7C.3 ADVANCES IN OBJECTIVE TROPICAL CYCLONE CENTER FIXING USING MULTISPECTRAL SATELLITE IMAGERY

Anthony Wimmers and Christopher Velden
University of Wisconsin - Cooperative Institute for Meteorological Satellite Studies
Corresponding author email: wimmers@ssec.wisc.edu

1. INTRODUCTION

Precise center-fixing of tropical cyclones (TCs) is critical for operational forecasting, intensity estimation and visualization. However, the large majority of TCs occur outside of the range of aircraft reconnaissance and other forms of direct observation, leaving the bulk of the task of TC measurement and characterization to satellite imagery. Routine satellite-based methods such as the Dvorak Technique (Dvorak, 1973) or the CIMSS Automated Dvorak Technique (ADT, Olander et al. 2004; Velden et al. 2006) require as a first step the location of the center of rotation in the TC. To this end we have developed an automated center-fixing algorithm, the Automated Rotational Center Hurricane Eye Retrieval (ARCHER), calibrated to passive microwave imagery and described in Wimmers and Velden (2010). The work presented here extends that methodology to geostationary longwave infrared (IR) and visible (VIS) imagery, explores additional metrics of positioning uncertainty, and applies the results to a more robust, multispectral, track-oriented center-fixing scheme. This leads to a capability that plays on the unique strengths of each spectral band to form a single position estimate; for example, the high precision of latent microwave imagery can be extended in time with the higher observation frequency of visible and infrared imagery.

2. METHODOLOGY

When applied to cloud-penetrating microwave imagery, ARCHER takes advantage of the curvature revealed in precipitation bands and organizing convective features to acquire a center fix. Similar curvature and cyclonically sheared patterns exist in IR and VIS imagery, but the patterns are often less obvious due to cloud debris, especially in weaker systems. Since a reasonably coherent level of organization is key to an accurate center-fix, we have developed an additional metric called the "Confidence Score," which quantifies the amount of axial symmetry in the ARCHER 'score' field. (The ARCHER score field is a gridded field of values that "lock in" to the rotational center of the observed patterns.) An example is shown in Figure 1.

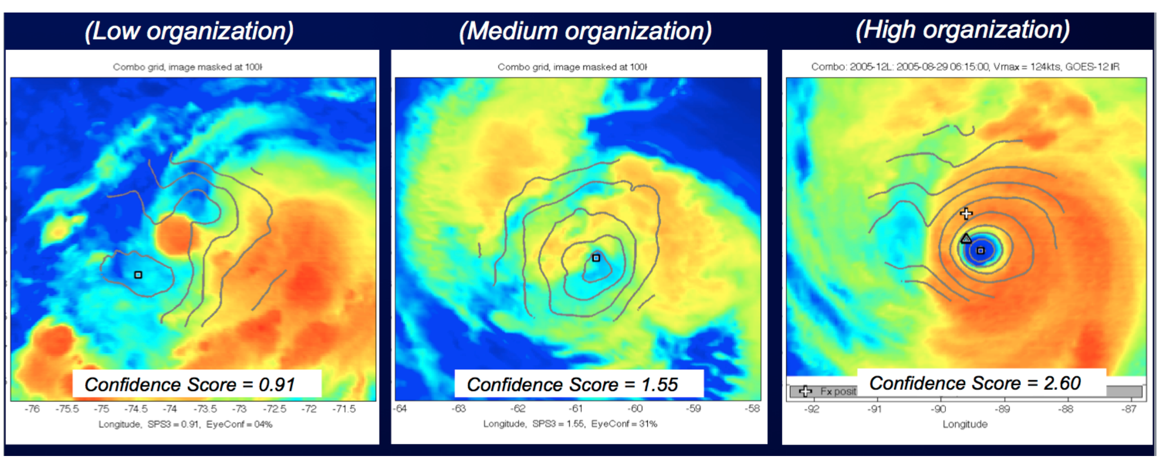

Figure 1. Examples of IR imagery yielding low, medium and high Confidence Scores corresponding to the amount of evident storm organization. Contours: ARCHER 'score' field.

In calibrating the IR Confidence Score to the ARCHER error relative to the corresponding best track position for all aircraft-validated cases in the North Atlantic from 2006-2010, we find that the error follows a Poisson distribution whose width varies proportionally with the Confidence Score (Figure 2). In addition, the IR error is on average 2-4 times higher than with microwave imagery, but we discuss in the following section that this can be partially mitigated with this knowledge of the center-fix precision.

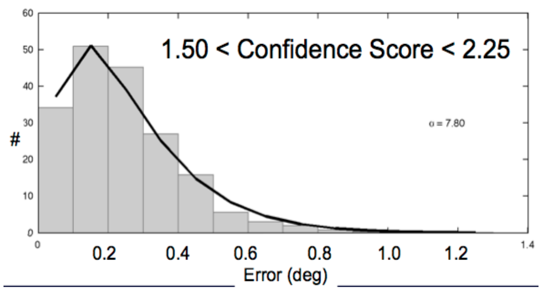

Figure 2. Histogram analysis of ARCHER errors for IR imagery when the Confidence Score is between 1.50 and 2.25. The black line is a best fit Poisson distribution with parameter α = 7.80.

