13.1 An Object-Based Approach for Identifying and Evaluating Convective Initiation

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1. Motivation

An objective assessment of the AutoNowcaster (ANC), developed by the National Center for Atmospheric Research, (NCAR) was conducted by the Forecast Impact and Quality Assessment Section (FIQAS) of the Earth System Research Laboratory (ESRL) of NOAA at the request of the National Weather Service (NWS). The goal of the study was to evaluate the value of the ANC to an aviation planner at the Center Weather Service Unit (CWSU) Air Route Traffic Control Center (ARTCC) in Dallas Fort Worth (FWD) (Lack et al., 2011).

The ANC is unique among short-term forecasts (nowcasters). It provides both a pseudo-reflectivity convective nowcast that is extrapolated from the existing convection as well as a field indicating the likelihood of convective initiation (CI). One specific aspect of the evaluation was to determine the accuracy of the CI field, which is explicitly displayed by the ANC as three levels of CI potential.

The ANC experiment provided a backdrop for further investigation into questions such as identifying initiation in convective products, and assessing the quality of the convective initiation component of a forecast. A new verification approach was developed in this context for the assessment of the ANC; this approach could be expanded to evaluate a variety of forecast models.

2. Introduction

Traditional verification metrics usually compare a forecast field with an observation field. This approach is problematic when CI is the field of interest. Most forecasts do not readily distinguish growing, decaying, and translating convection from newly initiated convection (NCAR's AutoNowcaster is one forecast that distinguishes extrapolation from initiation). Observations clearly do not make this distinction. The challenge in evaluating the forecast in the context of CI is in automating the identification of initiation in both the forecast and the observation.

An object-based approach can be used to identify initiation in the convective field. This approach will be described as applied to an observation field, with the understanding that it can also be applied to forecasts that do not provide a CI field explicitly.

The standard object-oriented verification scheme identifies objects in the observation field and compares it to that of a forecast with similarly defined objects. In the context of initiation, the forecast is replaced with a previous observation field (t-Δt). The verification scheme then matches like objects and assigns a penalty based on minimizing the cost function of all possible matches. In the end, some objects in the current observation field (t=0) may not match to objects from the previous observation time (t-Δt). These unmatched objects can be considered initiation if certain requirements are met. These requirements may include: a certain intensity threshold, a certain distance away from existing convection, the presence of intra-cloud lightning, etc. Once the observations of CI are made for the data set, forecasts of CI may be determined using similar rules. Care must be taken to ensure the CI definition for observations is consistent in some way to the forecast. For example, using lightning data to identify initiation may

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be supported physically but the inclusion of such data does not lend itself to identify CI in the forecast. Therefore, incorporating lightning presence in the observations may hinder the interpretation of results in evaluations when the forecast provides only a reflectivity-derived field. After forecast and observation CI is detected, comparisons of the resultant fields can then be made in either a deterministic or probabilistic framework.

The next section will review one such object-oriented approach that may be applied for the detection of CI.

3. Procrustes Methodology

Object-oriented verification is becoming more and more common in the evaluation of model performance on high-resolution grids. An advanced version of an object-oriented approach that involves a combination of object identification on multiple scales with Procrustes shape analysis techniques (Lack et al. 2010) is used and adapted for use in detecting convective initiation. The multi-scale object identification technique relies heavily on a novel Fourier transform approach to associate the signals within convection to different spatial scales. Other features of this verification scheme include: using a user-defined weighted cost function for object-matching using various criteria, delineating objects that are more linear in character from those more cellular, and tagging object matches as hits, misses, or false alarms. Although the scheme contains a multi-scale approach for identifying convective objects, standard minimum-intensity and minimum-size thresholds can be set when desirable. The components that make up this object-oriented verification listed above make it a good candidate for detecting initiation.

The first step in the Procrustes initiation scheme is to identify convective objects. For the ANC experiment, minimum intensity and size thresholds were applied to the domain of interest to identify objects at approximately 5-min intervals. The object-oriented scheme then matches like objects from some time (t=0) to those from a previous radar scan (t-Δt) and assigns a penalty equal to the minimum of the cost function of all possible matches. In this case, the cost function that is minimized is sensitive to the edge-to-edge distance of the objects detected. In the end, some objects in the current time step may not match any objects from the previous time step. These unmatched objects (tagged false alarms by the verification scheme) are considered initiation if certain requirements are met. Namely, the new object must be located a minimum distance from existing objects (to distinguish initiation from growth on the edge of a system) and its intensity must surpass a minimum threshold. Other requirements are included for quality control; for example, the new object must not exceed a minimum size to ensure that a pre-existing storm suddenly appearing after a radar outage is not labeled as initiation.

