193 THE EFFECT OF ADVANCED SATELLITE PRODUCTS ON AN ICING NOWCASTING SYSTEM

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1. INTRODUCTION

Products developed at the National Center for Atmospheric Research (NCAR) and disseminated by the U.S. National Weather Service provide nowcast and short-term forecast estimates of icing probability, severity, and the potential for supercooled large droplets (SLD). The Current Icing Product (CIP) system combines multiple data sources using fuzzy logic methods to produce a gridded, three-dimensional, hourly depiction of icing-related conditions (Bernstein et al., 2005). The CIP algorithms rely on basic satellite-derived information, such as a cloud mask and cloud top temperature estimate, as one source of input data. The goal of the NASA Advanced Satellite Aviation-weather Products (ASAP) program is to devise methods for incorporating more sophisticated satellite products into aviation weather diagnosis and forecast systems. The in-flight icing component of the ASAP program has successfully incorporated several satellite-based cloud products from the NASA Langley Research Center (LaRC) Cloud and Radiation Research Group into the CIP algorithms (Haggerty et al., 2008; McDonough et al., 2010). This paper examines the impact of those products on icing probability fields as estimated by CIP. Specifically, we investigate the difference in icing detection rates as compared to Pilot Reports (PIREPS) of icing conditions between the operational version of CIP and an experimental version which includes advanced satellite products.

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2. THE CURRENT ICING PRODUCT

The operational CIP algorithm combines information from satellites, radars, surface observations, lightning sensors, and pilot reports with model forecasts of temperature, humidity, supercooled liquid water, and vertical velocity. Fuzzy logic and decision tree logic are applied to combine up to fifty-six interest fields derived from these data sources into a single fused product. The algorithm generates a three-dimensional hourly diagnosis of the probability of icing and supercooled large drops over the continental United States at 20-km horizontal resolution (McDonough and Bernstein, 1999; Bernstein et al., 2005). Results are presented as numbers between 0 and 1 (or as a percentage) that indicate the probability of icing and for the existence of SLD within a given volume. Routine CIP output is available on the Aviation Digital Data Service web page at:
http://adds.aviationweather.noaa.gov.

3. SATELLITE CLOUD PRODUCTS

The cloud products under evaluation for inclusion in CIP are derived from the Geostationary Operational Environmental Satellite (GOES). The GOES Imager has channels in the visible, near-infrared, and thermal infrared portions of the spectrum. NASA LaRC algorithms are applied to half-hourly GOES-10 (Western U.S.) and GOES-12 (Eastern U.S.) Imager data. The Visible Infrared Solar-infrared Split-window Technique (VISST) is used during daytime hours. The Solar-infrared Split-window Technique (SIST) uses a subset of the Imager channels to derive products at night (Minnis et al., 2005; 2008).

Based on results of multiple validation studies performed on the LaRC cloud products in meteorological conditions associated with icing (Wolff et al., 2005; Haggerty et al., 2005; Khaiyer et al., 2003; Smith et al., 2002; Black et al., 2007; Black et al., 2008), specific fields were targeted as likely to provide useful information about the location of supercooled liquid clouds. Using results of these studies, methods for integrating specific products into an experimental version of CIP were developed.

4. INTEGRATION AND VERIFICATION

CIP algorithms apply fuzzy logic methods and decision-tree techniques to determine the likelihood of icing, supercooled large drops, and icing severity at each location. The fuzzy logic scheme employs interest maps for each data set to quantify the utility of a given variable in specified meteorological conditions. The LaRC satellite cloud products were integrated by developing new interest maps and/or modifying existing interest maps to incorporate additional information provided by these products. Efforts to incorporate, via fuzzy logic methods, the LaRC cloud mask, hydrometeor phase, cloud top height, and cloud effective temperature to refine estimates of the CIP icing probability field are described by Haggerty et al. (2008). Integration of additional products (including liquid and ice water path, particle effective radius and diameter, and optical depth) for icing severity estimates is in progress (McDonough et al., 2010).

