Future Capability for Monitoring and Nowcasting Convective Initiation within the GOES-R Era using a Data Fused Approach

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UNITED STATES DEPARTMENT OF COMMERCE

Introduction

Forecasting convective initiation (CI) is a problematic task in the Atmospheric Sciences today. One recent advance towards solving this problem was the development of the SATellite Convection AnalysiS and Tracking (SATCAST) system by researchers at the University of Alabama in Huntsville (UAH; Mecikalski and Bedka 2006). The original version of SATCAST utilized imager data from various channels on the Geostationary Operational Environmental Satellite (GOES) to infer various characteristics about early stage convection, such as cloud-top height, cloud-top glaciation, and updraft strength. SATCAST Version 2 (SATCAST_v2) provided an "object-tracking" based methodology, which provides superior tracking capabilities of developing convective cloud "objects", and therefore greatly improves the ability to monitor the characteristics of convection in its early stages. SATCAST_v2 was unveiled in the spring of 2010 and tested at the GOES-R Proving Ground at the Storm Prediction Center in Norman, OK, with positive feedback.

Responding to forecaster and user feedback, several enhancements were made and are in the processes of being tested in front of National Weather Service forecasters at the Hazardous Weather Testbed, and in Forecast Offices. Recent improvements involve use of various statistical approaches to provide (a) probabilistic nowcasts, and (b) significant (up to 50%) false alarm reductions. SATCAST's application and feedback from use within the FAA's Corridor Integrated Weather System (CIWS), in support of convective weather foresting for aviation, will be shown.

Methodology

1) Convective Cloud Mask:
Reads GOES satellite image data and classifies various types of convective and non-convective cloud elements. The output from this mask is used to define the input "cloud objects" for tracking and processing. Only immature, low-level clouds (e.g. cumulus) are considered for further processing.

2) Object Tracking:
Employs an extrapolated motion, temporal overlap technique using satellite-derived motions to consistently track and identify the same cloud objects between subsequent satellite images. This tracking method follows Zinner et al. (2008).

3) CI Interest Field Testing:
Uses a series of multi-spectral difference and trend tests (Table 1) to evaluate and determine which tracked cloud objects are likely to convectively initiate within the next ~1 hour. *For our purposes, CI is defined as the first instance of a 35 dBZ or greater base reflectivity radar echo (Browning and Atlas 1965; Wilson et al. 1992; Roberts and Rutledge 2003).* Using a CI and non–CI contingency table database.

4) Statistical Approaches:
Two methods are being considered as a means of providing the forecaster a probability-based forecast, and especially to reduce false alarms in our CI nowcasts. These are: Logistical Regression and Random Forest–Neural Network.

Interest Field	Physical Basis *(Mecikalski and Bedka 2006)*
(1) 10.7 µm	Cloud Depth/Glaciation
(2) 10.7 µm Temporal Trend	Cloud-top Growth
(3) 6.5-10.7 µm	Cloud Depth
(4) 6.5-10.7 µm Temporal Trend	Cloud-top Growth
(5) 13.3-10.7 µm	Cloud Depth
(6) 13.3-10.7 µm Temporal Trend	Cloud Growth

Table 1. List of Interest Field (multi-spectral difference and trend) tests along with associated values.

SATCAST Example & Validation

1) SATCAST version 2.2: Probabilistic Nowcasts
Beginning in late 2011, responding to National Weather Service forecaster feedback, the "yes"/"no" nowcasts based on thresholds applied to infrared CI Interest Fields were changed to probabilistic (0-100%) CI nowcasts. The methodology of this procedure is presented in Figures 2(a-b), and is referred to "Strength of Signal." These output can then be interpreted by forecasters for situational awareness purposes, in a relative sense to how SATCAST's CI nowcasts behave in their local region, and across various convective environments.

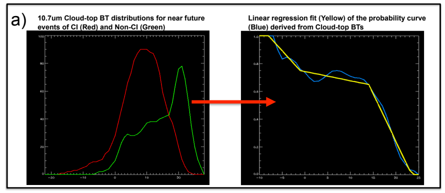
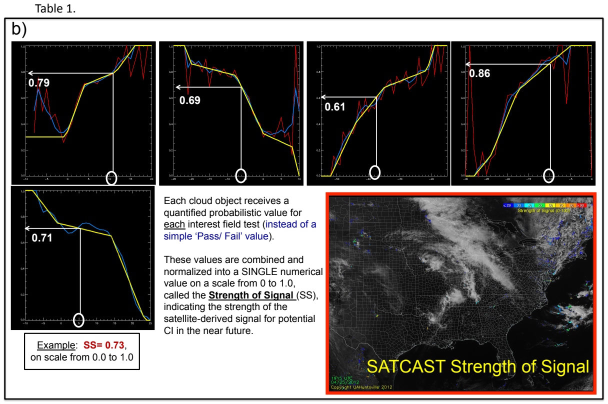
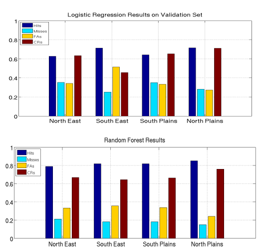


Figure 2.
(a) Development of a "fuzzy logic" probabilistic linear regression approach to glean more information from each interest field test, and combine them into a single "Strength of Signal" (SS) value in the CI forecast output. Here we show this for just the 10.7 µm cloud top cooling rate field.
(b) Example of a Strength of Signal nowcast. The five plots pertain to interest fields (1), (2), (3), (5) and (6) in Table 1.



