Aviation Forecasts in the Weather and Climate Impact Assessment Science Initiative.

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The Research Applications Program (RAP) has conducted aviation weather hazard research under sponsorship by the FAA for over fifteen years. Outstanding products for operational users have resulted from this program, which offers unique opportunities for applied weather research. However, we tend to lack flexibility to try new ideas and develop basic concepts; the Weather Assessment Science Initiative has allowed us to conduct exploratory work in these areas.

RAP's work within the AI targets two of our most important aviation weather research topics – icing and convective weather. To date, the AI has allowed us to combine model output statistics (MOS) techniques employed in other projects and adapt them to forecast icing events. In return, improvements in our applications have allowed us to provide feedback to other projects. The use of these types of techniques is not common across NCAR; this project provides an opportunity to introduce them.

Forecasting and verification of weather phenomena such as icing and strong convection are difficult because of the relative scarcity of such events. While all such events are not extreme in magnitude, within the range of normal weather conditions, their mere occurrence may allow them to be considered extreme events. The AI has allowed us to examine whether these icing potentials can be statistically post-processed, borrowing some extreme value analysis techniques, to create better information for the aviation community.

Project Details

The following sections highlight some of the results of work performed on the icing problem under the initiative as well as the future plans for studying convective events.

Icing Hazards

Initial studies for the AI have focused on analyzing possible improvements in the icing forecast system known as the Current Icing Potential (CIP). The CIP is an expert-based model that uses information from numerical weather prediction models and various types of observations (e.g. radar, satellite) to estimate the likelihood of encountering icing conditions affecting aircraft during flight. The output is a number from 0 (no likelihood of icing) to 1 (certain icing). This scale is currently uncalibrated, that is, it does not represent the true probability of the icing event occurring. This has been a source of confusion to users as long as the product has been available to users and one of the goals of this exercise was to attempt true calibration.

A variety of statistical models were explored to post-process the CIP output. For these models, the CIP and various environmental variables from numerical weather prediction models were used as predictors and pilot reports (PIREPs) of inflight icing were considered responses in the estimation of statistical models. To avoid the issue of stationarity, a relatively short time span of ~6 weeks was used. The suite of statistical models included neural networks, regression trees and general linear models. With data that were not used in the individual statistical model creation, weights were created that rewarded models for successfully predicting a PIREP. These models and weights were then used to make predictions for a subsequent time period. The CIP assesses the likelihood of icing in any given 20-km grid space across the CONUS. The POD (probability of detection) of yes/no predictions and occurrences (based on yes/no PIREPs) was used as a verification metric.

To assess the utility and differences between the post-processed and original model, receiver operating characteristic (ROC) plots and a summary of area under the curves for individual weeks were calculated. A composite ROC curve (Fig. 1) reveals some improvement achieved by the post-processing. However, this gain may be within the confidence limits of the original CIP. Whether it is significant and can run within operational time constraints (typically a few minutes) are further issues to be considered before implementation. One potential weakness in this approach is the many problems associated with PIREPs themselves. As subjective descriptions of icing conditions that are not random with respect to space or time, and not independent of the actual icing conditions, most traditional verification techniques fail and common statistical tools are limited.

The methodology used in statistically post-processing the CIP shares features with techniques used in many MOS tasks performed at RAP and elsewhere. Common problems include collinearity amongst variables and model weighting. Common solutions are variable selection tools, model weighting, neural networks and regression trees. These approaches can be applied to other topics after the examples we have been working on are completed and we are able to demonstrate that these are feasible and reasonable methods. Statistically post-processing the data may provide a more calibrated forecast. When people see a variable expressed on a [0,1] scale, as the CIP currently is, they often intuitively associate it with a probability. Statistically post-processing the CIP may allow pilots, forecasters and dispatchers to use the forecast in a more objective manner.

Convective Storm Properties

Another weather hazard facing the aviation community is deep convection. Convective storms can appear suddenly and cause huge disruptions in air traffic flow. Uncertainty in their duration and movement creates difficulties for air traffic dispatchers and controllers. While much is understood about conditions necessary for a storm's initiation, prediction of growth and decay has proved to be a formidable problem. To this end, we have begun to study the properties of convective storm events and are using some of the statistical tools used for icing to predict the duration and frequency of storms.

Initial explorations have been made using a dataset compiled by RAP scientists for May and June 2003. Convective storms were identified and tracked using an automated algorithm. From a numerical weather prediction model, fields related to storm formation were collected. Statistical models using these fields as predictors have been created to predict the duration of such events. The Random Forest algorithm developed by L. Brieman shows some still in predicting a minimum duration of storms that have lasted longer than 30 min (Figure 2).