As part of the effort to use LaRC products in the icing probability algorithms, a hybrid scheme for estimating cloud top height was developed. The hybrid scheme combines traditional CIP data sources with the LaRC products, and has been shown to reduce the overestimation of cloud top height in the operational CIP scheme (Haggerty et al., 2008)

Using a data set covering daytime cases for six weeks during the winter of 2005, the experimental version of CIP which includes the LaRC products was compared to the operational version. Estimated cloud top height, icing volumes, and probability of detection (POD) using PIREPS of icing were compared.

Statistics for the 6-week data set showed that 67% of the experimental CIP cases had less icing volume than the operational CIP. Overall, icing volume was reduced by 4.2% in the experimental CIP. By limiting the comparison to locations where both the operational and experimental versions agreed on the presence or absence of clouds, the number of cases with reduced icing volume was 83%. The overall icing volume was reduced from 9% in the operational CIP to 8.4% of the model domain in the experimental version.

CIP icing probability comparisons with over 5000 PIREPs from this time period reflect the reduction in icing volume as expected. The experimental CIP gives a higher probability of detecting “no” PIREPS (PODn - negative for icing) compared to the operational version, and a lower probability of detecting “yes” PIREPS (PODy - positive for icing). The PODy statistic changed from 83% in the operational CIP to 74% in the experimental version.

Examination of individual cases is necessary to understand the circumstances for which inclusion of LaRC products results in a better or worse estimate of icing volume and to refine the algorithms accordingly. A subset of the PIREP data set was selected for determining reasons that the experimental CIP failed to discern icing in cases where the operational CIP showed icing conditions. Of the original 5528 icing PIREPS, approximately 9% (462 observations) fell into this category. The subset was further subsampled by considering only cases where the cloud top height estimates in the experimental and operational CIP versions were within 5000 ft of each other. These constraints yielded a data set of 255 icing PIREPS which were correctly classified by the operational CIP, but not by the experimental CIP.

For PIREPS within this subset, the following procedures were executed:

1. Compare cloud top heights from each version of CIP with actual cloud top height from the PIREP
2. Examine corresponding CIP interest maps for equivalent potential temperature (θ_e), cloud top temperature (CTT), total condensate (TotC), relative humidity (RH), and a composite cloud top height interest map (CTZ), to understand features that produced the misdiagnosis.
3. Group cases into similar scenarios (i.e., common reason for misdiagnosis)
4. Refine algorithm and/or interest map to eliminate discrepancies where possible

5. Results

Analysis of these cases revealed various minor problems with the placement of the cloud top in the experimental CIP, and thus led to inaccuracies in estimates of the icing volume. Three distinct reasons for problematic cloud top height estimates were identified during review of this data subset.

In the first set of cases where positive PIREPS were missed, it was noticed that the estimated cloud top was only slightly below the real cloud top. The height of the top of the boundary layer inversion is often too low, so the cloud top is also placed below the actual cloud top. The modification for this scenario simply places the cloud top at the next highest grid level in these situations so the PIREP is captured.

A second set of cases occurred when multiple peaks were present in the cloud top (CTZ) interest map. The original scheme simply used the model height where the value of CTZ interest was maximized as the cloud top height (Figure 1). The refined method defines thresholds for RH and cloud top temperature interest, and then steps upward moving the defined cloud top level until those thresholds are no longer met. The highest level where the thresholds are present becomes the new cloud top height (Figure 1).

In a third scenario the maximum level of cloud top interest (where all the predictors are maximized) is below the observed cloud top. Beginning at the maximum interest level the RH and cloud top temperature interest are checked at each level above. If RH > 80% and the cloud top temperature interest is greater than 0.2, then cloud top is assigned to that level. This method locates higher cloud layers that may not be obvious in the other model predictors and are also within the range of values where the effective temperature interest map is non-zero

6. Future Plans

With these refinements for estimating the cloud top height more accurately and hence obtaining a more realistic depiction of the icing volume, a more reliable version of the experimental CIP has been achieved. LaRC cloud products recently became available in real-time, so routine testing of the experimental CIP is now possible and ongoing.

