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THE AVIAN HAZARD ADVISORY SYSTEM (AHAS): OPERATIONAL USE OF WEATHER RADAR FOR REDUCING BIRD STRIKE RISK IN NORTH AMERICA.

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Abstract

The Avian Hazard Advisory System (AHAS) was developed to use NEXRAD weather radar data and National Weather Service (NWS) weather data to forecast and monitor bird activity. The monitoring of birds in near real time uses algorithms developed by Geo-Marine, Inc to isolate biological targets from weather. Removing the weather returns permits subsequent processing to retrieve information on bird strike risk to be fully automated. Development of additional algorithms to isolate specific classes of biological targets is underway. These new radar datasets are in Geographic Information System (GIS) format and are being used for improving bird strike risk models and for conservation and ecological applications.

Key Words: Avian Hazard Advisory System, AHAS, Doppler Weather Radar, NEXRAD, Forecasting, Bird Avoidance Model, BAM, Weather Suppression Algorithm, Web page

Background

The United States Air Force (USAF), in common with other air forces in the world, has a long history of radar tracking of biological targets. (Blokpoel, 1996) Many studies have focused on the use of radar to reduce bird strikes with aircraft. In the late 1980's the USAF BASH Team funded research to determine the potential capability of the NEXRAD weather radar network as a source for near real time hazard advisories. Work conducted by Dr. Ronald Larkin, University of Illinois, concluded that NEXRAD Doppler radar could identify bird targets and that data could be processed to identify hazardous conditions. This initial investigation was conducted from 1985 through 1991 and a final report was presented in 1994 (Larkin 1994). This work resulted in algorithms for detecting migrating waterfowl, roost ring echoes and broad front migration and was demonstrated on the CHILL radar.

The work was not pursued after 1995, mainly for cost reasons, associated with the certification of the algorithms for use on a NEXRAD radar. However other limitations of the approach were now known which would make the approach operationally difficult for the USAF to use. For example the 4th Wing based at Seymour Johnson AFB in NC has direct access to data from the Raleigh Durham, NC, NEXRAD site. However, almost all of the low level training conducted by the base is located outside of the radars coverage. Even with bird detection algorithms a single NEXRAD site could not monitor the bird activity that threatens one of the primary low altitude-training units in the lower 48 states. A NEXRAD PUP has dial up access to other radars but many low level routes cover three or more radar coverage areas. Gaining the big picture from algorithms at single NEXRAD sites would be difficult.

The Avian Hazard Advisory System

Geo-Marine, Inc started an in house study in late 1995/1996 to investigate the use of NEXRAD as a part of an integrated system to manage bird strike risk. The study identified the key requirements for an effective system to manage bird strike risk for USAF low altitude training. It was found during this process that a near real time bird warning system, that would recall aircraft after birds had started moving and subsequently detected by NEXRAD would not meet USAF requirements. The major costs associated in low-level training occurred before the aircraft took off in maintenance, the fuel to get airborne, and mission planning by the aircrew. All was effectively lost when a mission was aborted. An effective system had to provide 24 hours warning, so that crews could plan to use alternative routes, ranges and mission profiles. Near real time monitoring information from a radar was required to confirm that alternative plans would have to be used and as a backup for a forecast that failed to identify a hazardous movement.

The Avian Hazard Advisory System (AHAS) was the result of the study by Geo-Marine, Inc, and the input of Air Combat Command Flight Safety (ACC/SE) and the 4th Wing at Seymour Johnson AFB. AHAS was structured to meet the requirements of USAF low altitude training units as an Operational Risk Management Tool (ORM) for bird hazard reduction.

The function of AHAS is not to eliminate bird strikes, but to reduce the hazards associated with a bird strike. The impact forces of a bird strike increase with the mass of the bird. Many of the vulnerable structures of military aircraft such as canopies and engines are engineered to withstand a high-speed impact from a small bird. Small birds are the most abundant avifauna in the atmosphere and therefore the most frequently struck. Their low body mass causes strikes that produce very little damage and consequently little risk to the pilot or aircraft. The loss of life and catastrophic damage to military aircraft conducting high-speed low altitude training is the result of collisions with birds with a body mass greater than 3lbs. The study showed that only a small number of bird species (11) created the majority of the risk (>95%). The number of strikes with these species is also very low, just a few hundred, compared to the 3000+ strikes reported each year.

