2013 GOES-R Convective Initiation Product Assessment

Introduction

This report describes an assessment by the NASA Short-term Predication, Research, and Transition (SPoRT) Program of an updated version of the GOES-R Convective Initiation (CI) product developed by the GOES-R Algorithm Working Group (AWG) CI Product Development Team at the University of Alabama in Huntsville (UAH). The CI product is a proxy to the future capabilities of the Advanced Baseline Imager (ABI) on GOES-R. The previous version used a "Strength of Signal" styled product based on satellite-only indicators and temporal trends (SPoRT CI Assessment: Summer 2012). The new version utilizes numerical weather prediction data to characterize the convective environment and it continues to utilize current GOES infrared channels to measure cloud growth rates, cloud depths, and cloud ice or water path. The new version also employs a logistical regression using a database of "training" cases in order to output a probabilistic value of CI. The GOES-R CI product provides situational awareness of the likelihood of a convectively developing cloud structure to result in precipitation; and, thus, can aid forecasters in the modification of nowcasts and short-term forecasts for aviation and the public as well as allow a user to more efficiently identify which of the numerous cloud structures to monitor more closely for convective development prior to mature Doppler radar signatures. The purpose of this assessment is to better understand the value of the additional model data and the change to a probabilistic-based product to the product utility, and to evaluate the use of GOES-West data within the current version of the algorithm for the first time in operations.

The assessment took place from September 1 to October 31 2013 within a small group of users in order to initially test the new version of the product ahead of a potentially wider demonstration in the prime convective Spring/Summer period of 2014 with WFO, National Center, and NOAA Testbed users. This period allowed for evaluation by forecasters observing late summer convection for inland locations of the southern U.S. and sea breeze or air mass convection for southern coastal locations. National Weather Service Weather Forecast Offices (WFOs) with prior forecast experience applying the CI product were selected to evaluate the new version of the product, namely Albuquerque (ABQ), Corpus Christi (CRP), Huntsville (HUN), and Miami (MFL). This SPoRT assessment was also supported by the AWG's product development team, led by John Mecikalski at UAH. The GOES-R CI product was provided within the users' native decision support system (i.e. AWIPS) in both image and gridded formats for use with other local datasets, including radar.

Assessments were conducted via a survey posted on SPoRT's webpage. Surveys are brief (about ten questions), comprising mostly multiple choice questions about the product performance. Forecasters may submit feedback anytime throughout the assessment period, and they are provided the option to ask SPoRT personnel, and occasionally product developers, questions via e-mail, phone, or online chat room. This assessment was interrupted by the federal government shutdown in early October, which ultimately resulted in only 10 official surveys submitted during the assessment period. Additionally, the HUN office began AWIPS II testing during the assessment. Hence, HUN only evaluated GOES-R CI in August, prior to the formal assessment period.

This report is intended for NOAA and NASA program managers, operational forecasters, product developers, other institutions participating in GOES-R Proving Ground and research-to-operations activities, and the general satellite remote sensing community.

Product Description

The GOES-R CI by UAH is a demonstration of the future ABI instrument capability. It is a nowcasting product used to identify convective initiation in the 0-2 hour timeframe using current GOES satellite data and 15 different model output fields [Walker et al. 2012]. The CI algorithm identifies and tracks potentially convective cloud objects across consecutive satellite scans, using a derived GOES cloud type product and model estimated winds to track the objects. Infrared image data from GOES determines factors like cloud growth and glaciation and their associated temporal trends. Environmental data such as CAPE and lifted index are determined from the NOAA RAP model. Twenty-four fields in all are regressed to determine a cloud object's probability of convective initiation, based on a training dataset from prior convective seasons.

