Semiannual Report on JHT Project entitled:

Real-Time Dissemination of Hurricane Wind Fields Determined from Airborne Doppler Radar Data

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Accomplishments:

1) PI became familiar with HRD radar software used to access raw information recorded by the P3 radar systems.
2) Software developed to remove the reflection of radar power by the sea surface. The preliminary testing has indicated success in this task.
3) Software developed to remove speckles of data that may be near the signal to noise ratio, and yet have an inordinate effect upon the radar analysis.
4) Several minor bugs that affect the single-ray de-aliasing software in HRD code were discovered and repaired. This has helped the automatic de-aliasing somewhat.
5) Development of two-dimensional de-aliasing software has just begun.

Discussion:

The goal of this JHT project is to provide information to the National Weather Service regarding winds in three dimensions near the core of the storm using the airborne Doppler radar. The expertise to synthesize quality-controlled Doppler measurements into three-dimensional analyses is already well developed at HRD; however, the means to quality control has always been from using "black box" software from NCAR, and doing much of the quality control manually, using people qualified to make judgments about which data are actually artifacts or will contribute to errors in the analysis. The analyses are also completed over a period that may span months or years, affording the analyst the luxury to mull over the data. Thus the analyses are performed in a laboratory using computers on the ground. Consequently, the major tasks to be accomplished to provide real-time data are 1) automatic quality control, 2) production of analyses aboard the aircraft, 3) successfully transmitting "superobs", (useful intelligent averages of the data that can be utilized by model assimilations) from the aircraft, and 4) transmitting and depicting the analyses conveniently for the very busy hurricane specialist.

For the P.I., the first major task was becoming familiar with the software that is employed regularly to ingest airborne radar data into analysis and depiction programs. Previously most of this software was not used for airborne Doppler analysis research, and instead the NCAR/ATD SOLO package was used to prepare data for ingestion into the Doppler radar interpolation. SOLO is a research tool, but is not designed for real-time quality control, nor is it software presently understood completely by HRD scientists and programmers. Since SOLO was not developed at HRD, it was decided that the best plan was to modify HRD software that could directly read data written by the onboard AOC/SIGMET radar-data collecting software. Software written to ingest this data stream would be modified to include automatic quality control, and then the three-dimensional analysis code would be modified to ingest the result of the quality control software and produce an analysis, as well as superobs.

The first software developed was to remove the reflection of radar data by the sea surface. This reflection will contaminate the analysis of precipitation intensity, since the reflectivity of the rough sea surface can be much higher than the precipitation above it. Also the motion of the capillary waves on the sea surface is much closer to zero than to the wind motion directly above, and thus the returned velocities are also a contaminant in the wind analysis. Software employed by Mr. Peter Dodge (HRD), developed originally by Jacques Testud of CNRS/CETP, France, and Wen-Chau Lee of NCAR/ATD to detect the ocean surface along each radar radial, was modified to remove the data from the surface and at all radii beyond. Since data in a given radar radial include scatter from objects located somewhat off the center of the beam, it was necessary to compare observations immediately above the detected surface to ensure that

they were not still contaminated by sea-surface reflectivity. Also included in surface-reflection artifacts are reflections of the side lobes off the sea surface. These appear as an annulus of artifacts approximately 2 km wide with a radius equal to the height of the aircraft above the sea surface. These are also removed in the new software. This software was developed and has been tested on two cases thus far. This addresses one of milestones in the project timeline.

In most airborne Doppler scans there are also data that are not continuous, but usually represent data collected at not much above the signal-to-noise ratio. These "speckles," if not removed, can reduce the effectiveness of the automatic Doppler de-aliasing ("unfolding") software and should be removed. First cuts at adding speckle removal look promising for the analysis. This addresses the same milestone as the tasks in the paragraph above.

Another milestone is to modify the three-dimensional software to ingest the automatically quality-controlled data stream. This is necessary in real time, and also for testing the quality control on a number of differing tropical-cyclone data sets. The ingestion has been tested on data obtained in Hurricane Humberto of 2001, and appears to be functioning properly.

For now the development of software to compress HRD wind analyses for transmittal over satellite data link has been postponed. It is possible that easily available software like "gzip" will be sufficient. Unless eventually desired by specialists, full analyses at many different levels will not be sent from the aircraft.

In the late winter and spring of 2004, the next major step in quality control is de-aliasing of the phase ambiguity in the airborne Doppler observations. To determine the relative velocity of airborne scatterers, the Doppler radar effectively compares the phase of reflected pulses with the expected return phase and determines a Doppler phase shift. In most past data sets, a phase shift of 180 degrees represented a relative motion of 12.88 m/s. Only phase shifts from –180 to 180 degrees can be measured unambiguously. Thus greater phase shifts from velocities higher than 12.88 m/s will be misinterpreted. The goal of the Doppler-analysis software is to prevent these misinterpretations. The high winds in the tropical cyclone, and the even faster motion of the aircraft, require an accurate "unfolding" of this phase ambiguity. Well established methods exist that can remove most of the ambiguity, but some remains. Methods will be tested in the coming months that require two-dimensional wind continuity in a contiguous portion of data within a radar sweep. These contiguous regions will be compared to the expected wind structure and intensity to ensure that these otherwise self-consistent regions are also consistent with the expected wind field. On the third page of this document analysis of data with the real-time quality-control software in its present state is compared to an analysis performed on data that was quality controlled manually by the PI. Some dealiasing errors can be seen particularly to the west of the circulation center, but the overall qualtity of the analysis is encouraging.

