Tropical Cyclone Motion Studies

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LONG-TERM GOALS

The long-term goal is to improve the prediction of tropical cyclone track and structure so that warnings to the Fleet units afloat and ashore are optimized.

OBJECTIVES

(1) Improve tropical cyclone track prediction by demonstrating that tailored objective aids within the framework of the Systematic Approach to Tropical Cyclone Track Forecasting will provide better guidance than existing objective aids. (2) Improve understanding of tropical cyclone structure including rapid intensification and extratropical transition.

APPROACH

(1) Utilize the Systematic Approach framework to demonstrate the feasibility of optimizing track forecast guidance. (2) Use the ONR-sponsored Tropical Cyclone Motion (TCM-90) field experiment data set to analyze the environmental factors leading to intensity and structure changes in Supertyphoon Flo. (3) Utilize a new data base of tropical cyclones undergoing extratropical transition in the western North Pacific to document the characteristics and the physical processes involved.

WORK COMPLETED

(1) A simple statistical-synoptic technique for tropical cyclone track forecasting to 72 h in the western North Pacific has been derived and demonstrated to have considerable skill. (2) An exhaustive study of the TCM-90 data set related to the structure changes of Supertyphoon Flo has been completed with the publication of the Ph.D. dissertation of David Titley (CDR, USN).

RESULTS

(1) A journal article by Chen et al. (1998) documents the simple statistical-synoptic technique. For a statistical-synoptic equation set derived and tested with tropical cyclones in the Standard/Dominant Ridge pattern/region for the entire 72-h forecast interval, the improvement relative to the operational CLIPER is 13% after only 12 h and increases to 24% at 72 h. For the Poleward/Poleward-oriented pattern/region, the improvement relative to the operational CLIPER is about 14% after 12 h, and is about 11% at 72 h. Given a perfect knowledge of the type and timing of these two transitions, the appending of a composited post-transition track can lead to about 50% reduction relative to the 72-h

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operational CLIPER errors if the transition occurs early in the forecast interval. This result is a validation of the environmental structure change focus of the Systematic Approach.

Elsberry et al. (1998a) and Boothe et al. (1999) describe a statistical post-processing of the Naval Operational Global Atmospheric Prediction System (NOGAPS) tropical cyclone track forecasts. Zonal and meridional adjustments to the NOGAPS-predicted track positions are derived from a 1992-96 sample of 152 tropical cyclones in the western North Pacific. The primary objective is to improve the early track errors that arise from an offset in the initial position in the NOGAPS model relative to an updated position that will be known 6 h after the 00 UTC and 12 UTC synoptic times, when the forecasters first make use of the NOGAPS predictions. Early track discrepancies relative to a persistence of past motion orientation that may arise from an incorrect analysis or a model systematic bias are also corrected by the post-processing technique. Validations with three independent data sets illustrate the likely usefulness of the post-processing technique throughout the Northern Hemisphere, even though the development sample contained only western North Pacific cyclones during 1992-96. Application to the 1997 western North Pacific tropical cyclones results in improvements relative to the unadjusted NOGAPS forecast errors of 50% at 12 h and 12% at 36 h. Corresponding percentage improvements for a 1995-97 sample of NOGAPS forecasts of Atlantic tropical cyclones are 38% and 14%. In the eastern/central North Pacific, the corresponding percentage improvements in the mean adjusted NOGAPS track error, are 50% and 17%.

An overview of the Systematic Approach and its likely global applicability has been prepared for the H. Riehl memorial volume (Elsberry et al. 1998b). This overview brings together the original concepts developed for western North Pacific tropical cyclones with the experiences gained in applications in the eastern/central North Pacific and in the Southern Hemisphere. Three of the four original synoptic patterns apply in all these regions. However, each basin has a special synoptic pattern: monsoon Gyre (G) in the western North Pacific, upper-tropospheric Low (L) in the eastern/central North Pacific, and High-amplitude (H) in the Southern Hemisphere. It is important that all tropical cyclone tracks may be classified into just four synoptic patterns in each basin, so that a consistent "storyline" can be used to describe each track. Extension to the Atlantic hurricanes is in progress, and cyclones in the North Indian Ocean will be classified in the future.

