Environmental Analysis and Evaluation of GOES-R Proving Ground Convective Initiation Products in the Plains

Jason Apke[1], Daniel Nietfeld[2], Mark R. Anderson[1], Casey Griffin[1], and Adam Taylor[1]

[1] Earth and Atmospheric Sciences Dept., University of Nebraska-Lincoln, USA

[2] NWS-Valley, NE

Introduction

Forecasting of convective initiation (CI) is a challenging task due to several nonlinear processes. *Roberts and Rutledge, 2003* discovered that upon comparison of cloud top cooling witnessed through satellite and radar trends, cloud top cooling can be observed on average 30 minutes before the first 35 dBZ radar returns. This sparked the creation of the cloud top cooling based CI forecasting algorithms. The University of Wisconsin Cloud Top Cooling (UWCTC) algorithm and the University of Alabama-Huntsville's Satellite Convective Analysis and Tracking (SATCAST) algorithm are being tested on current GOES East satellite data, and will become operational after the launch of GOES-R (*Seiglaff et al. 2011*; *Mecikalski and Bedka, 2006*). To provide an assessment of these products in different environmental conditions, a NWS/COMET cooperative project was developed with the University of Nebraska-Lincoln partnering with the National Weather Service in Omaha, NE. The goal of this project is to determine environmental variables that change the performance of these CI algorithms through analysis of case studies. These data will be combined into a fused data set, which will be used to give the forecaster better situational awareness.

Methodology

Several case studies have been collected and analyzed from the 2012 convective season to provide an assessment of the CI products based on events throughout the Great Plains (Fig. 1). Numerous CI indications from each algorithm are obtained and evaluated. Variables from one case study are presented here. CI in this project is defined as the first occurrence of a 35 dBZ echo through several radar heights. This definition is consistent with several earlier comparisons by *Roberts and Rutledge, 2003 Mecikalski and Bedka, 2006* and *Mecikalski et al. 2008*. Verification is done by comparing CI indications to National Mosaic Quantitative Precipitation Estimation (NMQ) composite radar data. Using composite radar will capture the first occurrence of a 35 dBZ value without bias of elevation.

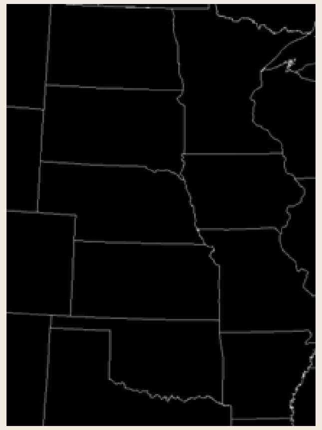

Figure 1. Study Area

To identify clusters of 35 dBZ, the w2segmotion algorithm is used from the WDSS-II suite of algorithms (*Lakshmanan et al. 2007*). This uses a hierarchical K-Means and advanced watershed clustering method to identify areas of CI given value and spatial thresholds. Through subjective analysis, a spatial threshold area of 50 km² was used, given that this appeared to identify areas of convection with reasonable spatial and temporal accuracy (Fig. 2). If these resolved clusters occur within 2 pixels (~2 km or within a 25 km² region around the pixel) within a two hour timespan of an algorithm indication, then that indication is considered positive.

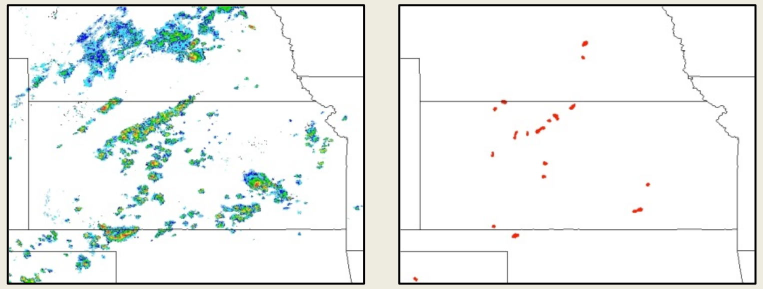

Figure 2. Example 4 km NMQ radar mosaic data *(left)*. W2segmotion output with resolved convective clusters shown in red (*right*).

The objective of this study is to compare CI indications to environmental parameters. However, given that UWCTC's native grid is ~4 km Lambert Conformal mapping, SATCAST ~1 km flat plan grid and Rapid Refresh is a ~13 km Lambert Conformal, it is helpful to create a single mapped set. The SATCAST ~1km grid is used and other datasets are mapped to this configuration using a nearest neighbor method. SATCAST grid pixels are assigned the value of the closest native grid pixel (Fig. 3). If a SATCAST grid pixel lies in between two values, then the maximum value is used. This process is used for UWCI, NMQ, and Rapid Refresh NWP (RAP) model data. The use of a constant grid with RAP data allows for simple validation and comparison of data points.

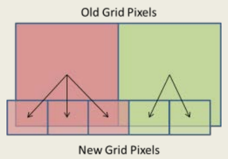

Figure 3. Example of remapping process. In this case the larger pixels are the old native grid, and the new grid is represented as the smaller pixels.

