12A.1 PREDICTABILITY OF CONVECTIVE STORM INITIATION

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1. Introduction

Data from the International H_2O Project (IHOP) is used to study the predictability of convective storm initiation and evolution. The approach is to use observations from IHOP to identify times and locations of storm initiation and then to try and determine the thermodynamic and kinematic mechanisms that led to the initiation and influenced evolution. The predictability of storm initiation by numerical models and/or heuristic[1] techniques will depend on their ability to predict the initiation mechanisms. For example if storms initiated in a conditionally unstable atmosphere from an updraft forced by the collision of two boundary layer convergence lines the predictability will be dependent on the ability to anticipate these events.

The predictability of storm initiation will also be dependent on the meteorological situation. For example the initiation of storms along a synoptic scale cold front in response to solar heating gradually reducing convective inhibition is predictable further in advance than the initiation of storms along a small gust front produced by scattered showers in a non-synoptic forced environment.

This present study will examine the ability of the RUC10[2] to forecast 3 and 6h storm initiation and evolution for two IHOP time periods (12-13 June and 15-16 June). Mesoscale Convective Systems (MCS) developed on both of these days. The model forecasts are evaluated based on knowledge of where and when the storms initiated and how they evolved with respect to triggering mechanisms and high resolution stability and shear parameters. Future studies will be expanded to examine all days of IHOP and to include at least the LAPS/MM5 numerical model.

[1] Heuristic is defined here as forecast rules based on experiment, numerical simulations, theory and forecaster rules of thumb.
[2] RUC10 – numerical forecast model called the Rapid Update Cycle on a 10 km grid; for description see http://ruc.fsl.noaa.gov.

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2. Data

The location and time of storm initiation is based on radar data from 10 WSR-88D's and the NCAR S-pol (Keeler et al. 2000). A mosaic of these radars is available at 10 min intervals for the purpose of identifying storm initiation locations and boundary layer convergence lines (boundaries). About 210 surface stations and GOES 8 and 11 visual cloud observations are used along with the radar data to identify and characterize boundaries.

Characteristics of boundaries and initiated storms are recorded. For storms this includes maximum reflectivity, storm organization, spacing, orientation, and lifetime. Boundary characteristics include wind change across the boundary, thermodynamic contrast, orientation, low-level shear normal to the boundary, boundary relative storm motion, CAPE, and CIN.

The RUC10 ingests a number of special data sets including mesonets (like OK mesonet), profilers (including RASS), integrated precipitable water from GPS sites, satellite cloud drift winds, VAD winds from Doppler radar and winds and temperatures from commercial aircraft. In addition empirical methods are used to adjust relative humidity at model grid points based on the presence or not of satellite observed clouds and radar observed precipitation (Benjamin et al. 2003). Model analysis and forecasts examined are rainfall location, horizontal and vertical winds, CAPE and CIN.

3. Analysis

3.1 June 15-16 case

A MCS about 600 km long develops in the late afternoon in southern KS and northern OK (see Fig. 1). It develops from the merger of three smaller systems. Fig. 2 shows these three smaller systems (numbered 1-3) 4.5 h prior to Fig 1. Satellite shows the first convective storms with system #1 initiated along the Colorado Front range near the center of a weak surface low that moved east to the position shown in Fig 2. This area of weak convection rapidly intensifies just prior to 2100 and produces a strong gust front and moves SSE. This gust front becomes the dominating triggering mechanism for additional storms and growth. Storm system #2 develops in north central KS as part of a larger area of storms that extended NW into western NB. These storms likely started as elevated convection, i.e. there appeared to be no associated surface convergence. System #3 develops along the Front Range of the Rocky Mountains near the NM/CO border and moved east to the study area by the

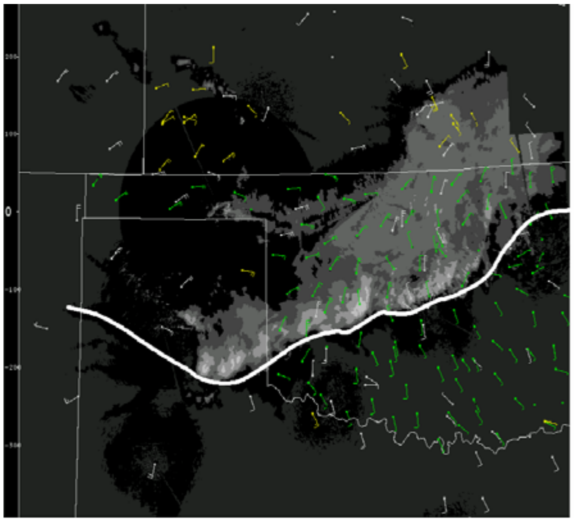

Fig. 1 Mature MCS at 0130 UTC 16 June 2002. White lines are convergence lines.

