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OPERATIONAL EXPERIENCE WITH WEATHER PRODUCTS GENERATED THROUGH JOINT USE OF FAA AND NWS WEATHER RADAR SENSORS

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1. INTRODUCTION

In this paper, we describe current joint use of Federal Aviation Administration (FAA) and National Weather Service (NWS) radar sensors to provide operational weather decision support for the FAA, airline operations centers, and NWS forecast offices. The capabilities that have been demonstrated include fully automatic data editing and short term “nowcast” product generation algorithms as well as display of data from the different radars in different windows; direct product distribution to operational decision makers without any intervening meteorologist input; and collaborative decision making between the various parties. The significant use of fully automated product generation algorithms has facilitated flexible, coordinated decision making in real time at many locations simultaneously, without the high personnel costs that would be required to achieve the same weather product generation capability manually through interpretation by experienced radar meteorologist/forecasters.

These joint-use capabilities have been demonstrated operationally at the Integrated Terminal Weather System (ITWS) demonstation sites in Memphis, TN, Orlando, FL, Dallas, TX, and Garden City, NY. These sites have provided operational service for the four major terminal areas since 1994.[1] Specific capabilities used operationally by FAA and airline users, which are discussed in the next section, include:

1. Addressing radar data quality issues such as rain attenuation and AP-induced ground clutter contamination,
2. High update rates for detection of rapidly changing weather while also obtaining 3D information on storms,
3. Estimating 3D winds, and
4. Reducing the fraction of phenomena that are not accurately characterized because the radars can directly measure radial velocity only.

Section 3 discusses the operational usage of integrated products by NWS forecast offices at the ITWS demonstration sites. The paper concludes with a summary of the operational uses to date and makes some suggestions for NWS and USAF use of FAA radar sensors in conjunction with NEXt generation weather RADars (NEXRAD).

2. OPERATIONAL FAA/AIRLINE EXPERIENCE WITH JOINT USE OF NWS AND FAA WEATHER RADAR SENSORS

The principal operational experience with joint use of NWS and FAA weather radar sensors to date has been through the ITWS depicted in figure 1. Information on the ITWS is available in Evans and Ducot (1994) and on the worldwide web at http://www.ll.mit.edu/AviationWeather/ and http://www.faa.gov/aua/ipt_prod/weather/itws.

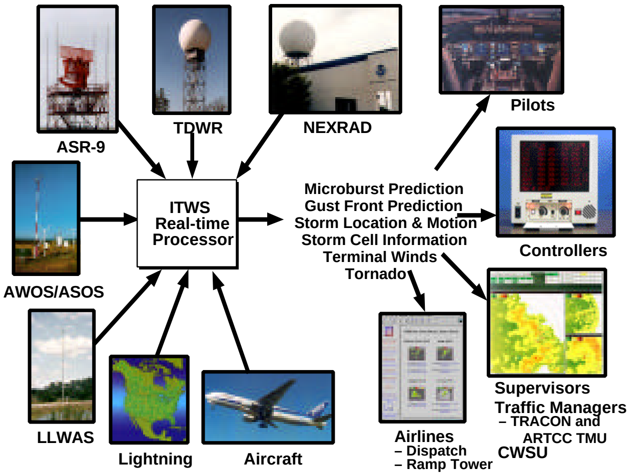

Figure 1. ITWS automatically combines weather data from a variety of FAA and NWS sensors to provide a suite of information products for improving airport terminal traffic flow management, capacity, and safety.

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[1] The New York ITWS was developed and is operated by MIT Lincoln Laboratory under a Cooperative Research and Development Agreement (CRDA) with the Port Authority of New York and New Jersey.