The integration of this software on HRD's airborne workstations will occur in the spring. The software will then be tested during the hurricane season. Analyses will be produced aboard the aircraft, but it is not expected that they will be made available in real time to the specialists until the 2005 hurricane season. Thus IT support to allow these analyses to be seen by the specialists on their equipment is not needed in the 2004 season, nor are they likely to be available online.

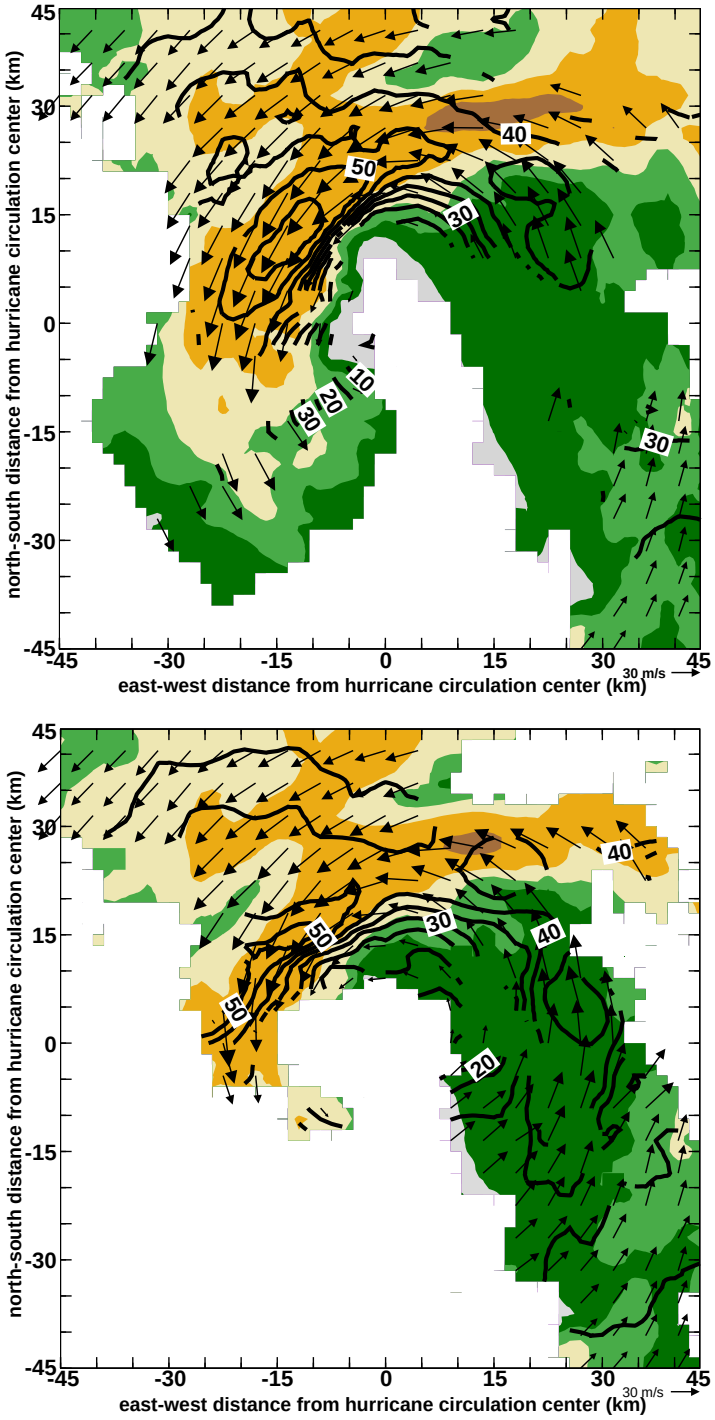
Next tasks:

1) Develop two-dimensional de-aliasing software
2) Begin discussions with EMC on how to make superobs most useful to them, including determining how to determine the best estimate of data error covariance for assimilation into numerical models
3) Migrate new software to airborne workstation

Future tasks:

1) Produce test Doppler-wind analyses aboard aircraft
2) Send a prototype superob from the aircraft by Oct 31
3) Develop capability to display analysis easily for hurricane specialist

Note: A possible adjustment to the 2004 hurricane-season timeline may be necessary if the software changes to the onboard radar data system by AOC are made without sufficient time for HRD to adjust.



Analyses of wind and reflectivity from a research quality data set (top panel) and from the automatic analysis software being developed for the JHT project. Analysis is from 2326 GMT on 23 September 2001. Contours are gray < 0, dark green 0-10, lighter green 10-20, 20-30 light brown, 30-40 orange, and brown 40-50 dBZ. Drawn contours display wind speeds in m/s. The research quality data includes data from both P-3 aircraft while the automatic analysis includes data from only one aircraft, One aircraft observed greater reflectivity than the other. Note, however, that the wind analyses are similar, which is a hopeful sign for the automatic Doppler analysis of the wind field.