DIS/SE/04

Real-time hurricane monitoring onboard NOAA aircraft

FY 2005 Proposal to the NOAA HPCC Program

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Proposal Theme: Crisis / Disaster monitoring or response

Funding Summary:

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Real-time hurricane monitoring onboard NOAA aircraft

Proposal for FY 2005 HPCC Funding

Prepared by: Mark D. Powell, Sonia Otero, and John W. Hill

Executive Summary:

Every hurricane season, scientists of the Hurricane Research Division (OAR/HRD) participate aboard of NOAA's aircraft (WP-3Ds and G-IVs) on reconnaissance, surveillance and research flights of tropical cyclones. Those flights provide hours of valuable flight-level, dropsonde and Stepped Frequency Microwave Radiometer (SFMR) observations that are sent straight to the ground without the ability to instantaneously plot them in a storm-relative map as they are collected. Partnering with Aircraft Operations Center (OMAO/AOC), we propose to study the feasibility of developing a real-time monitoring application that accepts aircraft feeds, and could eventually be made operational. We envision taking advantage of present aircraft network infrastructure so that each airplane can view not only its own data but also any collected data from simultaneous operating airplanes.

Problem Statement:

NOAA's hurricane research aircraft fleet, comprised of two WP3D Orions truboprop and a Gulfstream IV jet, conduct over 200 flight hours of research each year and also hundreds of hours of additional reconnaissance and surveillance flights into tropical cyclones. Real-time data are sent to the National Hurricane Center through a relatively low bandwidth satellite data link. While rudimentary onboard plotting capability exists, the observations are not presented in a storm relative sense nor is it possible to display information from other aircraft simultaneously investigating the storm. Since many research missions involve coordination with multiple aircraft (typically NOAA, Air Force, but also NASA and Navy), it is very important that the lead scientists and flight directors be able to monitor measurements of all aircraft involved in an experiment or reconnaissance mission. Currently this is not possible. Coordination is done by the flight directors and navigators aboard the different aircraft via radio communication, but the scientists on one plane have little feedback on the scientific information relative to the particular mission from the other plane. For example, a two aircraft mission may involve aircraft flying a "figure 4" pattern at two different altitudes. The wind field structure may vary at each altitude. The high aircraft may sample wind maxima on the North side of the storm while the low aircraft may sample wind maxima on the South side. If observations from each aircraft were available to each other, scientists on board could interpret the information during the experiment and work with the flight director to adjust the flight pattern accordingly. In this particular example, the locations of the wind maxima may indicate a wind shear pattern that could be investigated with GPS dropsondes at strategic locations. In addition to the ability to view and interact with each aircraft's observations, there may be opportunity to include ground truth measurements in the data stream. Since NOAA aircraft often test new instrumentation for remote measurement of physical processes at the surface, this is an important feature. For example, microwave radiometer surface winds measured by each aircraft in a two-plane mission could be plotted relative to each other, to GPS dropsondes, and recent NOAA C-MAN and moored buoy stations. It would be immediately obvious whether any problems were existent with the measurements collected by the instrument by comparing it to neighboring observing platforms. The proposed application brings scientific benefits of an adaptive integrated ocean and atmospheric observing system to the aircraft, where onboard scientists can diagnose storm structure and intensity.

Proposed Solution:

NOAA's WP-3Ds are already equipped with an intranet Ethernet network, and with two satellite communication systems (SatCom) on each airplane. One is a 9600-baud connection to an Internet Service Provider, and the other is a 2400-baud connection. The former is the one recommended as it is the most consistent and reliable for sending incoming and outgoing data via FTP downloads. One WP-3D obtained its SatCom system courtesy of a previously funded HPCC proposal (Marks, 2001).

Two types of data messages of particular interest are collected in the aircraft: MINOB and TEMPDROP. The acquisition of these data has not been designed for easy distribution on the airplane's network, since the primary goal has been to push them to TPC/NHC's data server. To access MINOBs, the current mechanism consists of parsing parameters from the aircraft's serial ASCII data stream over a 1Hz, 9600 baud, RS-232 connection. For TEMPDROPs, no mechanism exists. Nevertheless, OMAO/AOC can implement the necessary changes to make both messages directly available on the network.

For the onboard monitoring application we will use technology developed for the OAR/HRD Real-time Hurricane Wind Analysis System (H*Wind), winner of 2 HPCC awards. H*Wind is a distributed system that ingests real-time atmospheric observations (from all over the world) measured by land-, sea-, space-, and airborne platforms into an object-relational database, adjusts them to a common framework, and offers graphical capabilities and research tools to display the data relative to the storm so scientists can quality control, objectively analyze, and visualize the information. H*Wind's greatest strength is the ability to quickly evaluate and analyze observations from many diverse observation platforms. For aircraft purposes, the application will be stripped of the analysis package and the input reading module will be modified to accept ASCII flat files. The application will retain the features of zoom in/out, location, coordinate transformation, circulation center estimator, distance/heading calculation, surface adjustment and individual inspection of observation properties. Given the storm-relative plotting requirement, equally important is the ability to construct storm tracks by either manually entering coordinate positions or by viewing positions gathered by participating aircraft. In addition, scientists would like the ability to display derived or non-wind quantities: height of the pressure surface, mixing ratio, equivalent potential temperature.

OMAO/AOC will provide an aircraft server to host the Java client application. Scientists who bring their laptops to the aircraft could connect to the network and download the application. This server would also act as an intranet web server from which to launch the application via Java Web Start or run a web applet, and thus, facilitating centralized application deployment.

