6C.3

A CASE STUDY OF TROPICAL CYCLONE MERGER

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Between 6 September and 10 September 2001 an interesting tropical cyclone interaction event between Gil and Henriette occurred in the Eastern Pacific. The event was well-observed by geostationary satellite and by the SeaWinds instrument aboard NASA's QuikSCAT satellite. Fig. 1 shows a GOES-10 visible image at the initial stage of the interaction. Fig. 2 shows the tracks of the two storms and of their geographic centroid. We have analysed this event using absolute vorticity fields computed from the QuikSCAT surface winds. We have then used these vorticity fields, and ensemble perturbations of them, to initialize the adaptive multigrid nondivergent barotropic tropical cyclone track model MBAR (Fulton 2001) and the nested spectral shallow water model VICBAR (DeMaria et al. 1992). The model results show the sensitivity of the interaction process to the relative size and strength of the vorticity fields of the two storms. In addition we have run the models, which normally have the full effects of the earth's sphericity, in their β-plane and f-plane forms to test the sensitivity of the interaction process to these simplifications.

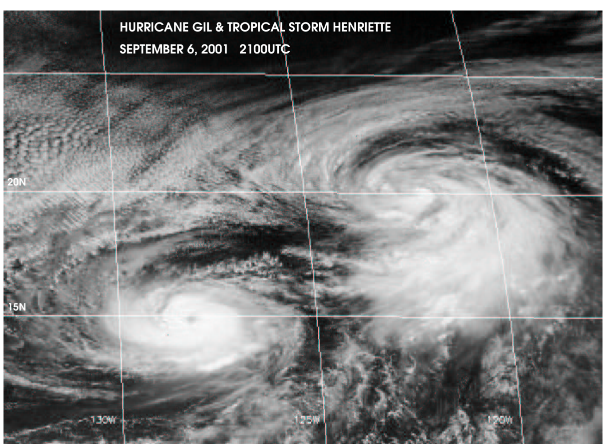

Figure 1: Hurricane Gil and Tropical Storm Henriette at 2100 UTC on 6 September 2001. Henriette is to the northeast. Longitude and latitude lines are 5 degrees apart, and Gil is at 15N 128W.

Our study can be considered an extension of the contour dynamics/contour surgery (CD/CS)

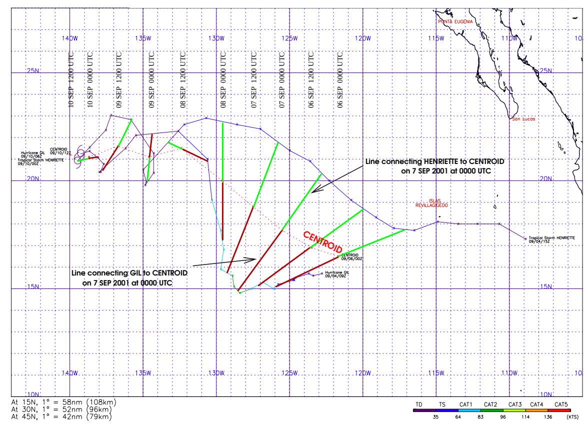

Figure 2: Tracks of Gil and Henriette, based on NHC advisories and GOES-10 imagery, shown with their centroid (dashed line). The thick lines connect the storm tracks to the centroid (dark is G-C, light is H-C) at nine times. Before merging, the storms had rotated approximately 540° about the centroid.

study of the inelastic interactions of unequal vortices in two-dimensional vortex dynamics (Dritschel and Waugh 1992). Consider two identical Rankine vortices, each with radius R, which can be interpreted as the radius of maximum wind and the radius of the circle over which the vorticity is constant. Suppose these two Rankine vortices are brought close together so that their centers lie a distance d apart. CD/CS results suggest that, if $2\,R < d < 3.305\,R$, a large part of the vortices merge into an ellipse, while the remaining vorticity is ejected as thin filaments. If $3.305\,R < d < 3.44\,R$, the vortices merge, exchange fluid, then separate. If $d > 3.45\,R$, the two vortices orbit about their vorticity centroid without making "vorticity contact." As they orbit, their shapes pulsate with the amplitude of pulsation inversely proportional to d. Interactions with $2\,R < d < 3.45\,R$ are termed "inelastic," while interactions with $d > 3.45\,R$ are termed "elastic."