The role of AHAS is to:

A) Forecast up to 24 hours ahead of time the activity of the 12 species considered to be a serious hazard to USAF training and provide advisories for all the published low altitude-training areas.
B) Monitor in near real time all species detectable by NEXRAD and provide advisories for all the published low altitude-training areas.
C) Archive data in a format accessible by a Geographic Information System (GIS) for improvement of the United States Bird Avoidance Model (US BAM)

The US BAM is a GIS based computer model for depicting the bird strike risk to low altitude aircraft operating in the lower 48 states and is used as a long range mission planning tool. The model is based upon survey data for the distribution of 60 + bird species frequently involved in bird strikes with low altitude training aircraft. The limit of this approach is that it can be overly restrictive on military training. For example a migration of waterfowl that past records indicate can occur any time during a one-month period will actually only take place on nights with suitable winds, visibility and other meteorological conditions. However like a weather almanac it is a very useful tool for long-range mission planning and as a source of spatial and temporal bird strike risk data used in AHAS.

The forecasting of bird activity within AHAS is divided into two groups, migratory and soaring birds. Neural networks are used to predict the likelihood of birds such as geese and swans migrating from known stop over locations based upon weather observation and forecast model data from the National Weather Service. When conditions are suitable for migration a warning is posted for every route segment, range or other training area that the birds will pass through.

The vertical distribution of soaring birds is determined using standard meteorological calculations for the height of the atmospheres boundary layer. The deeper the boundary layer, the lower the overall risk of a strike with a species such as a turkey vulture. Essentially the higher the birds can fly the more diluted they become in the training airspace. An area with a large number of vultures and weak thermals is more of a threat to low altitude aircraft than an area with an equal number of vultures distributed through a greater vertical extent. Measuring the depth of the boundary layer and using it to find concentrations of soaring birds is an important aspect of AHAS. The point target weather suppression algorithms used to remove “noise” from the radar display nearly always prevent NEXRAD from detecting soaring birds.

The AHAS system uses a broadband satellite data link to gather weather data and NEXRAD weather radar data from the NEXRAD Information Distribution System (NIDS). Due to budget constraints AHAS was designed to use commercial data streams and whenever possible commercial off the shelf equipment.

The near real time monitoring system takes the incoming NIDS data stream and converts the incoming data stream to GIS raster image files. The data is rasterized at the 1 x 1 km resolution of the radar data. The raster image from each site is merged into a very large regional mosaic. Mosaics are created in-house because commercially available products do not have 1 x 1 km resolution or many of the safeguards used in our process to preserve the data produced by the radar. For example the data preserves reflectivity values in the mosaic image regardless of if the radar was in clear air mode or precipitation mode. Each mode has only sixteen levels of reflectivity. Clear air mode 16 levels in the low and middle range of reflectivity and precipitation mode at higher levels of reflectivity. In the middle of the reflectivity range the reflectivity values in each mode are not exactly the same. The values encoded in the mosaic image can store 256 levels and preserve all the values found in the two modes rather than force them to a new set of sixteen levels, drop or average values. This ensures the highest quality data is available for additional processing.

The work of Larkin used algorithms to process data looking for biological targets. This requires specific algorithms to look for specific classes of targets. This is an intensive process on weather radar that is optimized for detecting precipitation and atmospheric particulates to indicate wind flows.

The majority of returns on NEXRAD are meteorological or non-biological in origin. AHAS took a different approach and sought to classify all the targets that were meteorological or non-biological in origin. Meteorological targets can easily be recognized by most observers with a modest level of training with weather radar so are relatively easy to classify as meteorological in origin even if the type of weather they relate to takes more skill to recognize. Another advantage is that large numbers of highly skilled observers are available to ground truth weather targets 24 hours a day, seven days a week, through the NWS. It is therefore much easier to confirm the presence of weather than it is any other target type.