Use of data from multiple sensors can be achieved by means of integration at various levels:

1. User-level visual integration, wherein the user can view data from different sensors in different windows or view data overlaid in a single window (e.g., ITWS permits users to view precipitation products from the Airport Surveillance Radar (ASR), NEXRAD and Terminal Doppler Weather Radar (TDWR) in separate windows);
2. Product level integration without any automatic cross checking of the products (e.g., ITWS determines whether cloud-to-ground (CG) lightning strokes have occurred near a region of high radar reflectivity and provides a text message of lightning if the user clicks a cursor positioned over the area of reflectivity); and
3. Full data integration where data from different radar sensors are used to create new products that could not be created from a single radar.

We will consider the operational experience with each of these, in turn placing the greatest emphasis on the full data integration products.

2.1. User Visual Integration of Products on Separate Windows

Aviation decision makers have found simultaneous displays of information from the various weather radars to be operationally useful for validating information from a given radar and providing complementary information. For example, both the ASR-9 and NEXRAD are vulnerable to contamination from anomalous propagation (AP), and all three radars have experienced problems with rain attenuation. Since the radars have different locations, AP clutter contamination and rain attenuation do not usually occur in the same spatial locations. Similarly, the problems all radars have in characterizing the intensity of non-precipitating storms in the “cone of silence” is easily addressed by data from sensors at different locations. When the various radars provide confirming information on the location, movement and severity of weather, the users have much greater confidence in the overall product reliability.

This has been particularly evident in the use of NEXRAD data: FAA en route facilities, which previously had access to NEXRAD data only, tended to put a great deal of reliance on validation of the NEXRAD data with CG lightning stroke data displayed on the same screen. Although ITWS has the data on locations of individual CG lightning stroke available internally, the operational users have not requested that these locations be overlaid onto the radar reflectivity products since they could confirm NEXRAD data with ASR-9 precipitation data.

There currently are differences between the precipitation intensity as depicted by the various radars. Both the ASR-9 and the NEXRAD composite reflectivity are fundamentally vertically integrated products that generally show good agreement in summer convective weather. However, the NEXRAD maximum composite reflectivity can indicate severe weather erroneously when there is “bright band” contamination[2]. This “overwarning” of storm severity is of concern operationally since users will tend to use pilot reports from “scout planes” to validate a weather product that is not believed to be reliable. Such use of planes is not consistent with proactive avoidance of weather encounters. Thus, in such cases, the joint use of the ASR-9 and NEXRAD data is very helpful operationally.

On the other hand, some ASR-9 installations tend to underestimate significantly the intensity of a storm when it is near the ASR-9, (which is typically at the airport) due to the parameters of the ASR-9 site-specific clutter residue editing map (Crowe, et al., 1999). In such cases, the ITWS TDWR-based precipitation product is very useful in identifying cases of heavy precipitation that are not being depicted by the ASR-9.

Since the TDWR-derived precipitation product used by ITWS typically corresponds to precipitation about 200 m above the airport surface, it is much more useful than either the NEXRAD or the ASR-9 precipitation product in characterizing the precipitation reaching the runways, taxiways, and apron area. This characterization of precipitation reaching the airport surface should be of particular operational value during winter storms; however, there has been too little operational experience to date to determine such benefits.

The other major benefit of simultaneous display of various precipitation products is resolving the trade-off between high update rates and volumetric sensing. In locations such as Florida, which have very rapid air mass storm growth and decay (e.g., storm lifetimes of 15 minutes), the six-minute volume scan time for a NEXRAD is quite slow relative to the rate at which the storm changes. The very high update rate (30 second) of the ASR-9 has been very useful in identifying rapidly evolving weather near key locations such as runways and transition areas from the en route airspace to the terminal airspace.

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[2] The use of vertically integrated liquid water content (VIL) is under investigation as an alternative NEXRAD based depiction of storm severity

The operational benefit of the high update rates together with confirming weather radar information has been that ATC users have confidence that they will quickly detect cases where rapid storm development necessitates changes in routing planes and that they can advise the pilots accordingly, whereas with weather information that updates more slowly, ATC might feel that greater reliance must be placed on pilot-initiated weather avoidance.[3]

2.2. Product Level Integration on a Single Window with No Cross Checking of the Information

Where two radars have very different capabilities, one can provide complementary information on displays that facilitate the operational user's decision making. The basic ITWS TRACON precipitation window provides several instances of this. First, wind shear locations (microbursts and gust fronts) derived from the TDWR are overlaid onto the ASR-9 precipitation products. This enables the users to quickly see both rapidly developing cells throughout the terminal area at the same time as wind shear locations. The gust front product explicitly show movement; movement of microbursts can be inferred by observing the motion of the parent cell's precipitation.

