# Final Report to the COMET Outreach Program

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Partners Project: **Central Pacific Hurricane Tracks Derived from Global Analysis Winds**

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Section 1: PROJECT OBJECTIVES AND ACCOMPLISHMENTS (academic and forecaster partners)

OBJECTIVES

Our initial objective was to utilize model NCEP/NCAR Reanalysis (NNR) wind data to empirically identify the steering layers that might show the best correlation with tropical cyclone motion in the Central North Pacific (CNP). Since there is no previous work which can provide initial guidance regarding the nature and definition of steering for the CNP, we intended to explore different combinations of eight atmospheric pressure levels in order to find a suitable Environmental Steering Layer (ESL) for tropical cyclones in the CNP. The technique of defining steering as an average of the winds in an annulus 5 to 7 degrees from the cyclone center was utilized. Sensitivity analysis of the ESL dependence on tropical cyclone intensity was performed by stratifying the tropical storms and depressions separately from hurricanes. Translational speed and angle mean differences between ESL and tropical cyclone motion were calculated for both categories. Since the number of cases available for the project was considerably smaller compared to the abundant tropical cyclone data in the Northwest Pacific and the North Atlantic, we limited the stratification of the data to six other categories: three for motion direction (westward, northward, south/east), and three for speed (slow, moderate, and fast moving cyclones). The analysis for the intensity categories was the main focus of the project.

Tropical cyclone speed and angle differences relative to steering flow at eight different pressure levels were analyzed following a procedure similar to previous studies.

The results could then be compared with the other hurricane basins. Also, we addressed the question of the possible dependence of steering on vertical wind shear for both tropical storms and hurricanes by analyzing the ESL's that show the best results (i.e., smallest differences) for each category.

It is the ultimate goal of this work to provide the first comprehensive analysis of tropical cyclone motion and the relation with its environmental steering flow for the Central North Pacific as defined from NCEP/NCAR Reanalysis model wind data.

## ACCOMPLISHMENTS

The relation between tropical cyclone motion and its surrounding environmental steering flow was studied for the region of the Central North Pacific and Hawaii, utilizing model analysis from NNR as an alternative to the lacking rawinsonde and aircraft data. The tropical cyclone data set available for this project is small compared with the other more active North Atlantic and Northwest Pacific regions. It was found that most analyzed tropical cyclones move in a west-northwest track, and south of 20 degrees N. This tropical cyclone activity, concentrated southeast and southwest of Hawaii, coincides with a prevailing easterly wind flow with an average speed between 5 and 10 m/s. The influence of these easterlies is observed at all the levels of the mid-low troposphere (from 850 to 500 mb) during the months of the hurricane season. Most tropical cyclones were observed to move with a forward speed between 4 and 8 m/s.

It was found that mid-low tropospheric steering shows a better correlation with tropical cyclone motion than the higher levels. This is in agreement with most previous work in other basins. No direct evidence was found to support a previous report regarding the 700 mb level as best descriptor of tropical cyclone speed, although low levels (850, 700 and 600 mb) have lower speed differences than levels above 600 mb.

Vertical variation analysis for tropical storms and depressions indicate a mean tropical cyclone motion to the right of the environmental steering flow, up to five degrees, and very close to or slightly faster (less than 1 m/s) than the mid-low tropospheric wind at 850, 700, and 600 mb. Above these levels, tropical storms and depressions move to the left (up to 10 degrees), and also faster. Hurricanes show similar profiles, with angle differences of up to 12 degrees at 850 mb, and moving to the right above 500 mb. The speed profile looks virtually identical to that of tropical storms and depressions.

Most cyclones are moving in the CNP domain where prevailing easterly (trade) winds dominate the mid-lower troposphere throughout the hurricane season. The observation of cyclones moving to the right of the steering flow at these levels is in good agreement with results reported by earlier researchers of a general rightward turn in tropical cyclone motion south of 20 degrees N. This supports the findings of beta effect impact on cyclones embedded in easterly flow, which causes cyclone motion to be faster and to the right of the environmental steering flow. Also, the fact that hurricanes show a slightly bigger deviation to the right of the steering flow than tropical storms suggests that the beta effect might be more significant in the stronger cyclones.

Westward, moderate and fast moving cyclones exhibit a better correlation with the environmental steering flow than northward and slow moving cyclones. This is also in good agreement with most previous findings in other regions of the world.