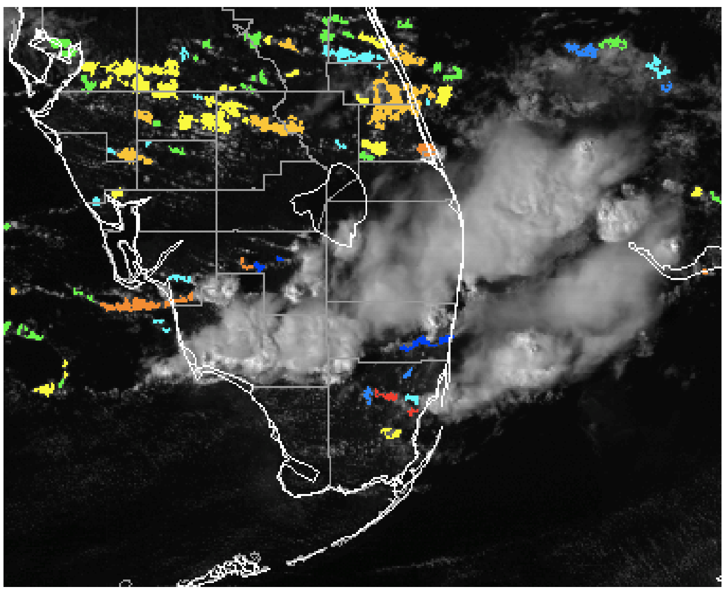

Figure 1. GOES-R CI proxy product overlaid on GOES visible imagery for 26 September 2013 in southern Florida, submitted as part of the feedback from the Miami, FL WFO.. CI probabilities are colored with warm (cold) colors representing high (low) probability while the visible imagery is displayed in a gray scale. A line of mature convection stretches west-east across southern Florida and into the Atlantic with no CI objects as these clouds are past the initiation stage or are of a non-convective cloud type. High probabilities of CI are west of Miami, FL at the end of a mature line of convection and several other medium to high CI probability objects are indicated across central Florida.

The product is generated in near real-time from GOES-East and GOES-West data over CONUS from each satellite scan given that the previous 2 scans were available for temporal trending. The spatial resolution is 1 km during the day and 4 km at night for GOES. To provide context to the CI product, the GOES visible (infrared) imagery is used as a background to the product during the day (night). The combined CI and GOES imagery product allows forecasters to see the non-CI cloud structures which are not being tracked by the algorithm and where cirrus and other high clouds are potentially blocking the view of low-level developing convection (Fig. 1) The product is available in all AWIPS platforms and a web display format, and forecasters evaluated the AWIPS and AWIPS II displays in this assessment.

The previous version of GOES-R CI did not incorporate model data as predictors, and the algorithm was not previously applied to the GOES-West domain. These new applications to the algorithm were the result of forecaster feedback from previous SPoRT evaluations (Fall 2011, Summer 2012). ABQ used and evaluated the GOES-West version of the product for the first time during this evaluation. Limitations to the CI product include false indications of CI due to a mismatch of object tracking that causes an indication of rapid cloud height growth, and the inability to observe CI when cirrus clouds obscure developing convection from the satellite. Another potential problem is data flow. In order to track cloud objects, and therefore reach the steps to produce a probability of CI, the product needs three consecutive satellite scans. When there are data interruptions, it takes three scans to produce the next CI image. Therefore, even brief data interruptions can cause noticeable delays in the GOES-R CI product as the processing "catches up". Both the data interruption and cirrus interference issues were limitations in the previous SPoRT CI assessments. Another limitation is the training dataset for the probability determination is still growing. Data from new regions and seasons are being added to it, but in the meantime, some regions might appear to have better or more consistent results than others. Finally, the resolution for nighttime processing is 4 km, vs the daytime resolution of 1 km, and the jump from day to nighttime processing can result in cloud objects being "lost" between scans.

As for the CI product strengths, this product helps provide data in regions that are generally data-sparse, like off-shore, over mountains, or in other locations where there is little other instrumentation. Also, being data-fused with NWP has greatly improved the False Alarm Ratio of this version of GOES-R CI over previous versions. It is anticipated in the GOES-R era, that the improved spatial and temporal resolution will continue to improve the utility of this product for end-users due to shorter periods between any missed scans and a greater likelihood of capturing small scale changes in developing cloud structures both during the day and at night.

The GOES-R AWG CI Product Development Team validated the statistical performance of the satellite-only algorithm and its relative improvement when adding NWP model fields to the algorithm (Table 1).

Method	LR-Sat	LR-SatNWP
% correct CI nowcasts	79.8	84.55
% correct non-CI nowcasts	48.64	64.25
Total Performance	67.18	76.33
Positive Predictive Value	69.53	77.65
Negative Predictive Value	62.12	73.9
Area under ROC Curve	0.714	0.831
CSI	0.59	0.68
Equitable Threat Score	0.17	0.33
True Skill Statistic	0.28	0.49

Table 1 Validation statistics of the GOES-R CI satellite field algorithm and the GOES-R satellite and NWP algorithm as shown on a test dataset of 4461 convective and non-convective cloud objects.