A broader perspective on progress and prospectives for providing early (and more accurate) warnings of tropical cyclones was prepared (Elsberry 1998a) for an international conference in Potsdam, Germany during September 1998. This conference was both a retrospective on progress during the International Decade for Natural Disaster Reduction and a planning for future activities. In addition to providing the keynote address on tropical cyclones, a session was organized that brought together forecasters and emergency managers from around the globe. Four of these presentations were edited for inclusion in the proceedings volume.

As Topic Chair 3 for the International Workshop on Tropical Cyclones (IWTC-4) in Haikou, China, an overview (Elsberry 1998b) was prepared of the achievements in understanding tropical cyclone motion during the four years since IWTC-3. Much of the new understanding was contributed by the ONR program.

As co-chair of the U. S. Weather Research Program Hurricane Landfall Workshop in Miami, Florida, during November 1997, a Workshop report (Elsberry and Marks 1998) was prepared. This report summarizes and ranks opportunities in research and observations in five topics related to hurricane landfall on the U. S. coastline from Texas to Maine. These topics are track, outer and inner (including intensity) structure changes, modifications of circulation as hurricane crosses coastline,

quantitative precipitation estimation and prediction, and social-economic impact assessments. This workshop report will serve as the basis for developing a five-year research plan beginning in October 1999.

(2) Titley (1998) developed a Multi-Quadric (MQ) analysis and compared it with the TCM-90 four-dimensional data assimilation (4DDA) analyses of the evolution of Typhoons Flo and Ed. The MQ analysis is shown to provide an alternate, plausible depiction of the tropical atmosphere. These analyses are then used to analyze the physical processes leading to rapid intensification of Flo, but not of Ed. Significant results (Titley and Elsberry 1998, 1999) include: (i) existence of a "cyclonic wind burst" extending beyond 1000 km radius at 200 mb during a pre-conditioning period prior to the rapid intensification of Flo; (ii) Flo had developed a warmer core near the tropopause, and was less stable than Ed in the lower- and mid-troposphere prior to the beginning of rapid intensification; (iii) a strong sustained eddy flux convergence (EFC) in the upper troposphere during the pre-conditioning period had the role of a catalyst, since the EFC forcing was significantly reduced during the rapid intensification; (iv) vertical wind shear was not an inhibiting factor in the intensification, rather it appeared to decrease as a result of the rapid intensification; (v) Supertyphoon Flo rapidly decreased in intensity while over warm water and while large EFC forcing aloft was still present, presumably because the interaction with the midlatitude circulation also produced a mid-tropospheric EFC that led to an outward secondary circulation that tends to spin down the mid-tropospheric vortex.

(3)The so-called extratropical transition of a tropical cyclone to an extratropical cyclone is not well understood because it involves complex interactions on various horizontal and vertical scales and over a range of time scales. As pointed out in the report of P. A. Harr in this volume, predictions of extratropical transitions are often erratic with some surprisingly large errors on 3-day time scales for which mid-latitude numerical models would normally be expected to be accurate. Thus, the tropical cyclone must have some special characteristics that complicate predictions of extratropical transitions that threaten the safety of the Fleet afloat and ashore. A preliminary study of Klein (1997) has been extended (Klein et al. 1999) to a sample of 37 extratropical transition events in the western North Pacific. While Klein's conceptual model of the first transformation stage continues to be applicable for the larger sample, the characteristics and evolutions of the key circulation features are being documented with high resolution NOGAPS analyses and satellite infrared visible and microwave imagery. Three-dimensional trajectories illustrate the complex evolution of these key circulation features. During the second (re-intensification) stage of extratropical transition, the cases of most interest are those that subsequently explosively deepen. The objective is to understand what environmental features distinguish these dangerous cases from the more benign cyclogenesis cases or the dissipators.

TRANSITIONS

The feasibility of the statistical-synoptic track prediction technique will be tested as part of a 6.4 project funded by SPAWAR and offered to JTWC for operational testing. The post-processing technique for NOGAPS will be re-derived for the combined data sets throughout the Northern Hemisphere (and separatly for the Southern Hemisphere). A version for the Advanced Tropical Cyclone Forecast (ATCF) workstation will be tested as part of the SPAWAR project and provided to JTWC, Pearl Harbor, and Norfolk centers.

RELATED PROJECTS

Separate summaries of other collaborative work with Lester Carr, Patrick Harr, and Elizabeth Ritchie are included elsewhere in this volume.

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