Figure 1 gives an example of how the Procrustes technique can identify initiation using minimum intensity and size criteria listed above. In the top panels the two larger storms merge into a single storm, while the third storm remains relatively unchanged. In the bottom panels, two new cells initiate to the north of a cluster of storms that have grown since the previous time step. These new cells have sufficient distance away from the original cluster of storms to be tagged as CI.

An alternative approach for detecting initiation can be used based on the multi-scale aspect of the Procrustes identification technique. Identification of objects is accomplished using band pass filters in Fourier space. The band pass filters are selected in a way to match end-user decision criteria. This methodology is beneficial when matching objects at larger time steps (30 min, 1-h) and over larger spatial scales or forecast domains. Although isolated convection may be missed due to its low signal strength, significant convective initiation may be detected in longer time steps or time steps consistent with current numerical weather prediction output, which

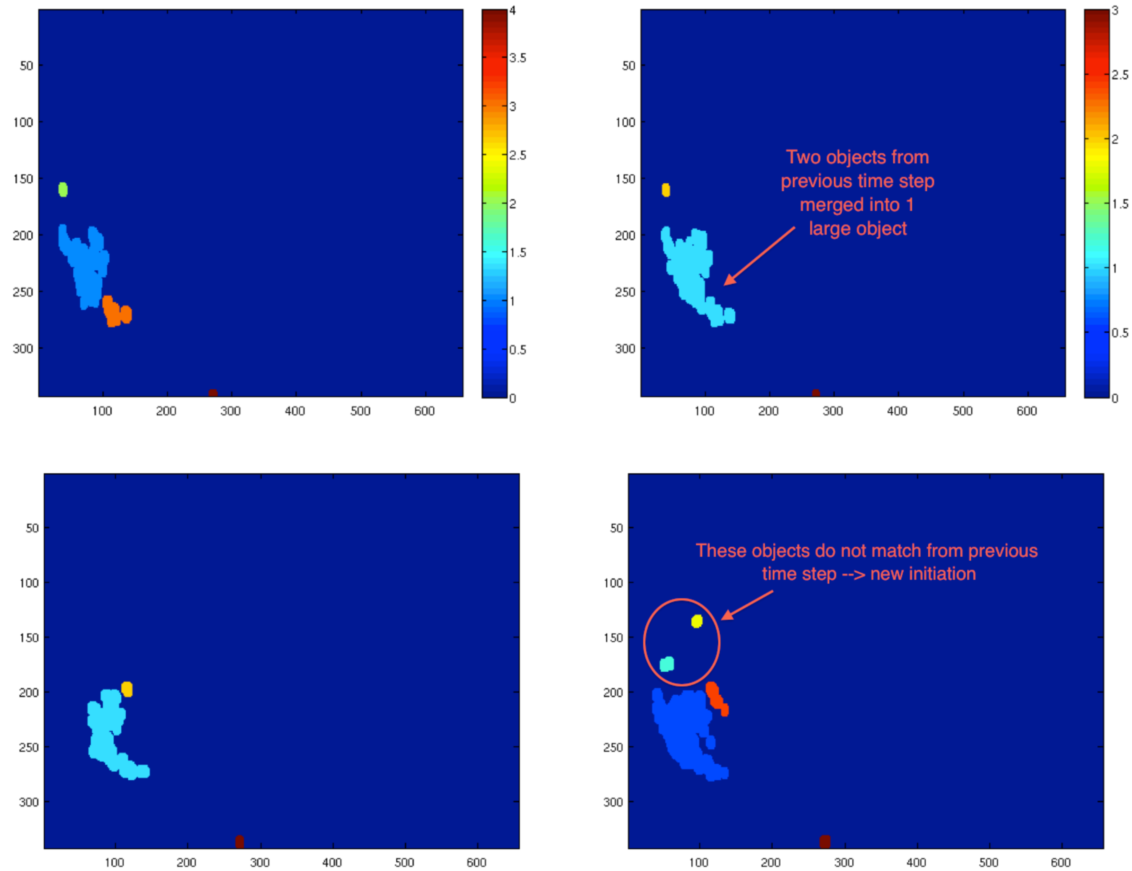

Figure 1. Example of consecutive time stamps with no initiation cells present (top) and consecutive images with initiation (bottom). No initiation was detected in the top image although merging was present. Two new cells initiated in the bottom image with considerable growth of the existing convection.

