Comments on "The Detection of Flow Asymmetries in the Tropical Cyclone Environment"

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1. Introduction

In a recent paper, Reeder et al. (1991; hereafter referred to as RSL) used an analysis of forecasts from a barotropic model to assess the quality of the data collected during the Tropical Cyclone Motion (TCM-90) field experiment and the collaborating international experiments SPECTRUM, TYPHOON-90, and TATEX-90. Their specific conclusions were that

> "a regular data network with resolution on the order of 100 km is required. Such a network would be feasible in practice only with aircraft reconnaissance including regular dropwindsondes . . . the enhanced network for the ONR experiments (is) inadequate to resolve the gyres satisfactorily."

Since the basis for the TCM-90 experiment was to test hypotheses related to the effects on cyclone motion of interaction between the cyclone and its environment, RSL's paper is a sharp attack on the planning and conduct of the experiment. They also imply that little useful research can be done using the data to further extend our knowledge of the processes occurring when tropical cyclones interact with their environment.

In this note, the RSL approach is examined and it is demonstrated that their methodology contains serious flaws. First, a brief summary of state-of-the-science analysis techniques for diverse meteorological data is presented and it is shown that the methodology adopted by RSL is far too simplistic. Second, the vortex used by RSL is compared with a mean tropical cyclone profile for the region to illustrate that they have used an unrealistically small vortex as a proxy for a tropical cyclone. Third, the data resolution in RSL is very much worse than that obtained during TCM-90. Finally, we show by example that simply using observations at the density obtained from soundings and satellite winds alone provide an excellent reconstruction of the asymmetries from a barotropic model forecast using an average-sized cyclone and a good reconstruction using the small vortex profile of RSL. We note that even more accurate analyses will result from the use of modern analysis methods and the full experimental dataset.

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2. Analysis method

Reeder et al. (1991) used the bicubic-spline method of Ooyama (1987) directly with full wind observations to attempt to reconstruct their model fields. Although this method is suitable for producing a static analysis, the overall approach is not representative of current meteorological data-analysis systems, such as those used at the Bureau of Meteorology Research Centre (Mills and Seaman 1990). For example, RSL completely ignore the time dimension, which clearly is important in data-sparse regions. We note that the time dimension can be obtained from observations alone by use of previous analyses and does not necessarily require the use of a numerical model, as implied by RSL in their conclusions. Data assimilation, however, which is the basis of modern analysis techniques, uses increments relative to a short-term numerical forecast. Such assimilation methods help considerably in data-sparse regions through propagation of information by the model. To state that this approach is necessarily wrong, as RSL do (p. 853), is incorrect and belies the enormous amount of work that has been done in this area.

An additional advantage of analyzing increments from a background field is that only the increments are filtered. This avoids the degradation from oversmoothing of the full field encountered by RSL (p. 851) and provides a substantially improved analysis (Seaman and Hutchinson 1985).

3. Vortex size

The vortex used by RSL follows that used by Smith et al. (1990). It is compared in Fig. 1 with the radial profiles of outer-region winds in an average typhoon from the western North Pacific (Frank 1977). The sharply truncated RSL vortex was developed to counter

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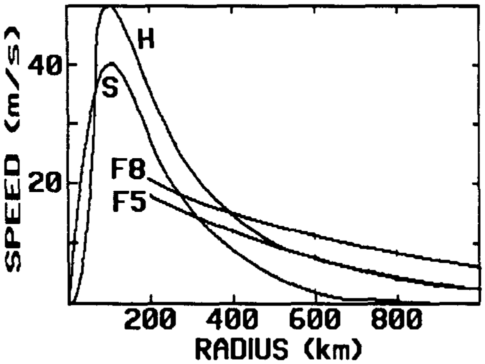

FIG. 1. Radial profiles of azimuthal winds in the vortex used by RSL (S), the composite typhoon from Frank (1977) at 850 hPa (F8) and 500 hPa (F5), and the vortex used in this study (H).

boundary-condition problems in the small domain used by Smith et al. It bears little resemblance to the general dimensions of actual tropical cyclones in the TCM-90 region,[1] and its use in a numerical model will markedly underestimate the amplitude and scale of the asymmetries that develop in such cyclones (Fiorino and Elsberry 1989). Also shown in Fig. 1 is the vortex profile adopted by Evans et al. (1991) and Holland and Evans (1992) in their study of the interactions that occur between tropical cyclones and the environment. This profile was carefully chosen to be representative of the outer structure of Pacific cyclones and is used for the reanalysis in section 4.