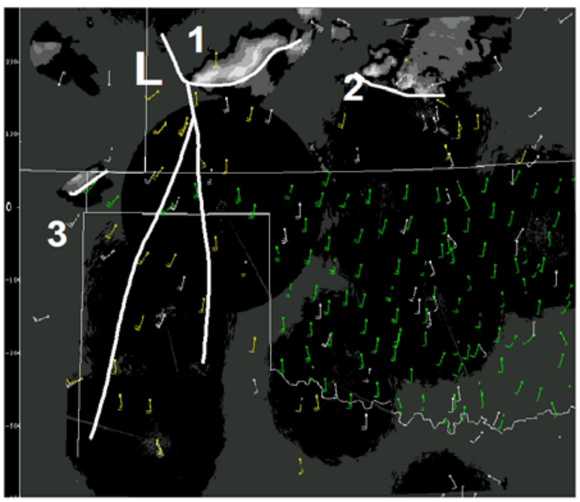

Fig. 2 Three small systems at 2100 UTC that merge and form MCS in Fig. 1.

time of Fig 2. A gust front became apparent with this storm at the time of Fig 2.

Figure 3 shows initiation locations of storms and the hourly positions of the boundaries. Animation of this data shows the large majority of storms are initiating close to the boundaries as they move south and southeast. The mature MCS in Fig. 1 is the result of the merging of these storms and boundaries.

At 2100 (Fig. 2), as indicated by RUC analysis, system #1 was moving into a region of high CAPE and relatively high CIN, #2 was moving into an area of low CAPE and low CIN, and #3 was moving into an area of high CAPE and low CIN. This mixed combination of stability parameters did not seem central to the evolution of convection.

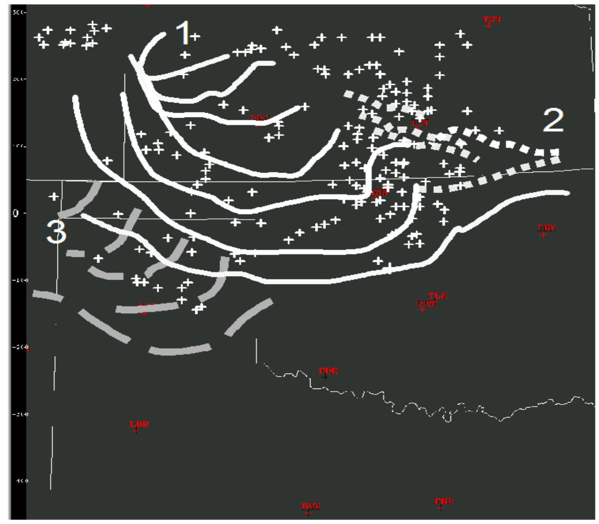

Fig. 3 Initiation locations of storms (+) and hourly positions of boundaries (lines) for the period from 1830 June 15 to 0000 June 16.

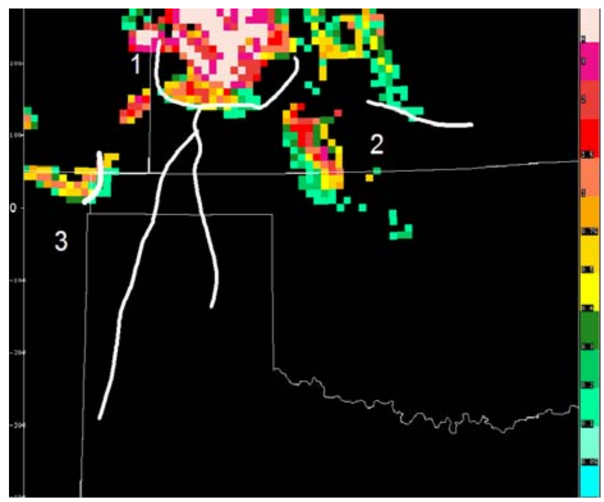

Fig. 4 RUC10 3h forecasts valid at 2100 UTC (same time and boundaries as Fig. 2)

Surface station reports indicate there was strong low-level convergence with each gust front. There was a differential wind velocity across and normal to gust front #1 of 15-25 ms^{-1}. Corresponding values for gust fronts #2 and #3 were roughly 15 ms^{-1} each. Cell motions were from 300 deg thus long lived storms would be favored for boundaries moving towards the south and east. (Wilson and Megenhardt 1997). As would be expected for this cell motion, storm growth and merger was most likely along the portion of the gust fronts with a NE-SW orientation that were moving toward the south and east.