2) Validation of New Approaches:
In addition to the Strength of Signal logistical regression method, a Random Forest approach is also being used with SATCAST data, coupled to other numerical weather prediction (NWP) fields *(to be demonstrated in real-time in summer 2012)*. The NWP fields include CAPE (surface & elevated), CIN, LFC, precipitable water and sun angle.



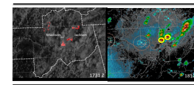
Logistic Regression Method
- Produced PODs of 63-73%
- False Alarms at 40-50%
- Results have no strong regional bias

Random Forest Method
- Increased POD to ≥80%
- False Alarms reduced to 25-35%
- Results have no regional bias

Figure 3.
Validation statistics for Logistical Regression (top) and Random Forest (bottom). Courtesy of MIT–Lincoln Labs (H. Iskenderiak, M. Veillette).

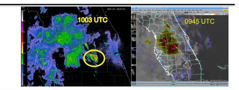
NWS Feedback & RUC Model Assimilation Results

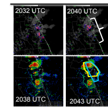
1) SATCAST Used within NWS Forecast Offices
Below are examples of how the NWS is using SATCAST output for situational awareness and enhancing warnings. To date, feedback from the Huntsville (AL), Melbourne and Miami (FL) have been most constructive.



- WFO-HUN on 22 September 2011
- Used for threat of CI, lightning, and impacts to aviation and outdoor activities in Madison and Jackson Counties
- Courtesy Christina Crowe and Kris White, NWS-HUN

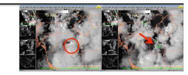
- WFO-MLB on 07 September 2011
- Nocturnal thunderstorm event in rapid scan mode: would CI occur ahead of a system moving toward Orlando metro and impact Brevard County?
- Courtesy Jonathan Guseman and David Sharp, NWS-MLB





- WFO-MLB on 29 September 2011
- From MLB/SPoRT training module for warning decision-making with experimental products: "You Make the Call"
- Used to determine if all or part of Brevard County needed to be under Severe Thunderstorm and Marine Warnings
- Courtesy NASA SPoRT; J. Guseman, and D. Sharp, NWS-MLB

- WFO-MIA on 18 August 2011
- Evaluating CI and 5-min lightning coincidence
- Courtesy Jeral Estupinan, NWS-MIA



2) Development RUC Model Experiments:
Working with NOAA ESRL and in collaboration with MIT–Lincoln Labs, SATCAST infrared CI Interest Fields were "assimilated" into the Development version of the RUC model. Figure 4 presents an example of how radar reflectivity was enhanced as a result of the SATCAST data in the RUC forecast, which is seen as a positive result.

SATCAST data on RUC grid for 1600 (left) and 1700 (right) UTC 5 April 2012

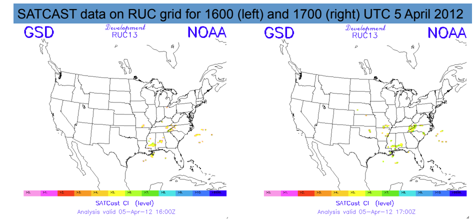
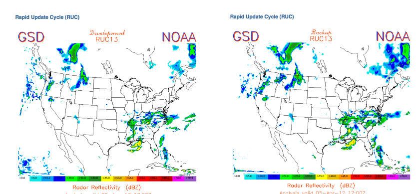


Figure 4.
Example of SATCAST infrared data in the Development RUC model.



Developmental RUC reflectivity field for 1700 UTC 5 April 2012 (–SATCAST left & +SATCAST right)

Future Developments

In light of a data fused solution to CI nowcasting, the following activities are planned (based on research) that merge satellite, radar and lightning data. The lightning work brings in the Geostationary Lightning Mapper (GLM), while the satellite work prepares us for GOES-R. All radar work involves dual-polarimetric observations. Specifically, developments will be for (1) Lightning Initiation–Quantitative Lightning Estimation (Harris et al. 2010; McCaul et al. 2009), and (2) for an NWP–model Random Forest method that nowcasts CI in the 0-1 hour timeframe. All activities will be demonstrated for the HWT, OPC and AWC, and involve the NWS (via NASA SPoRT collaboration).

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NOAA GOES–R Science Week 2012 Kansas City, Missouri