By removing all other target types one can assume, through this process of elimination, that all or the majority of targets that remain, are biological in origin, birds, bats and insects. AHAS currently relates these positive biological detections to other spatial and temporal data sources such as the US BAM. A positive detection in an area known to include migratory birds is flagged as hazardous and an advisory is issued. In the near future as the archive of known radar targets grows, computer processing speeds increase and refined neural network processing techniques are refined, a new processing technique will be introduced that will further sub divide categories of biological targets.

The image classification techniques that are currently used to remove non-biological targets rely heavily on the reflectivity values and the horizontal and vertical extents of weather returns to determine the target type.

AHAS was demonstrated to HQ Air Combat Command (HQ ACC) during the fall of 1998 on a small number of low altitude training locations in the eastern United States. This successful demonstration used commercial off the shelf software and minimal programming to process the data from thirty NEXRAD radars and NWS forecast and observation data. Advisories were posted hourly to the Internet at a leased server off site.

Funding for phase two was secured in 1999 while Geo-Marine, Inc pursed development of the AHAS concept and the new radar algorithms using in-house funding. In late 1999 the AHAS infrastructure was expanded to include additional and faster computer processing to accommodate all published low-level training areas and military airfields in the eastern United States. The Internet server was moved in-house to eliminate the time consuming process of transferring data off site. Once data had to be updated for over 2000 areas per hour it was no longer practical or efficient to move the data offsite.

AHAS went fully operational in the eastern third of the United States in February 2000. USAF pilots and other DOD aircrews can now access the extensive database behind AHAS through a simple web page, with a browser and an Internet connection. If a data request is received for a time period in excess of twenty-four hours from the time of the request, the data is retrieved from the US BAM database. If the data is from a period more than an hour ahead, but less than 24 hours, then the bird strike risk data comes from the AHAS forecast database. A request for data in the current hour retrieves the latest observation from the AHAS system, which includes the NEXRAD radar observation. The only input required by the pilot is the airspace, date and time to evaluate. The AHAS system server does all other processing and database selection automatically.

Discussion

In the fall of 1998 when the AHAS test program was underway and again in the fall of 1999 while AHAS was undergoing system expansion major migratory movements that impacted large areas of the United states were accurately predicted days in advance despite them being unseasonably late due to El Nino and La Nina. Warnings were issued and USAF flying curtailed. It is impossible to say that strikes were prevented by these actions. However these are exactly the circumstances under which many aircraft and lives have been lost in the past. A static system such as the US BAM cannot predict when out of normal range events will occur. The AHAS forecasting system has so far proved to be robust under such circumstances.

A civil version of AHAS is now being discussed with the FAA. The expansion of the AHAS concept to Canada is the next logical step as they have many of the birds affecting the US before the fall migration and the US birds before their spring migration. This type of International cooperation is currently being discussed spurred by the successful AHAS demonstration.

Despite years of research into using radar as a means to manage bird strike risk the successful use has been very limited. Examples of successful usage are to be found in Germany and Holland. The use of a large network of radars over such a vast area for bird hazard operational reduction is unprecedented. However the success of AHAS is more a function of radar being a part of a system. Radar has some serious limitations in target recognition. Biological targets can be detected but the risk they present to aviation cannot always be discriminated by parameters measured by the radar alone. AHAS plays each technique (BAM, spatial datasets, forecasts and radar processed data) to it’s strengths and offsets the weakness with another technique. The lack of soaring bird detection by the current NEXRAD radar is offset by measuring the boundary layer of the atmosphere and using that data with the spatial distribution found in the US BAM to calculate risk.

In the future as the biological targets isolated in AHAS can be further classified to different target groups allowing the application of radar data to environmental monitoring to become more common. Because the AHAS data exists as GIS datasets much more powerful spatial analysis techniques are possible. Radar data describing bird and other biological target activity can be related to landscape level features such as topography, land cover, hydrology at 1km resolution across the United States. This makes possible many spatial studies that were too difficult and time consuming to achieve with photographs of radar displays or simple graphic images. Geo-Marine, Inc is now developing new methods that significantly improve the techniques for processing of radar data for long-term time series analysis. The savings in time and money can be directly translated into improvements in the detail, range and number of analysis, which will be possible in the future.

References

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