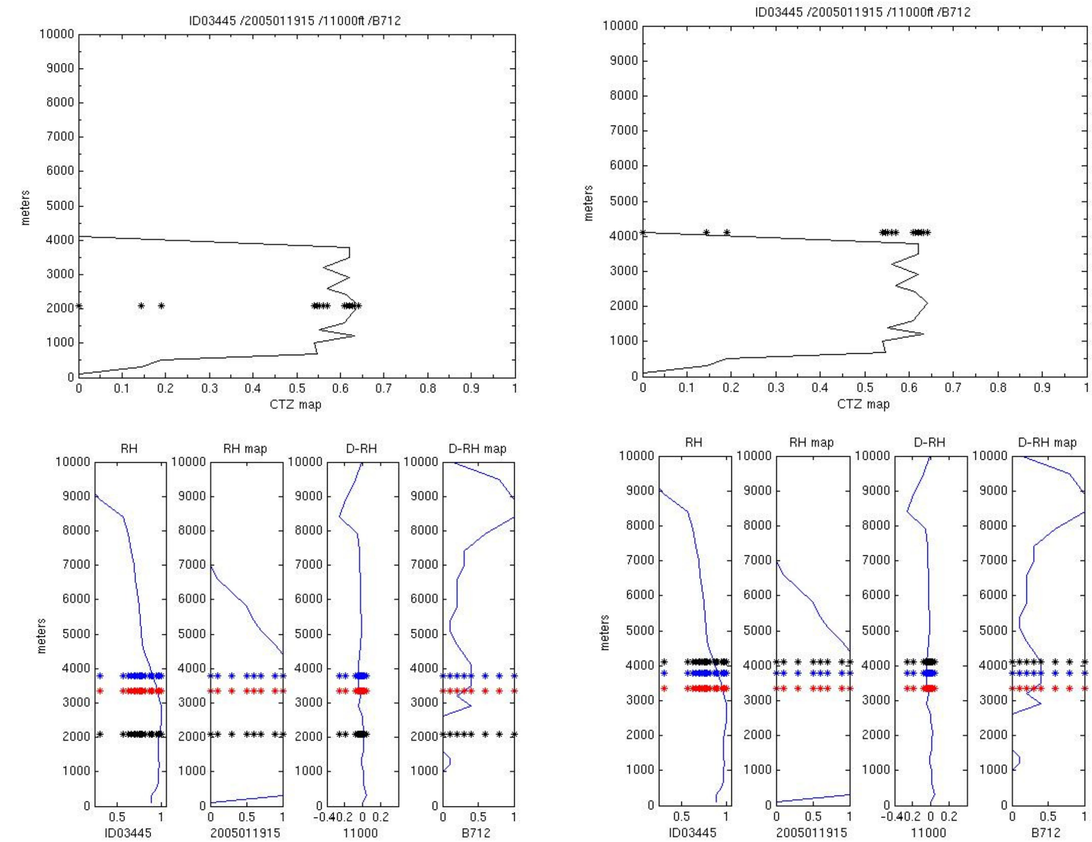

Figure 1: (Upper left) Cloud top interest map (solid line) with estimated cloud top height (symbols) before algorithm corrections were applied; (Upper right) Cloud top interest map and estimated cloud top height after corrections were applied; (Lower left) Relative humidity profile, relative humidity interest map, change in relative humidity, and change in relative humidity interest map (solid lines). Blue symbols represent height of cloud top as estimated by the operational CIP, black symbols represent cloud top height as estimated by the experimental CIP, and red symbols are the observed height according to PIREPs. (Lower right) Revised cloud top height estimate shows that algorithm modifications have improved the estimate by the experimental CIP.

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