Figure 4 shows the 3h RUC10 forecast verifying at 2100, the same time as Fig. 2. Since there was essentially no storms at the initialization time (1800) this is primarily an initiation forecast. This is a remarkably good forecast apparently capturing the initiation of all three smaller systems. However, the timing was in error since precipitation was forecast for three hours earlier i.e the 3h forecast made at 1500 forecast storms to occur at 1800. This earlier erroneous forecast had a large area of precipitation extending from northern KS far south into TX. The three hour forecasts for 0000 and 0300 decrease progressively in accuracy. The RUC forecasts were not moving the gust front and precipitation fast enough to the south and the 3h forecast for 0300 almost completely dissipated the precipitation. The RUC did not produce sufficiently vigorous gust fronts to propagate the storms far enough south and the tendency was to dissipate the storms too early.

3.2 June 12-13 case

The MCS on this day again develops near the KS/OK border in the late afternoon. Fig. 5 shows the mature MCS at 0300 June 13. This MCS evolved from the storms that initiated about 5h earlier along on outflow boundary left from an earlier MCS. Fig 6 shows the location of this boundary at 2200, as well as, a cold front that was associated with a low centered in the OK panhandle. The storm initiation locations between 2100 and 2300 are also shown. Fig 6 shows the first storms developed along the cold front and outflow boundary. It was only the storms that initiated along the outflow boundary within the dotted oval in Fig 6 that are eventually responsible for forming the MCS. The reason for this becomes apparent when subsequent storm initiation is examined.

Both the cold front and outflow boundary were located in regions observed to have high CAPE, low CIN and relatively large surface to 6 km shear values. The RUC10 tended to indicate considerably higher CAPE and lower CIN values than observed by the special IHOP soundings. Nonetheless, both data sources indicated large instabilities and potential for strong storms.

In Fig 7 four gust fronts are labeled (1-4). These were produced by the storms along the cold front and outflow boundary. Gust fronts 3 and 4 where produced by the storms within the oval in Fig 6. These gust fronts initiate many more storms than #1 or #2. The primary reason is believed to be the magnitude of the associated convergence. The differential wind velocity across and normal to gust fronts #3 and #4 is roughly 20-25 ms^{-1}, the larger values with #3. Corresponding values for boundaries 1 and 2 are 10-20 ms^{-1} and 5-10 ms^{-1} respectively. The convergence with gust front #1 is greater than #2 and it does initiate more storms. Other boundary relative characteristics which influence storm longevity (surface to 2.5 km shear and boundary relative cell speed) are only borderline favorable for long lived storms; being most favorable for gust front #1.

Fig 8 shows the 6h RUC forecast for 0000 this can be compared with the reflectivity for 0000 in Fig 7. This again is an excellent initiation forecast and clearly the best RUC forecast for the period. However as with the 15-16 June case the timing is in error. Extensive precipitation was forecast in the area 3h too soon and to a lesser extent 6h too soon. The 3h and 6h RUC forecasts for 0300 at the time of the mature MCS were not far enough south and significant dissipation was already being forecast. Examination of the RUC boundary layer wind fields indicate the RUC did have the location of the cold front approximately correct but did not anticipate the outflow boundary. The reason for the correct forecast of precipitation along the KS/OK border appeared to be convergence associated with the low. The good location forecast for precipitation was apparently correct for the wrong reason.

SUMMARY

This paper represents only 2 days of a much larger study in progress of convection initiation on all IHOP days. These two days are notable in that MCS's formed on each day. Although a surface low and synoptic fronts were present on both days details of storm initiation, growth and merger into the MCS stage were triggered by individual gust fronts. The primary function of the surface low seemed to be providing a strong southerly flow of warm moist unstable air.

Although the gust fronts were not predicted by RUC impressive forecasts of the location of storm initiation resulted although the timing and evolution of the convection was in error. These forecasts of storm initiation appeared to be the result of triggering by model predicted synoptic scale features. That is storms were triggered along cold fronts, warm fronts and near low centers. A forecaster observing the model forecasts in real-time would have difficulty in anticipating which would verify correctly.

It is speculated that more accurate predictions of storm initiation would best be accomplished by blending numerical weather prediction, statistical and heuristic methods into one system. Predicting the evolution of convection even after the initial storms have formed will be very dependent on predicting the development, motion and characteristics of the gust fronts and other boundaries. Until methods exist to accurately predict these mesoscale features accurate forecasts of storm evolution will not likely be possible prior to directly observing these features in the surface, radar or satellite data.