The radar echo tops and whether there is lightning associated with an ASR-9 precipitation cell are provided by a pop-up window that opens when the user clicks on a cell. Here again, information on the movement of lightning activity can be inferred from the displayed motion of the corresponding radar precipitation cell. This motion information has been useful operationally in providing an indication of when CG lightning might impact aircraft boarding and refueling at the airport.

It would have been possible to provide echo tops and lightning stroke information as additional overlays to the basic precipitation intensity and wind shear location information. However, this would result in a very cluttered display that the ATC users considered operationally undesirable.

2.3. Data Level Integration of Multiple Sensor Data

Visual integration of the products can in some cases require the user to make fairly sophisticated mental computations to determine the desired products. This is probably well beyond the capabilities of the ATC users In most cases. Hence, numerical algorithm integration is operationally necessary.

The most notable case of the need for numerical data fusion algorithmsis the ITWS terminal winds product (Cole and Wilson, 1994). Information on the winds aloft is critical to determining the time-of-flight for aircraft which must be merged and sequenced. The ITWS terminal winds product[4] initially was intended for terminal automation systems. However, it was discovered that controllers could use the results of the gridded product, provided as a table of vector winds at various altitudes above ATC fixes, to manually determine aircraft spacings aloft that are required to achieve the desired spacing on final approach (Cole, et al., 1997). The delay reduction provided by this product is expected to be over $70 M per year when the ITWS is fully deployed operationally (Evans and Wolfson, 2000).

The ITWS TRACON precipitation product has been given very high operational effectiveness ratings by the ITWS users due to its high update rate and coverage over the entire terminal area of "large TRACONs" such as Dallas and New York. This high degree of operational effectiveness has been possible only through the combined use of similar <u>and</u> dissimilar radars. Since the AP contamination on an individual ASR-9 radar changes relatively slowly in time, the data from the comparatively slowly updating TDWRs and NEXRADs can be used to edit out the AP on an individual ASR-9 radar. The AP-edited data from the various ASR-9s is then mosaiced (when possible) to provide the resulting TRACON precipitation product. The mosaic product improves on the individual ASR-9 precipitation products in several respects:

- Less underestimation from cone-of-silence or attenuation due to precipitation, beam blockage, hardware malfunctions, or excessive clutter residue editing.
- Reduced AP clutter residue (when there is coverage from at least three ASR-9s).
- Greater spatial coverage.

A similar mosaic algorithm is being researched for the ITWS NEXRAD precipitation product in view of the operational benefits obtained with the ASR-9 mosaic.

Overall, the ATC and airline operational use of the joint radar ITWS products at the various

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[3] The study by Rhoda and Pawlak (1999) suggests that pilots do not have particularly good awareness of storm severity from their airborne weather radar when nearing the runways.

[4] This product is generated through multiple Doppler weather radar analyses that also use aircraft reports, surface sensors and RUC data (Cole and Wilson, 1994).

locations has been fairly similar, with the exception of the ITWS terminal winds product which is much more important operationally at New York due to the characteristics of the coastal storms and the need to optimize runway usage during instrument meteorological conditions.

3. NWS FORECAST OFFICE USE OF FAA RADAR SENSOR DATA IN CONJUNCTION WITH NEXRAD

The ATC and airline-oriented products from the ITWS demonstration systems at Orlando, Memphis, Dallas and New York have been provided in real time to the local NWS forecast offices that operated the NEXRADs used by the ITWS. This product distribution to the NWS offices was determined to be necessary because the ITWS demonstration systems were generating advanced tornado and mesocylone products that had not yet been installed on the NEXRAD Radar Product Generator (RPG). These demonstration displays (which are not planned for the production ITWS system) have offered an opportunity to gain operational insights on how an NWS forecast office might utilize the FAA radar sensor data.