From the "Deep Layer Mean" (DLM) analysis, an important finding in this work is the observation of a positive correlation between tropical cyclone intensity and the depth of the environmental steering layer. The analysis for angle differences shows that hurricanes have a better correlation with deeper layers than tropical storms and depressions. This supports a similar conclusion of Dong and Newmann (1986) of a positive correlation between intensity and DLM depth in the North Atlantic region.

It is concluded that the layer from 850-400 mb is the recommended steering layer candidate for tropical storms and depressions, with storm motion having an absolute mean angle difference of 11.8 degrees, and a speed mean difference of 1.8 m/s. For hurricanes the layers of 850-300 and 850-250 mb are recommended steering layer candidates, with an absolute angle difference of 13.5 degrees, and a speed mean difference of 1.2 m/s. These values provide an estimate of typical error associated with the steering layer concept. The above DLM's have been mentioned in previous work as best predictors for tropical cyclone motion in other regions. The angle difference parameter $Aa_d$ was chosen as the criteria for environmental steering layer selection due to the lack of significant differences between layers in the speed analysis.

As mentioned in most previous work, the DLM approach proved to be very useful for steering analyses. As an example, in the hurricane analysis, the Deep Layer Mean of 850-400 mb has an absolute angle difference of 12 degrees and an absolute speed difference of 1.8 m/s. The 500 mb steering level on the other hand, identified in the literature as a good descriptor of tropical cyclone motion, has an absolute angle difference of 19 degrees, and an absolute speed difference of 2.2 m/s.

Is vertical wind shear related to steering? Contrary to expectations, the results for the shear vs. Deep Layer Mean difference analyses do not show a plausible correlation. The fact that the number of cases is small compared to other regions might present a problem when stratifying for wind shear categories. Therefore it has not been possible to definitively establish a relation between these two parameters at this time.

This project has shown that by utilizing the NCEP/NCAR Reanalysis model wind data for steering analyses, it is possible to obtain results that are in good agreement with most previous work based on rawinsonde and aircraft data, which focused on other regions.

SECTION 2: SUMMARY OF UNIVERSITY/NWS EXCHANGES (academic and forecaster partners)

1. Used preliminary results as part of NWS training of Hurricane Specialists at the Central Pacific Hurricane Center during Summer 2002.
2. Forecaster partner and members of NWS staff attended Graduate Research Defense during April 2003 to examine the final results of thesis research.
3. Close research interaction between graduate student and NWS forecaster during thesis research
4. After completion of the MS thesis and degree, graduate student was employed by the National Weather Service at another office.

SECTION 3: PRESENTATIONS AND PUBLICATIONS (academic and forecaster partners)

Reynes-Figueroa, A., D. Stevens, and S. Houston, 2002: Hurricane Risk in Hawaii, Part I: Steering Flow Analysis in the Central North Pacific. AMS meeting on Tropical Meteorology and Hurricanes. April 29 - May 3, 2002. San Diego, CA.

Reynes-Figueroa, A., 2002: "Steering flow analysis of Central North Pacific tropical cyclone tracks", Presentation at Central Pacific Hurricane Center Training Seminars, Session 2, August 2, 2002.

Reynes-Figueroa, A., 2003: Thesis Defense for MS degree. April 2003.

Reynes-Figueroa, A., 2003: Environmental Steering Flow Model Analysis of Central North Pacific Tropical Cyclones. MS Thesis, University of Hawaii at Manoa. August 2003.

Reynes-Figueroa, A., D. Stevens, and S. Houston, 2004: Environmental Steering of Central North Pacific Tropical Cyclones. Weather and Forecasting. In preparation.

SECTION 4: SUMMARY OF BENEFITS AND PROBLEMS ENCOUNTERED

4.1 (academic partner)

1. Benefits:
   a. Close research interaction between graduate student and NWS forecaster
   b. Better understanding of hurricane forecast problem from operational perspective
   c. Graduate thesis research is applied to real-life forecast problem in the central Pacific.
   d. Graduate student continued on to employment with the National Weather Service.
2. There were no significant problems.

4.2 (forecaster partner)

1. Benefits: The academic researcher has determined the best levels to use for the steering of a) "hurricanes" and b) "tropical storms and tropical depressions" in the Central North Pacific basin. This knowledge can be applied at the NWS to update the derived quantities used in the suite of model (e.g., the GFS model) products that are applied to determine the motion and future track of tropical cyclones in this basin.
2. There were no significant problems.