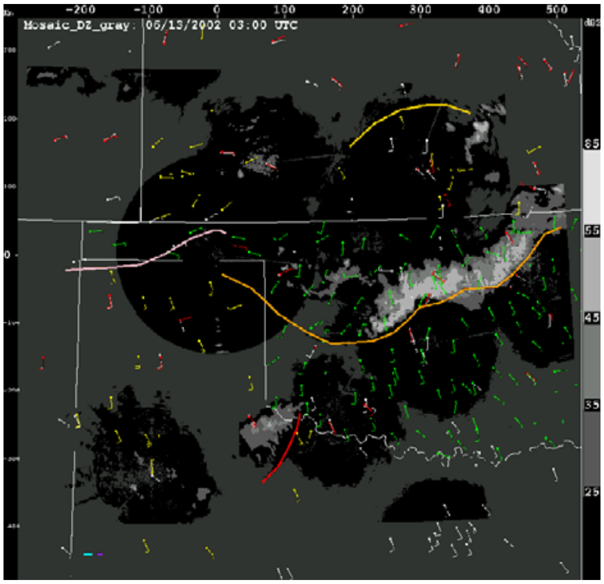

Fig. 5 Mature MCS at 0300 June 13.

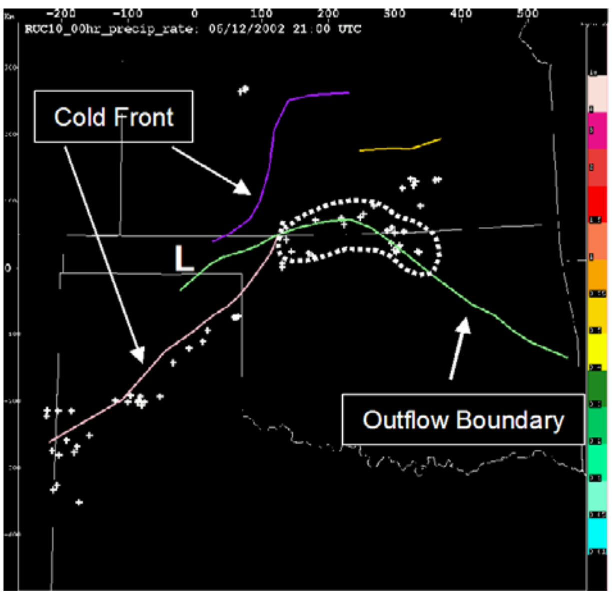

Fig. 6 Storm initiation locations (+) between 2100 and 2300 overlaid on boundary locations at 2200. Storms initiating in the dotted region formed the MCS.

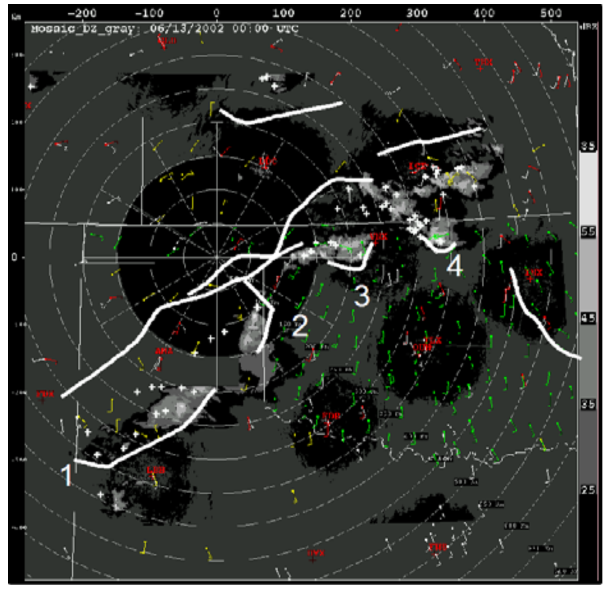

Fig. 7 Boundaries and storms at 0000 June 13.

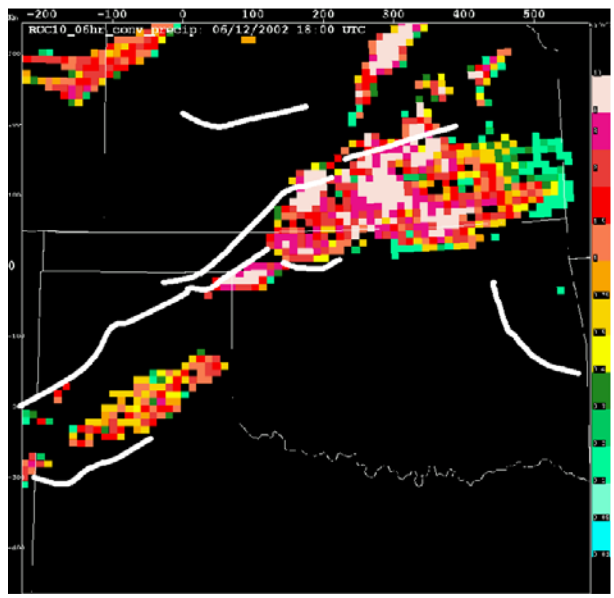

Fig. 8 Six hour RUC10 forecast valid at 0000 June 13 with actual 0000 boundaries (white lines).

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