Given that variables are identified in blocks, the maximum, minimum and average values of surface based CAPE, surface based CIN, cloud top cooling values (UWCTC), and storm motion are calculated for the clusters. In addition, equilibrium level heights and planetary boundary layer heights are considered. Even though these values are calculated for all indications, no indication is considered within 50 km of ongoing convection resolved by w2segmotion. This is to prevent data contamination of points that the RAP's low temporal resolution cannot resolve. These variables are tested using an analysis of covariance (ANCOVA) approach for significant differences between positive and false indications.

Case Study: 25 July 2012

A weak long wave ridge that had dominated most of the 2012 convective season was giving way to a short wave trough propagating along the Alberta-Saskatchewan border. A cold front associated with the short wave surface low coupled with a moderately unstable air mass allowed for convective coverage throughout a large portion of the study area (Fig. 4).

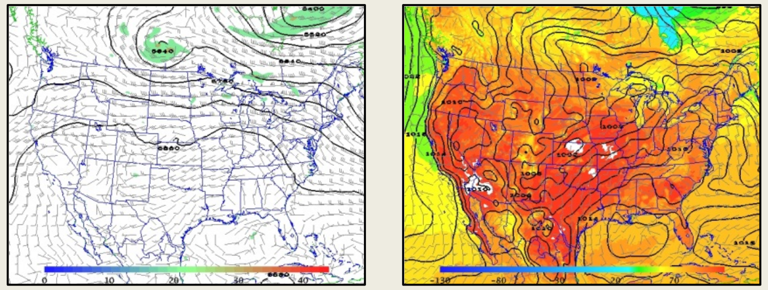

Figure 4. 25 July 2012 21 UTC RAP 500 mb heights (m) with absolute vorticity (*scale on bottom*, $10^{-5} s^{-1}$) and true wind (*left*). 21 UTC RAP MSLP with temperature (*scale on bottom*, °F) and surface winds (*right*).

Three bands of convection initiated in association with the front. One band initiated in southeastern Kansas with an eroding capping inversion and low level warm air advection. A second band initiated along the cold front in northwestern Kansas. The third band of convection initiated along the cold front in eastern Nebraska (Fig. 5). Several separate CI events occurred that were not associated with the three main clusters. They will all be considered in this study.

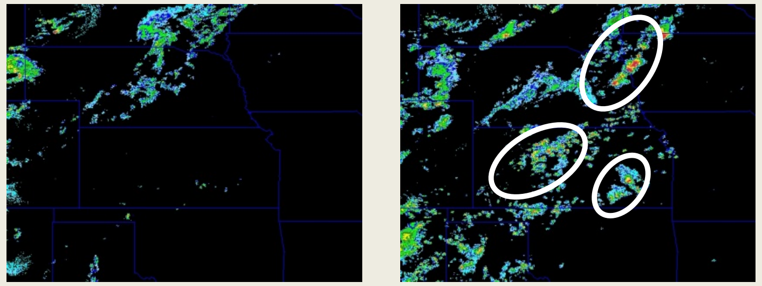

Figure 5. 20:00 UTC 25 July 2012 4 km NMQ radar mosaic data (*left*). 23:00 UTC 25 July 2012 4 km NMQ with CI bands of interest circled in white (*right*).

Results

CI indications collected and validated resulted in a large number of false alarm samples. For SATCAST, out of 37,339 observations, 35,194 are false indications. For the UWCTC, out of 341 observations, 218 are false indications. Given that these data were collected using a 50 km radius mask around initiated convection, it is possible that several positive detections were filtered out of this testing process. Therefore these data should not be used to determine POD and FAR values. However, it is noted that SATCAST produced a larger percentage of false indications than UWCTC throughout the time period. Therefore, a RAP based filtering method may be helpful.

Table 1. 25 July 2012 Mean values of several variables for positive and false indications in SATCAST and UWCTC products.

	SATCAST		UWCTC	
	False	***Positive***	***False***	***Positive***
CAPE Average	1417.67	1200.41	1557.04	1179.047
Cape Max	1472.02	1279.49	1677.61	1302.276
Cape Min	1362.84	1121.95	1441.83	1067.48
Cin Average	-10.93	-13.61	-7.38	-10.9762
Cin Max	-8.9	-10.61	-5	-6.02718
Cin Min	-13.31	-17.34	-10.29	-19.2788
EL Heights	12209.02	12286.13	12656.37	12610.44
SM Average	8.64	8.39	8.848	6.366309
SM Max	8.87	8.77	9.35	7.174175
PBL Height	2627.15	2900.68	2842.92	3314.688
CTC Average			-8.503	-9.34594
CTC Max			-6.0367	-5.68293
CTC Min			-10.9541	-12.8862