4. Observational density

Reeder et al. (1991) used an approximate distribution of the planned special sounding sites for the combined field experiments (their Fig. 2a) in the near vicinity of their model vortex. They neglected to include the full array of routine upper-air soundings in the region, the extensive cloud-drift winds (derived in a careful postanalysis by Velden and Merrill at the University of Wisconsin at the low, middle, and high troposphere), and the TOVS (TIROS Operational Vertical Sounder) data, which were collected during the experiment. They also did not include the additional observations that were obtained from surface stations and from commercial and military aircraft or the information about the location and intensity of the tropical cyclones. Good estimates of moisture soundings also can be obtained from the satellite imagery (Mills and Davidson 1987).

The typical TCM-90 observational density from atmospheric soundings and from cloud-drift winds in the lower troposphere is shown in Fig. 2. The TOVS data along ascending and descending paths are of similar density to the cloud-drift winds and are not shown. This observational density is over an order of magnitude higher than used by RSL (their Fig. 1).

[1] As noted by Merrill (1984) and discussed by Holland and Evans et al. (1992), the large cyclone structure in this region is a result of the monsoon shear zone in which it is embedded.

5. Vortex reanalysis using actual observational density

Next, we show directly the impact of using the full experimental data and a more representative vortex profile on the reconstruction of an asymmetric barotropic vortex. The analysis scheme and the barotropic model are part of a set of schemes developed by Leslie and are described in Holland et al. (1991). Briefly, the model equations are identical to those used by RSL but are solved using a semi-Lagrangian technique at 30-km resolution over the full TCM-90 domain (integrations at 10-km resolution, as used by RSL, were also made, with no effect on our conclusions). A version of the Barnes technique is used for the reanalysis. We started with the symmetric vortex labeled by "H" in Fig. 1, then integrated for 72 h to produce the streamfunction fields in Fig. 2. The representative vortex profile has produced asymmetries extending over a substantial domain, which is far larger than the total model domain used by RSL.

Reanalysis of data sampled at only the upper-air sounding points in Fig. 2 (Fig. 3a) quite clearly reproduces the major features of the original field. Although with some loss of amplitude of the circulation centers occurring, differences of the analysis from the original model were less than 20% over the whole domain. An

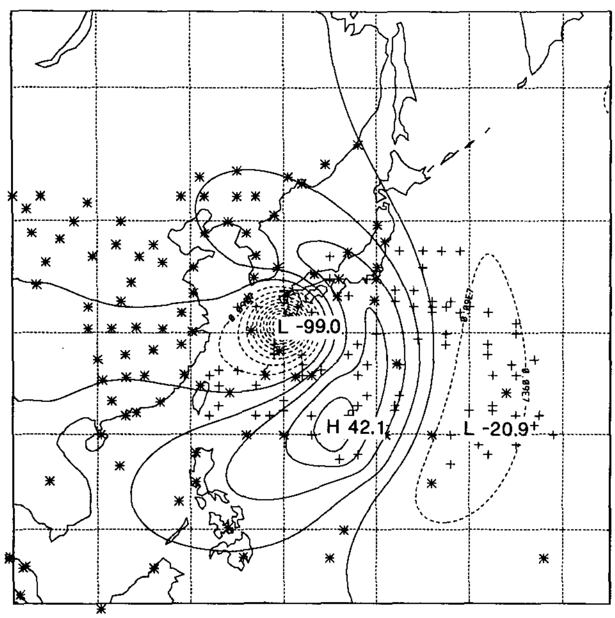

FIG. 2. The regular upper-air sounding network over the TCM-90 experimental domain (*) together with locations of a typical set of cloud-drift winds at 850 hPa (+), superposed on the streamfunction field (increments 9×10^5 m^2 s^{-1}) for the model vortex used in the analysis simulation.