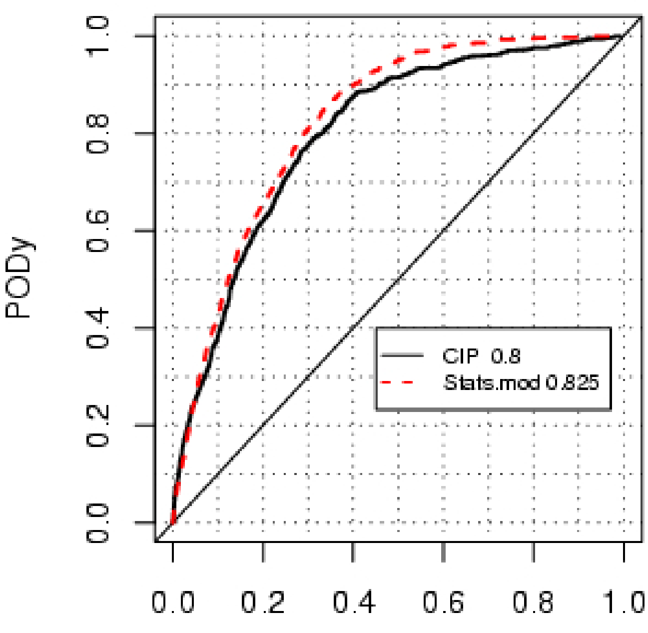

Figure 1. Composite ROC curve for CIP and statistically post-processed CIP. Vertical axis is the hit rate while the horizontal axis is the false alarm rate for a range of thresholds.

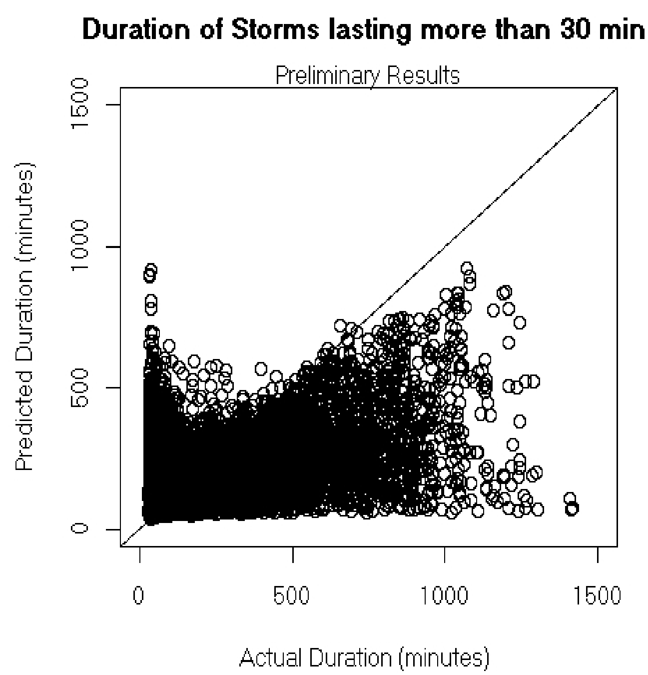

Figure 2 Preliminary results for the prediction of storm duration.

Methods for this study are being implemented using this particular dataset because it is readily available. However, these techniques could also be used with storm tracks identified using other techniques. This opens the door to future collaboration with others working on storm-tracking algorithms. These collaborations will allow us to take advantage of others' capabilities in identifying and classifying unique storms, and holds promise for future work that could be very productive.

Extreme value statistics will be used to model the duration of unusually long-lived storms as well as the amount of moisture aloft or as rainfall. One of the biggest challenges of this work is the incorporation of censored data; clearly a storm that has lasted twelve hours before moving out of radar range (such as off the coast) is different from a storm that passes out of range after only four hours. This is a new area of extreme value statistics that warrents further study and may be useful to other applications to censored data. Working with data that is high in spatial and temporal resolution may allow us to make better inferences about data that has coarser resolution such as H. Brooks' sounding re-analysis dataset.

Summary

These topics allow have the potential to provide a benefit to society in several ways. On the one hand, better prediction of aviation hazards such as icing, turbulence and convective events helps minimizes the inconvenience to the traveling public and allows airlines to operate more efficiently. On the other hand, these hazards also have the potential to threaten lives, so a better understanding of them improves safety.

Scientists in RAP are very directed toward products aimed at decision makers. Aviation weather hazard products we have developed are used daily by operational decision makers such as airline dispatchers and pilots (see http://www.aviationweather.gov for examples). Many of the research projects in this and other areas, including road and range weather and hydrology, are developed into prototypes and may ultimately be developed into operational systems. Placing more of our work under the larger umbrella which the AI provides, broadens the community with which we are involved. These resulting interactions will in turn, enhance our work on weather hazard extremes.