SATELLITE-BASED CENTER-FIXING OF TROPICAL CYCLONES: NEW AUTOMATED APPROACHES

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1. INTRODUCTION

Automated implementations of the Advanced Objective Dvorak Technique (AODT, Olander and Velden, this volume) developed at CIMSS require an accurate estimate of the analyzed tropical cyclone (TC) center of rotation. Contemporary automated estimates of the center of rotation using IR imagery are often hampered by high clouds covering the eye, or by misleading, high brightness-temperature "moats" (false eyes) in close proximity to the eye. We describe two new approaches to resolve the center of rotation of a TC objectively and automatically, with algorithms that can be applied to either infrared (IR) or microwave imagery. Another important benefit of this operation is that it makes possible a smooth "rotating morph" animation of infrequent microwave imagery for TC applications.

2. SPIRAL-CENTERING

In our first approach, we pursue an objective method of calculating the best fit of the long-used "10-degree log spiral" (Dvorak, 1984) to the curve bands of TCs. The algorithm works as follows. A spiral-fit "score" is calculated for gridded points within a field of imagery data, where the score at each point is based on the cross product of the image gradients and a spiral-shaped unit vector field centered on the given point (Figure 1). The maximum score occurs at the point where the spiral unit vector is in maximum alignment with the image gradients. The method is invariant to missing data, which includes instances of only partial coverage (Fig. 1). This approach has the advantage of using the composition of the whole image instead of just the orientation of the spiral bands. Also, by using only the curvature of the image, the algorithm is not drawn to high-temperature "motes", but rather uses their curved shape as a guide to the optimal center. The technique closely mimics the method used by experienced meteorologists to determine a center of rotation because it naturally assigns appropriate weights to rotation-induced gradients of all sizes. However, the algorithm is quite sensitive to the effects of upper-level shear in IR imagery, leading to center estimates driven by patterns in the cirrus clouds rather than low-level clouds. In TCs without significant shear, the technique typically locates the spiral center on IR imagery to within 25 nm or less of the TPC "best track" position. The average error is higher in weaker (< Category 2) storms. We are currently working to incorporate the CIMSS hurricane shear product (Gallina and Velden, 2002) to adjust the position estimate in more highly sheared systems.

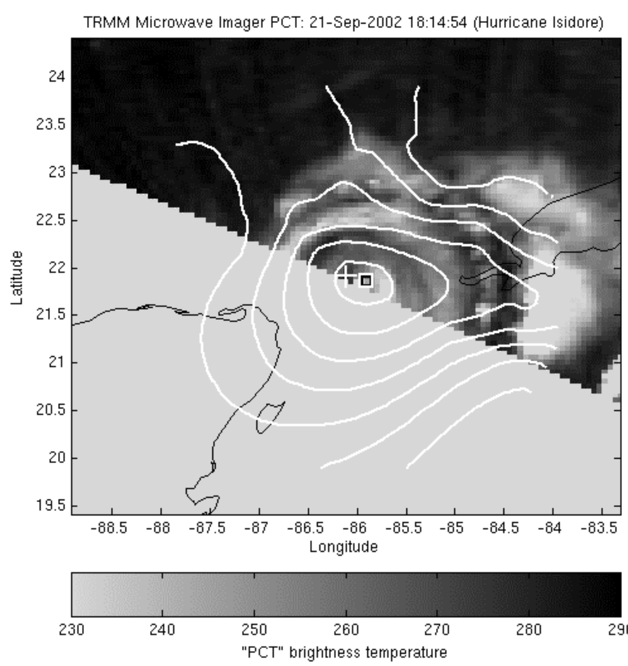

Figure 1. TRMM Microwave Imager (TMI), 85 GHz overpass of Hurricane Isidore (2003); best track center, white cross; spiral-fitting score field, white contours; optimum spiral center, white square. "PCT" is a weighted difference between vertical and horizontal polarizations that indicates scattering by ice crystals and is a proxy for precipitation.

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3. EYE-FITTING

Further calculation beyond the spiral-fitting method is needed to resolve the exact center of rotation in storms with a well-defined eye. Although finding the eye of a TC is a simple task for the meteorologist, it is made computationally difficult by partial obscurations and nearby high-temperature “motes”. To address the issue, we apply a variation of the Hough transform (Hough, 1962) to determine the optimal position and size of a circle that fits the gradient map of the image around the eye. When coupled with the spiral-centering algorithm, TC eyes can be robustly resolved even when the “first-guess” (i.e. forecast) is displaced away from the actual position by up to 200 km (Figure 2).

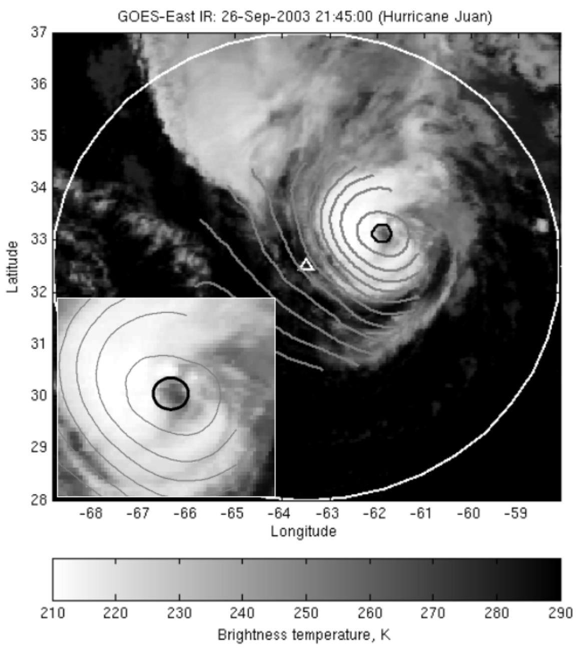

Figure 2. GOES IR image of Hurricane Juan; initial guess from forecast, white triangle; spiral-fitting score field, gray contours; area used in calculating the score field, white circle; optimum eye ring, black circle. Inset: detail around the eye.

4. MORPHING ANIMATION

With an objective, automatically-determined rotation center, it is possible to apply a center-fixed “morphing” algorithm to infrequent microwave imagery of TCs to simulate the transition between images. “Morphing” is a type of image transformation often used in the special effects industry to present a seamless transition from one image into another (Wolberg, 1998). Currently, the sometimes large and irregular temporal spacing between microwave imagery of TCs can seriously complicate the visualization of events such as the eyewall replacement cycle. However, by tracking the advection of certain “targets” over sequential images, we can parameterize a morphing transform function that rotates, morphs and blends sequential images into smooth transitions that approximate the changes between images. These morphed images can then be displayed in the form of an animated loop of the imagery over long time segments to provide an improved visualization of TC structure tendencies.

5. REFERENCES

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6. ACKNOWLEDGMENTS

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