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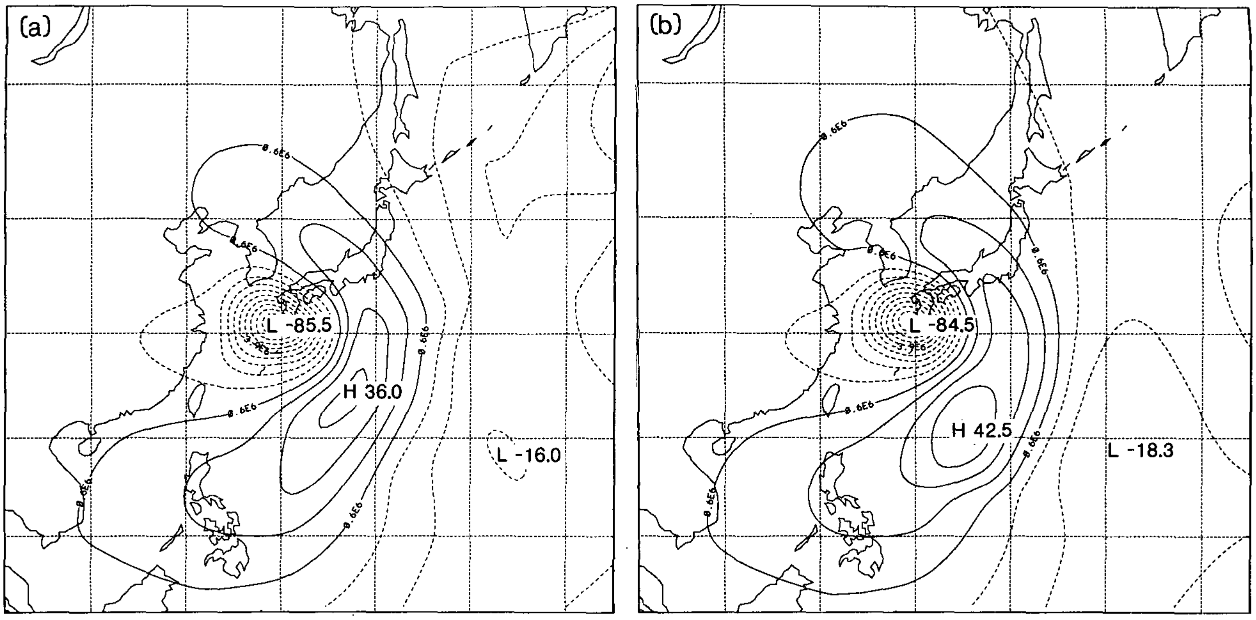

FIG. 3. Streamfunction fields (increments 9×10^5 m² s⁻¹) resulting from the reanalysis of winds sampled at (a) the upper-air sounding points and (b) the upper-air and cloud-drift wind sounding points shown in Fig. 2.

analysis using data sampled at points corresponding to both the upper-air soundings and the lower-tropospheric cloud-drift winds[2] in Fig. 2 produced further improvement (Fig. 3b). With these data, the major asymmetries are reproduced almost exactly, although there still is a 10%–15% loss of amplitude in the unsampled core region.

The retention of the asymmetric beta gyres is demonstrated (Fig. 4a) by subtracting the azimuthally averaged cyclone from the reanalysis in Fig. 3b. These

[2] For this illustrative case, we do not adopt the inclusion of data error characteristics, as would be done in a normal analysis cycle.