Table 2. ANCOVA F-Value tests for SATCAST and UWCTC

	ANCOVA F-Values	
	SATCAST	***UWCTC***
CAPE Average	2.225216	2.50407
Cape Max	26.05924	1.45045
Cape Min	12.34559	4.12857
Cin Average	17.95203	0.42084
Cin Max	4.361891	1.15905
Cin Min	23.5439	3.2154
EL Heights	30.30275	0.39809
SM Average	57.6286	4.36899
SM Max	61.26082	1.46966
PBL Height	167.4233	0.49086
P = 0.001 F-Value	3.26	3.264
P = 0.05 F-Value	1.88	1.91

SATCAST and UWCTC means for CAPE (CIN) averages are higher (lower) for false indications than positive indications. These means are contradictory to findings by *Mecikalski et al. 2008* and *Seiglaff et al. 2011*. It is possible that lower instability was found in regions with greater positive detections due to the fact that a majority of the convection in this case was forced by a cold front (as opposed to free convection). Upon further analysis, convergence appears to correlate spatially well with the 3 main clusters of CI positive detection. This suggests that instability may not be a good discriminator for this type of CI case. However, these results will be noted and examined in future case studies. Further analysis shows that storm motion in both SATCAST and UWCI have larger values with false indications (P value < 0.05, Table 2). Therefore it is possible that storm motion can be a good discriminator in future studies. PBL height and EL height were found to be significant only in the SATCAST algorithm. It is possible that these are caused by use of the Water Vapor-Infrared Window differencing method, to which height of the equilibrium level may be related to large differences in strength of signal output.

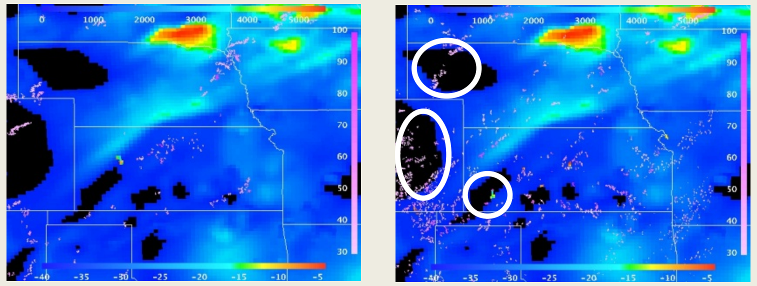

Figure 6. 20:45 UTC 25 July 2012 UAH SATCAST (*scale on right*) positive indicators compared to UWCI (*scale on bottom*) positive indicators (*left*) and false indicators with 21 UTC RAP CAPE values in J kg^{-1} (*right*). The white circles outline areas of SATCAST false alarms in areas without instability.

It is noted that SATCAST variables had no positive indications occurring in areas without CAPE. However, several false indications occur in areas void of instability. This suggests that CAPE, while not a good discriminator in cold front situations, can show us areas where horizontal motion is incorrectly resolved as vertical development (Fig. 6).

Conclusion

In this study of environmental variables in relation to cloud top cooling algorithms, a few key points can be made:

- Due to contradictory results, it is possible that CAPE and CIN are not good discriminators in forced convection. This principle may not be true in cases of free convection.
- Despite this fact, CAPE may be used in the future to resolve areas without instability. This can be applied to filter incorrectly resolved vertical cloud motions.
- Storm motion is found to be a good discriminator between areas of false indications on both products. Therefore, this variable should be considered with future case studies.
- It is possible that EL height can be useful for products that use a water vapor channel

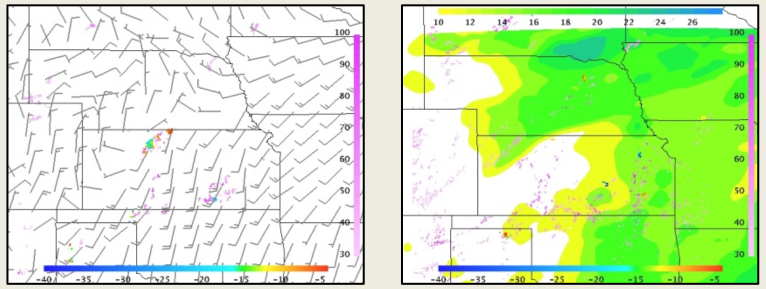

Figure 7. 25 July 2012 21 UTC RAP surface winds (ms^{-1}) with SATCAST positive indications (*scale on right*) and UWCTC positive indications (*scale on bottom*) (*left*). 21 UTC RAP surface dew points (*scale on top*, °C) with false indications (*right*).

More cases need to be tested in the same manner to look for similarities in the CI algorithms. Future research should also improve the validation process and test additional atmospheric variables. It is possible that the lack of advecting products forward can create a false result in significance towards storm motion. This may also change the results for instability, which were contradictory to data found in previous publications. Convergence and moisture will be considered in future calculations (Fig. 7). The significant variables will be used to create a "data fused" product that will act to filter CTC indications based on RAP output. This improved product can help increase the accuracy of a cloud top cooling based product, and assist the forecaster in the nowcasting process.

Acknowledgements

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Data Sources

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Contact Information

Jason Apke | jason.apke@gmail.com | 112 Bessey Hall, University of Nebraska-Lincoln, USA