Finally, we also apply fix history as a way to prevent large deviations in the current center-fix. A "persistence forecast" is used to favor positions that are consistent with the prior course of the storm center by following the previous ARCHER center-fixes relative to a warning center's forecast track (Figure 3). A second method involves using the most recent microwave observation's score field to provide additional information on the rotational patterns underlying the cloud cover (not shown).

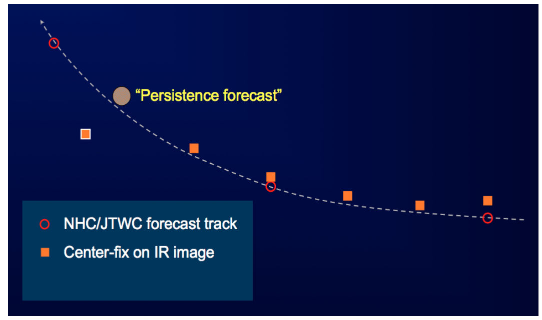

Figure 3. Demonstration of the persistence forecast approach. The persistence forecast is a weighted field centered on the position at a consistent offset from the forecast track, extrapolated to the time of the given IR image (where the corresponding initial IR center-fix is shown with a white border).

3. RESULTS AND OBSERVATIONS

Our calibration of ARCHER to IR and VIS imagery to the 2006-2010 dataset allows for a product with similar output as with microwave imagery, but with additional guidance about the precision of the center-fix. As shown in Table 1, the output includes the single parameter describing the expected Poisson-distributed probability density function, which can be converted to a probability of error within any given benchmark distance (for example, 0.2, 0.4, 0.6 or 1.0°).

Table 1: Example output from ARCHER using IR (center image from Figure 1).

Forecast position (lon, lat): -61.10, 36.70
Center-fix position (lon, lat): -60.81, 36.47
Error distribution parameter (alpha) = 6.39
Probability of error < 0.2° (%) = 36.5
Probability of error < 0.4° (%) = 72.4
Probability of error < 0.6° (%) = 90.0
Probability of error < 1.0° (%) = 98.8

The addition of track history and complementary microwave input can yield improvements in IR and VIS center-fix accuracy. The greatest advantages occur in 55 to 85 knot TCs, where the microwave image features are usually highly organized, but the cirrus canopy in IR or VIS imagery often obscures the core structures (Figure 4). This example (IR) shows the potential for a future center-fix product that operates at the temporal resolution of geostationary imagery and retains the accuracy of the occasional microwave center-fix. However, further work is needed to implement a consistently high-accuracy alignment between a given IR or VIS image and a microwave image with ~1-4 hours latency.

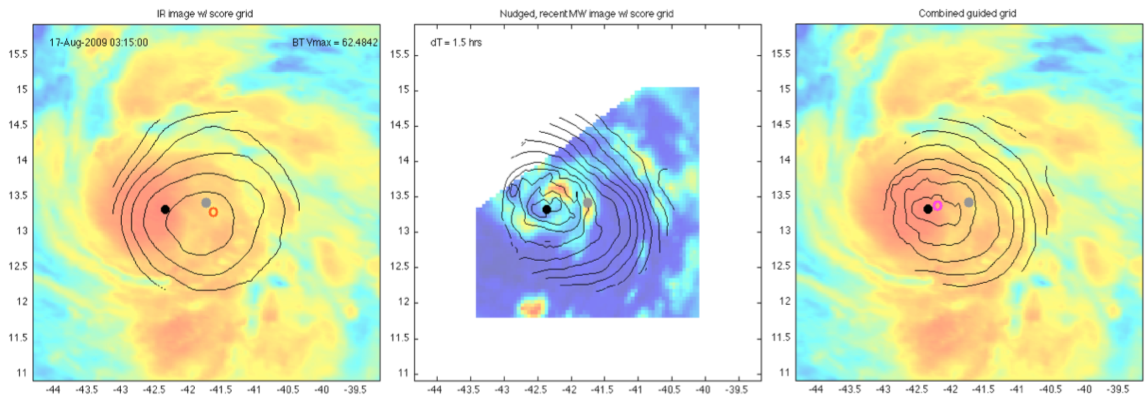

Figure 4. Left: Geostationary IR image for Hurricane Bill (2009) when at 62 knots max wind, with contours of the original ARCHER score field. Center: most recent (1.5 hrs old) 85 GHz microwave image from the TRMM satellite with ARCHER score field. Right: Same geostationary IR image with a combined weighted average score field from the IR and microwave image, showing an improved centering pattern. The right image also contains guidance from the "persistence forecast." For all images: Gray dot – forecast position ("first guess"), Black dot: Best track position ("truth"), Orange circle: Initial ARCHER IR center-fix, Magenta circle: final center-fix position.

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