The greatest operational benefit was clearly realized when the forecast office NEXRAD was down for repair or maintainence and significant weather occurred in its coverage region. In such cases, the products from the FAA radars were clearly very helpful in enabling the forecast office to issue appropriate severe weather warnings.

The most aggressive operational use has been by the Melbourne, FL NWS office which routinely uses ITWS products to amend their terminal aviation forecasts (TAFs) and to issue local airport advisories for high winds. A three-year study was done on the use of ITWS, and one of the recommendations made was that if a 35-knot microburst or greater were detected/displayed on the SD within 5 nm of MCO, the forecaster should issue an airport advisory. The gust front product is watched closely to determine what the winds are going to be at MCO. Some of the NWS users open multiple windows on the ITWS display to monitor weather at different locations simultaneously. Forecasters also use the ITWS storm cell information to check whether a cell contains severe hail and/or severe storm circulation.

By contrast, at the Memphis, TN forecast office, the ITWS products are not used to generate severe weather warnings; however, they are used to “keep up with” the current weather situation, and the aviation forecaster (the desk where the ITWS display resides) can assist the warning forecaster by pointing out areas of concern. It is also used by the aviation forecaster as the “prime radar” in updating the TAFs, as it has a much higher update rate than the NEXRAD. Also, for this reason they use ITWS wind shear products, including the gust front product, to issue high wind advisories for the airport (when winds are expected to exceed 40 knots).

The Ft. Worth, TX forecast office has found the ITWS products very useful for providing severe weather surveillance when the NEXRAD is down. Additionally, the ITWS microburst product has been useful operationally for warning of storms that may becoming more severe.

Local forecast office operational use of products from the NY ITWS has been very limited. The principal use has been the gridded winds product output to make aviation weather forecasts.

Clearly, there have been significant differences in the operational use of the FAA weather radar data at the various NWS forecast offices. At some locations (e.g., New York), the NWS forecasters have indicated that they would prefer to have access to the “base data” from the TDWRs and make their own interpretation rather than using the ITWS algorithm outputs.

4. SUMMARY

This paper has reviewed the operational, joint use of NWS and FAA radar sensor data to make important aviation weather decisions. It is clear that the non-meteorologists, typified by the ATC and airline users, have found such use of information via separate display windows, overlays on a single window, and output from data-level integration algorithms all very useful. We believe that these operational benefits also would apply to other non-meteorologist decision makers such as emergency management services. For example, the New York City Office of Emergency Management has expressed great interest in a graphical depiction of the NY ITWS terminal winds product surface winds when there are chemical spills/gas releases and damaging winds from ocean storms or hurricanes.

There have been significant operational benefits from the ITWS joint-use radar products at some NWS forecast offices. However, there is also a significant NWS interest in access to the “base data” from the TDWR so that the forecast office meteorologists can fully utilize their data interpretation skills.

One of the important issues to be addressed by the NWS will be whether the NWS would want access to both the ITWS products and the base data from the FAA radar sensors used by an ITWS. At this point, there is no plan for access to the ITWS products for the NWS (albeit, it is expected that they will be available to airlines on the CDMnet (Maloney, 2000). We suggest that some experiments be carried out where forecast offices with access to the demonstration system ITWS products also be provided access to the base data to determine the NWS operational requirements and potential benefits.

The USAF has a number of bases which are relatively close to an ITWS or ASR-9 Wind Shear Processor (Weber and Stone, 1995). The USAF operational weather decision makers include meteorologists with responsibilities similar to those of the NWS forecast offices as well as aviation operations personnel who would be in roles similar to those of the ATC and airline users. The ITWS/ASR-9 WSP products would appear to be particularly well suited for use by the USAF aviation operations personnel.

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