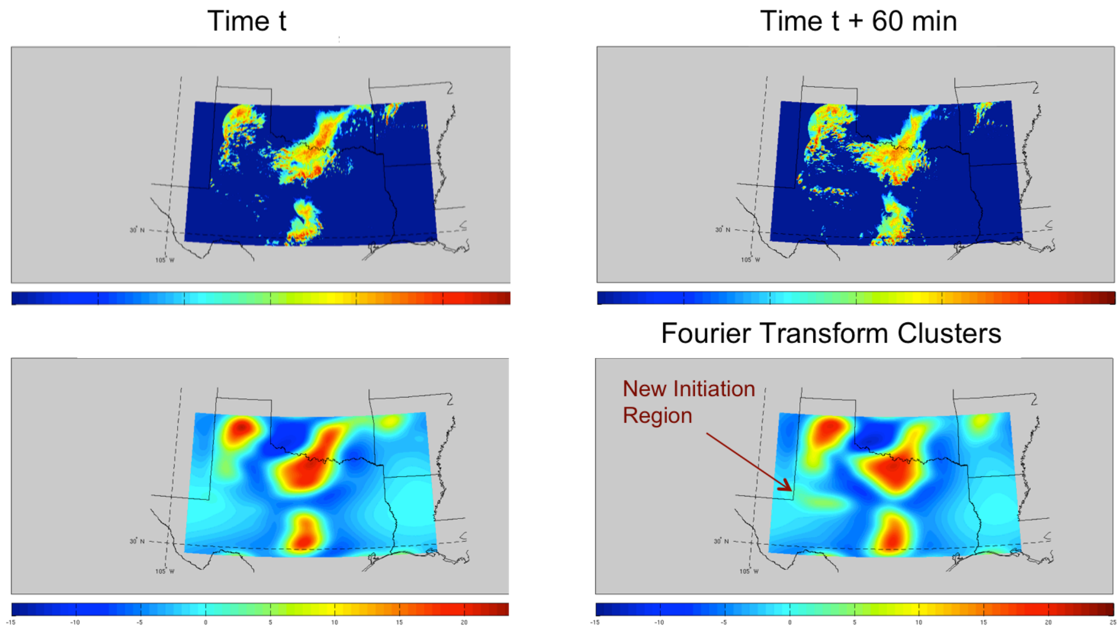

Figure 2. An example from 14 May 2010 with observed reflectivity (top) and identified clusters of initiation from the band pass (bottom). The time on the left corresponds to 1745 UTC while the time at the right is 60-min later at 1845Z. A new initiation feature can be seen in W TX.

may be of value in the context of ATM planning. An example of the identification of convective initiation using a band pass filter approach is shown in Figure 2, where widespread CI is detected at an hourly time-step in W TX and is identified as a weak cluster in the band pass clusters.

4. CI Verification Methodology

Evaluation of convective initiation presents unique challenges. The overarching goal is to assess the correspondence of the convective initiation forecast and observed convective initiation. Once convective initiation in the forecast and observation is identified an object-oriented verification approach can be used to characterize the skill of the initiation forecast. In the case of the ANC experiment, the metric of interest was the distance of the observed convective initiation to the regions of initiation potential identified by the ANC. If the observed initiation was contained in an initiation potential region in the forecast, the distance was set to 0, otherwise the minimum edge-to-edge distance was recorded. If there were no convective initiation cells identified in the observed field with the presence of an initiation potential in the forecast, the forecast was considered a total false alarm. Conversely, if there was observed initiation and no forecast of initiation potential, the forecast is considered a total miss.

The distributions of the distances between observed and forecasted CI is a useful result to examine. Additionally, time series plots of the occurrence of observed and forecasted CI gives a picture of the temporal correlation of CI, along with any forecast biases. For examples of an analysis based on the above framework see Lack et al. (2011).

5. Future Work

User-based input will drive future applications of CI-detection and verification techniques. Input from the user is essential to establish definitions of convective initiation. The use of lightning data in CI detection will be further explored. For a true observational data set of CI, lightning data with a high detection efficiency of total lightning is a necessary data set to include when determining the onset of convective activity; however, using lightning data as a true representation of CI is problematic during validation exercises as there is often no parallel model field that includes lightning occurrence.

6. Conclusions

Managing the safe flow of aviation air traffic in hazardous weather conditions is dependent upon weather forecasts that accurately depict the initiation of convective thunderstorms 4, 6 and 8 hours in the future. Since forecasts of convective initiation are in their infancy, they require improvement to become a reliable and accurate depiction of the hazardous weather for improved flight planning. In order to measure the accuracy of the convective initiation element of a forecast, new verification techniques are being developed and tested. One specific technique used to assess the National Center for Atmospheric Research's AutoNowcaster is the Procrustes Technique, an object-based verification approach. In general, the Procrustes object-based verification scheme identifies objects in the observation field and compares them to the similarly defined forecast objects. The verification scheme matches like objects and assigns a penalty based on minimizing the cost function of all possible matches. In the end, the unmatched objects are considered initiation if certain requirements are met. Examining the distance from the observed CI objects to the forecasted CI objects or areas can then be used as a possible verification metric.

7. References

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