components remained essentially unchanged in all of the regimes. A next step in advancing the regimes would be to use an objective statistical analysis technique to examine the importance of individual predictor fields to the overall nowcast. An effort ongoing for the FAA AWRP program is using the random forests statistical technique to examine predictor field importance for the CoSPA development effort (Williams et al. 2008). This technique shows promise in identifying ways to improve the regimes and possibly the manner in which regimes are used within the system. During 2008, we will begin using the random forests analysis method on FOTL demonstration data as well.

The NWS Meteorological Development Laboratory (MDL) is working with NCAR to integrate the Auto-Nowcaster user interface functions into the Advanced Weather Interactive Processing System (AWIPS) used in all of the NWS WFO's (Ba et al. 2008). This transition will allow forecasters to interact with the Auto-Nowcaster on the same workstation routine duties are performed rather than a separate workstation located in the operations area. The new AWIPS functionality will include the ability to select and change the current Auto-Nowcaster regime as necessary.

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