Given the 9600-baud bandwidth, much work by OAR/HRD will be devoted to the research of compression techniques and maximizing incoming and outgoing throughput over full 1-minute transmission periods, without disrupting operational regular transmissions. During this hurricane season, the common practice of OMAO/AOC has been to keep the SatCom connection open over the entire flight ($70/hour), and continuously stream the serial ASCII feed via UDP (User Datagram Protocol) broadcast. This appears to decrease reception delays or gaps. In this competitive environment it takes around 1 minute to transfer 1KB of data, which is expected to be the maximum size of any periodic transfer intended for the application's input.

The network link common to all aircraft lies at TPC/NHC's data manager server, which is already accessible by OAR/HRD scripts. In addition to flight-level data from other participating aircraft, other data platforms could accompany the compressed bursts ftp'd to a host aircraft. Initially, the application would only be used to plot and interact with, in order of priority:

1. Onboard MINOB (flight-level data) on host P-3 aircraft
2. Onboard TEMPDROP
3. MINOB from 2nd P-3 aircraft
4. TEMPDROP from 2nd P-3 aircraft
5. HDOB (flight-level data) from Air Force C130
6. Moored buoys
7. C-MAN platforms
8. Drifting buoys

Depending on the success of this feasibility project, additional observing data platforms and onboard real-time Doppler radar wind fields could potentially be added.

We foresee the following list of major activities:

- OMAO/AOC would modify MINOB and TEMPDROP distribution for easy access on aircraft network.
- OAR/HRD would study and test efficient transmission timing patterns from aircraft to ground.
- OAR/HRD would code a simplified H*Wind plotting application to accept local and SatCom feeds.
- Test application on a simulated environment at OAR/HRD.
- Test application on a WP-3D aircraft on the ground.
- Test whole system on at least one training mission next season.
- If this pilot project is successful, both groups will collaborate on a follow-on proposal in FY2006 to implement similar infrastructure on the other WP-3D and on the G-IV aircraft.

Analysis:

This proposal seeks to combine experience and resources gained through several years of funding, while pushing technology available even further in more extreme conditions. The hardware involving the network and the communication systems on the aircraft was studied by OMAO/AOC prior to 2001, and it has been upgraded subsequently as OMAO/AOC found feasible. Therefore, it is assumed to be the best possible option nowadays in terms of efficiency and affordability. Obviously, the SatCom systems currently installed on the WP-3Ds could not be by any means considered high-speed Internet access. OMAO/AOC has recently outfitted the

G-IV with a "high-speed" 64K-baud SatCom system (released to the market late last year). But, being one of few customers using the system in a non-conventional way, their frustrations and feedback are serving to debug and refine the system, while being far from reliable for operational use. Understanding the need for better air-to-ground communications support, OMAO/AOC has budgeted a similar effort to equip one WP-3D with better bandwidth for FY2006.

Regarding software options, Java continues to be chosen because its write once, run anywhere strategy lends itself to development and maintenance of one set of code for a wide variety of computing platforms. Four hurricane seasons have passed in which H*Wind has been actively used for real-time quality control and surface wind analysis by OAR/HRD personnel from Macintosh, Windows, Linux or HP-UX operating systems. At a rate of approximately 120 analyses per season, the software has evolved to match users' growing requirements with major revisions designed to improve content and friendliness. The developers of H*Wind have acquired significant expertise on client-server and J2EE (Java 2 Enterprise Edition) architectures.

The greatest benefit to be achieved is to increase the productivity and effectiveness of experiment or reconnaissance missions, by improving coordination among lead scientists and flight directors of all aircraft involved. In addition, when tasked operationally, these aircraft become the "eyes and ears" of the National Hurricane Center. An onboard integrated observing system will enhance the ability of onboard scientists to perform reconnaissance and diagnose hurricane structure, motion, dynamics, and intensity.

Our research goals are consistent with the National Academy of Sciences (1996) report, "Computing and Communications in the Extreme" which identified challenges confronting crisis managers, including: 1) "need for cooperation among many different actors", 2) "need to rapidly identify, collect, and integrate crucial information about the developing situation", and 3) "capability to make projections and initiate actions in the face of an inevitable degree of uncertainty and incompleteness of information".

Performance Measures:

Milestones:

- Month 2 – OMAO/AOC sets up hardware for aircraft server, and makes MINOB and TEMPDROP messages available on a network port.
- Month 4 – OAR/HRD will develop programs to read local stream, along with establishing a flat-file directory structure.
- Month 5 – OAR/HRD will implement framework for handling compressed data in satellite transmissions, while evaluating timing patterns.
- Month 6 – OAR/HRD will implement simplified H*Wind to read flat files, and test multiple-aircraft scenario at HRD's simulated environment.
- Month 8 – Test system aboard WP-3D on ground at OAMO/AOC (Tampa, FL).
- Month 10 – Test on calibration flight.
- Month 11 – Finalize debugging/troubleshooting learned from all tests.
- Month 12 – Train personnel. Publish application's User's Guide.

Deliverables:

- Source code to handle aircraft's local data stream and compressed SatCom transfers.
- Linux web server to host application on the network of a WP-3D aircraft.
- A Java application, launchable or runnable over the web, capable of comprehensively integrating observations from several observing platforms, plotting flight-captured data plus some ground measurements in a storm-relative or earth-relative mode.

Project References:

- Marks, Frank D., 2001, "Development of a Prototype Wireless-Based WLAN Technology on the NOAA WP-3D Research Aircraft", FY 2001 Proposal to the NOAA HPCC Program.
- Powell, Mark D., 2003, "A Scientific Web-based Application for Global Tropical Cyclone Monitoring", FY 2003 Proposal to the NOAA HPCC Program.
- H*Wind home web page: http://cat5.nhc.noaa.gov
- http://java.sun.com