Now consider two Rankine vortices with the same value of core vorticity, but with radii R_1 and R_2. More complicated interactions are now possible, as shown in Fig. 3. Five types of interaction are possible, depending on the size ratio R_2/R_1 and the dimensionless gap Δ/R_1, where $\Delta = d - R_1 - R_2$. Elastic interactions still occur for $\Delta/R_1 > 1.45$ (equivalent to $d > 3.45\,R$ when $R_1 = R_2 = R$). How-

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ever, for smaller gaps, four other types of interaction are possible: complete merger (CM), partial merger (PM), complete straining out (CSO), and partial straining out (PSO). Above the line separating CM/PM from CSO/PSO, there is a net circulation gain of the larger vortex, while below this line there is no such gain. The adjective "partial" implies that a fraction of the smaller vortex is left behind and remains a coherent structure while the rest is merged into the larger vortex (PM) or strained out and wrapped around the larger vortex (PSO). The boundary between CSO and PSO can be theoretically predicted (dashed line in Fig. 3) by simple arguments about the adverse shear placed upon the smaller vortex by the larger vortex. Theories explaining the other regime boundaries do not yet exist.

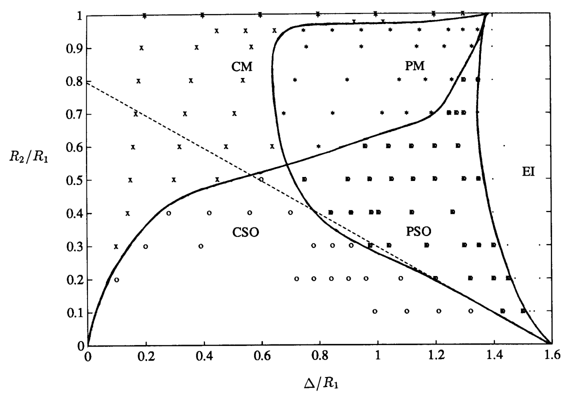

Figure 3: Flow regimes for CD/CS calculations of the inelastic interactions of unequal Rankine vortices. Five regimes are found, depending on the size ratio R_2/R_1 and the dimensionless gap Δ/R_1 (from Dritschel and Waugh 1992).

The CD/CS results are restricted to vortex patches of equal vorticity but unequal radius. In 2-D turbulence, the processes of vortex stripping and vortex merging do tend to create vortices with very sharp edges. However, tropical cyclones probably have more diffuse edges to their vorticity patterns. In addition, interacting tropical cyclones often have quite different values of peak vorticity, as was the case for Hurricane Gil and Tropical Storm Henriette. This indicates that several additional variables should be added to the simple analysis summarized in Fig. 3, including the effects of the earth's sphericity and the differences between divergent and nondivergent barotropic dynamics. We have attempted to extend the CD/CS vortex interaction results by making idealized simulations with both MBAR and VICBAR. These models are ideal for such a study because of their nesting and their formulation in Mercator coordinates, which allows comparisons of spherical, β-plane, and f-plane versions with simple parameter changes.

As an example from a VICBAR run, Fig. 4 shows isolines of normalized relative vorticity (see

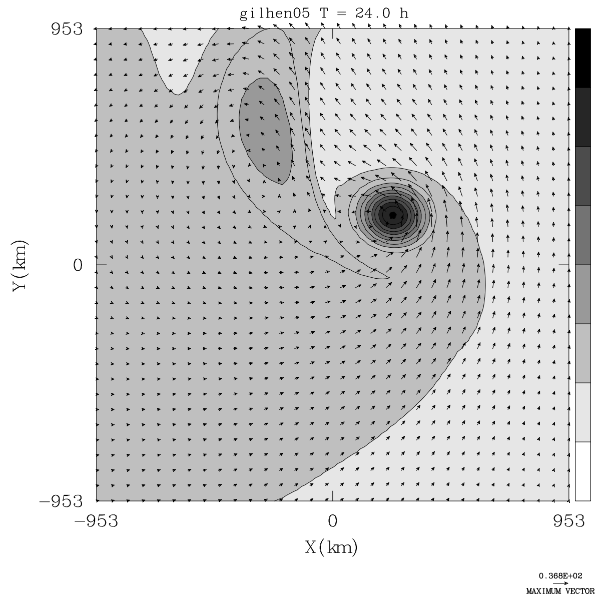

Figure 4: Isolines of normalized relative vorticity and horizontal wind at t = 24 h for a VICBAR simulation initialized with Gil and Henriette idealized as two circular vortices.

scale bar where a vorticity of 6.0×10^{-4} s^{-1} is scaled to unity) and wind at t = 24 h. The initial condition was based on observations at the time of Fig. 1, with a smaller, intense vortex (Gil) located southwest of a larger, weaker vortex (Henriette). The peak vorticity in Gil was approximately six times that in Henriette. Gil's model track was northward and then westward, as in the observations of Fig. 2. The vorticity of Henriette moves around the north and west side of Gil as it is strained out. Our preliminary finding is that this modeled event resembles more closely the complete straining out process rather than the true merger process.

Acknowledgments

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