Based on 4461 ground truth cases of CI and non-CI events which were subjectively identified by scientists, improvements in all monitored performance categories were noted with the modified algorithm. An event was determined to be convective if ground-based radar reflectivities reached 35 dBZ within the region. Such validation is practical and insightful from a research perspective and provides motivation for this additional product evaluation, but this and other assessments will help determine whether a forecaster in operations will be aware of the impact of this algorithm improvement. [Mecikalski et al. 2013]

Methodology

SPoRT developed a product transition and assessment strategy for GOES-R CI in collaboration with end users and product developers to address the value of the product to provide greater situational awareness of developing convection prior to radar reflectivity signatures and how this increased awareness might impact short-term forecasts or nowcasts. As with all SPoRT-sponsored evaluations, the participating WFOs were provided several different types of training on the products prior to and during the assessment period. Prior to the assessment they were provided a 12 minute self-paced, online training module that describes the current version of the CI product and contains a few operational examples. In addition, the SPoRT Quick Guide for CI was provided, which is a single sheet training guide (front-and-back) that briefly describes and illustrates what the product is and how it can be used in operations. The Quick Guides were located in the operations area for easy reference by the users during the assessment period itself. The training module and Quick Guide were both posted on SPoRT's training page (http://weather.msfc.nasa.gov/sport/training/) and several of the Quick Guides were physically printed, laminated and sent to the WFO offices.

To submit formal feedback, participants were asked to go to the SPoRT assessment page (http://weather.msfc.nasa.gov/sport/survey/) and fill out the "two-minute feedback form" on GOES-R CI. Survey questions in this assessment focused on, for example, what type of convection was being observed, forecasters' confidence in GOES-R CI's identification of CI, and what lead times the product provided. Survey questions were written to capture user feedback from a post-event perspective. Pursuant to the goals of assessing the utility of the new combined satellite and NWP version of GOES-R CI in operations, the multiple choice questions within the survey ask forecasters to identify the type of event observed, help address specifically if the output looked reasonable for the event observed, and whether the output was valuable for that event. The comment section concluding the survey allowed forecasters to elaborate on answers or provide additional feedback. Pertinent findings are summarized in the following Results section. In addition, product developers or SPoRT personnel would occasionally ask follow-up questions via email to gather more information about specific feedback. Participants were also given the option to submit blog posts to the World Wide of SPoRT blog (http://nasasport.wordpress.com/) or to email SPoRT or product developers with cases or questions.

Results

This limited evaluation resulted in 10 surveys submitted from 5 different forecasters at 4 WFOs. During the assessment, the government shutdown began, which limited the amount of time forecasters could spend on the assessment process. The HUN WFO submitted one evaluation in August and refrained from further assessment activities, due to AWIPS II testing.

Except for one user, all participants had medium to high confidence in the product's identification of CI. The two coastal offices, MFL and CRP, reported "some" impact on their nowcasting process and that GOES-R CI provided 30 to 45 minutes of lead time on 35 dBZ radar echoes for the events they evaluated

(Figure 2), most of which were convective events driven by sea breeze and boundary interactions. Those forecasters expressed qualitatively in written comments that,

"[…] The CI product did very well south of the boundary where it captured the development of new convection over water and land within 30 minutes. However, north of the boundary the CI product constantly overdid the convective initiation by focusing on Cu or Sc clouds that did not developed into rain showers."

Coastal forecasters also mentioned the obstruction of CI by cirrus clouds (from storm tops or otherwise), as a product limitation. The GOES-R CI algorithm attempts to filter out cirrus clouds, in order to avoid producing false CI signals, as illustrated in the SPoRT-provided training module, but CI is still not visible underneath the cirrus. However, in non-cirrus cloud areas, user submitted comments indicated that the product provided value in the analysis of CI developing due to outflow boundaries. In addition to several feedback submissions by multiple forecasters, MFL also submitted a case example (via PowerPoint slides) where a GOES full disk scan had resulted in 30 minutes between GOES-R CI products and a new CI object with high probabilities in the latest time appeared to the user to be falsely strong. The user perspective was that the large time between scans may have resulted in a mis-match of cloud objects being tracked, and hence the value of the CI probability was unrealistically high. A subsequent CI product 15 minutes later had a lower value of CI probability for this same object, thus confirming to the forecaster (in hindsight) that a possible mis-match of cloud objects had likely occurred. This same cloud object continued to indicate increasing values of CI in following 15-minutes time steps and eventually resulted in precipitation (same case as Figure 1.) With a limited number of online user feedback submissions, HUN, MFL, and CRP forecasters concluded their observations by stating that the product had "some" impact on their nowcasting process in the events they evaluated, given a 5-step, Likert Scale choice ranging from "very small" to "very large".