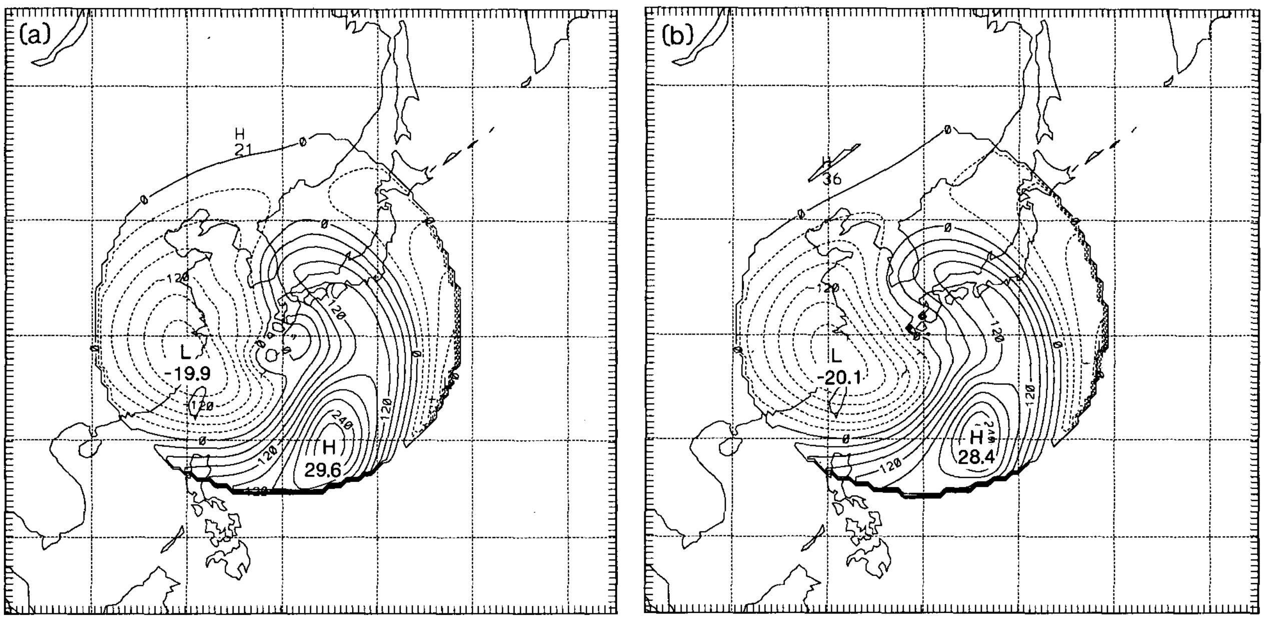

FIG. 4. Asymmetric streamfunction fields (increments 3×10^5 m² s⁻¹) resulting from removing an azimuthally averaged vortex from (a) the reanalyzed field in Fig. 3b and (b) the original field in Fig. 2.

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are shown in cylindrical coordinate view, similar to that used by RSL. Comparison with the original model asymmetries (Fig. 4b) indicates that the gyres are reproduced within a few percent away from the unsampled cyclone core.[3]

The sensitivity to location in the TCM-90 domain was tested by moving the vortex to the southeast sector with little change in results. For completeness, the above was reanalyzed using the same vortex and location as RSL. The results were quite similar to those in Fig. 3. The gyres could be easily discerned in the full field and were located *accurately* but with increased amplitude error compared to the larger vortex. The vortex center was mislocated by several tens of kilometers, however, which prevented any meaningful separation of the asymmetric and symmetric components. *We caution against using such mislocated vortex centers in deriving asymmetric fields, since major inconsistencies may result.*

In summary, we have demonstrated that the TCM-90 data are capable of accurately reproducing the fields associated with an asymmetric barotropic vortex including the beta-gyre asymmetries. The negative findings by RSL in this regard arise directly from their misrepresentation of the actual observational density during the experiment and from their use of a small vortex. We look forward to fruitful research with the experimental data using analyses based on a modern and well-founded data-assimilation system.

[3] We are surprised by the very smooth core and apparently accurate center location analyzed by RSL (their Fig. 4) in the absence of any data. Although not stated in the paper, it is assumed that they used some form of bogus observation to locate the center.

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