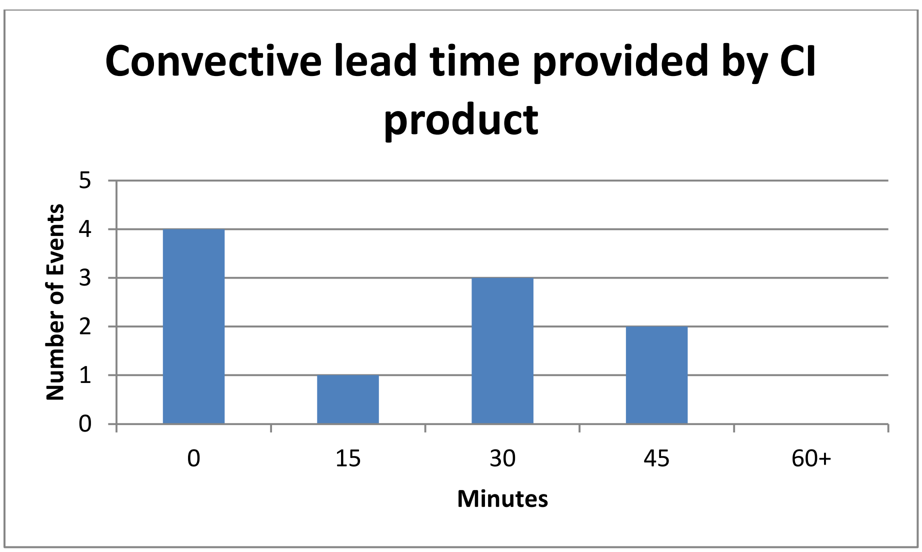

Figure 2. Lead time feedback from all users for the GOES-R CI product.

ABQ was the only office to evaluate the GOES-West version of the product. The forecasters stated that the product has a "small" impact on their operational nowcast process, likely because they did not benefit from improved lead time for any of the 4 different events. ABQ forecasters also reported a number of problems with the product within the region, including cirrus interference and high variability in CI probabilities for orographically-induced convective events, which will be discussed below. Email communication between the forecaster at ABQ and product developers resulted in the potential identification of the source of some of these errors in the GOES-West algorithm. User feedback noted that convective initiation probabilistic values did not accurately capture the development along orographic features resulting in precipitation, given the resulting radar signature as the storm matured. For example, probabilities corresponding to cloud objects that resulted in CI varied from 50-60% to 70-80% for different orographically-induced events, and in one event there was no discernible percentage threshold at which CI occurred. After discussions between the user and the product developers, the hypothesis was that the training cases from GOES East database did not accurately reflect the environment found in the convection observed throughout the GOES-West domain. As a direct result of this interaction, the GOES-R CI Product Development Team began to assemble a GOES-West domain-specific event database that would be used to train the regression equation used within the GOES-West version of the product. Lastly, similar to user feedback from MFL, CRP, and HUN, high cloud cover limited the utility of the GOES-West version of the CI product, which was noted by ABQ in their comments.

Recommendations and Conclusions

Overall the feedback from a small group of operational forecasters familiar with previous versions of the product showed that the addition of the environmental model data and a new probability method for GOES-R CI had some positive impact to the situational awareness of developing convective clouds; and the implementation of this new version using GOES West data still needs further refinement. The specific nature of the criticisms by forecasters (e.g., inconsistencies in CI identification in sea breeze convection, and GOES-West case examples in which the algorithm did not perform as expected), allowed some adaptions and further modifications to begin immediately. Other feedback indicated that for the GOES-East events evaluated during this assessment, this year's satellite and NWP version of UAH GOES-R CI has led to effective lead times on several convective events. However, users indicated that the viewing restrictions due to cirrus clouds are notable limitations to their application of the product. However, the initial positive impact to the GOES-East version and anticipated corrections to the GOES-West version may lead to a plan for a broader dissemination of UAH GOES-R CI alongside NASA-SPoRT's Pseudo-GLM lightning product suite in Spring 2014.

Based on the results presented herein, the following recommendations are suggested to product developers, preferably before the broad-scale dissemination:

- Improve performance and correct algorithm specific to the GOES-West application, specifically in orographically-induced convection;
- Improve performance in sea breeze convection situations;
- Improve the detection of CI in the presence of thin cirrus;

- Minimize the impact larger image separation times on tracking mis-match and erroneous CI.

References

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