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MODELING TRACK DEFLECTION FOR TROPICAL CYCLONES PASSING OVER A MESOSCALE MOUNTAIN AND ITS POTENTIAL APPLICATION TO TRACK PREDICTION

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1. Introduction

In this study, we use observed tropical cyclones and a simple mesoscale model (GFDM), along with a control parameter, V_{max}/Nh, on track continuity associated with the passing of modeled tropical cyclones over a mesoscale mountain proposed in a parallel study, to examine the validity of this control parameter and the model predicted tracks. The data set includes Typhoon Nari (2001) and Supertyphoon Bilis (2000) during their passage over Taiwan. Simulated tracks using the GFDM compare reasonably well with the observed tracks. Results from the simulation show that the track of the low-level wind center is often different from the low-pressure center. Observations support this phenomenon, which can make cyclones passing over a mesoscale mountain very difficult to track.

2. Dynamics of the Track Discontinuity

Lin et. al (2001) proposed a set of control parameters which dictate track continuity (or lack thereof) over a mesoscale mountain. The non-dimensional parameter, which may serve as the control parameter is V_{max}/Nh, with V_{max} being the speed of maximum tangential winds of the tropical cyclone, h is the height of the mountain, and N is the Brunt-Vaisala frequency. There are two basic regimes: 1) Discontinuous, when $V_{max}/Nh < 1.6$, and 2) Continuous, when $V_{max}/Nh > 1.6$. V_{max}/Nh may be regarded as the Froude number associated with the typhoon circulation, or the inverse of the nonlinearity of the airstream associated with the typhoon circulation.

2.1 Supertyphoon Bilis

The track of Bilis was typical of many typhoons which strike Taiwan. The track is shown in Fig. 1. Bilis took a steady northwest track at approximately 6 ms^{-1}. Bilis hit in the southeast part of Taiwan, and proceeded northwest across Taiwan, eventually making landfall in China. Maximum sustained winds exceeded 60 ms^{-1}.

Variables used to obtain the control parameter were as follows: $V_{max} = 50$ ms^{-1}, $N \sim .01$ s^{-1}, and h = 3000m. The resulting control parameter V_{max}/Nh is 1.67. This exceeds the critical value of 1.6, indicating the track was continuous. Observations show a continuous track, with a slight increase in forward speed before landfall.

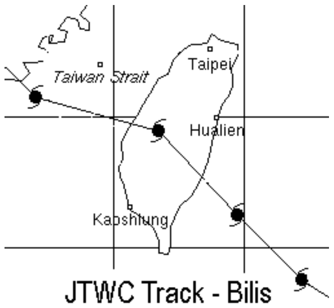

Fig. 1. Track of Supertyphoon Bilis from the Joint Typhoon Warning Center.

2.2 Typhoon Nari

Nari took an unusual southwest track into Taiwan, with an average speed of 2 ms^{-1}. The best track is shown in Fig. 2. An upper level high over China and an upper level low south of Japan combined to provide a northeasterly flow. Nari made landfall on the northeast coast with maximum sustained wind of 35 ms^{-1}, and then went south along the eastern side of the CMR. The northeast flow persisted while Nari crossed Taiwan. The center crossed over the island about 2/3rds down the coast, where the height of the CMR begins to decrease. After crossing Taiwan, the upper level flow switched to an easterly direction. Nari restrengthened to a moderate tropical storm and struck China.

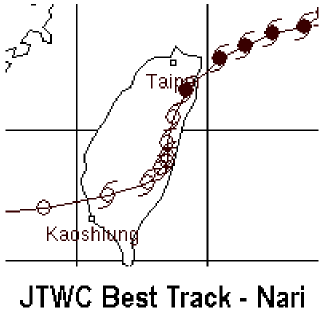

Fig. 2. Best track of typhoon Nari from the Joint Typhoon Warning Center

The variables for Nari were as follows: $V_{max} = 35$ ms^{-1}, $N \sim .01s^{-1}$, h = 3000m. Substituting the above into the control parameter, V_{max}/Nh is 1.16, indicating that the track was discontinuous. As the system weakened due to interaction with land, V_{max} would be reduced. Conversely, a continuous track is possible if the height of the mountain is lowered. Assuming no weakening of the winds, V_{max}/Nh would exceed

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the critical value of 1.6 when the mountain height h falls below approximately 2100 meters. This phenomenon coincides with observation very well. As the circulation traveled down the eastern side of Taiwan, elevations in the CMR exceed 2500 meters. When the circulation tracks sufficiently far down the coast, the height of the CMR drops below 2100 meters. At this point, the circulation would be able to track across the island.

3. Using a simple model to investigate track continuity and deflection

To investigate the track behavior into a mesoscale mountain like the CMR of Taiwan, a simple, dry, hydrostatic model, the GFDM, was used (see Lin et al. 1999 for details). The horizontal dimensions of the bell-shaped mountain are 40 km and 120 km in the x and y directions respectively. The mountain height is 2500 meters. A value of .01 s^{-1} was used for the Brunt-Vaisala frequency, and free-slip conditions were set at the surface. The mean environmental flow was calculated from all positions in the 36 hours prior to and including landfall.

3.1 Bilis simulation

As in the Nari case, a control run was made. In the basic flow during Bilis, lee eddies were present, meaning the track will be affected by interaction with the mountain and with the lee eddies.

A vortex with strength of 20 ms^{-1}, which is assumed to be in gradient wind balance (see Lin et al. 1999 for details), was positioned so the basic flow would hit the southeast part of the mountain. As in the observations, the modeled track of Bilis was straightforward. Both the pressure center and the circulation center were continuous (Figs 3a, 3b). An acceleration of the centers is also seen, consistent with observations.

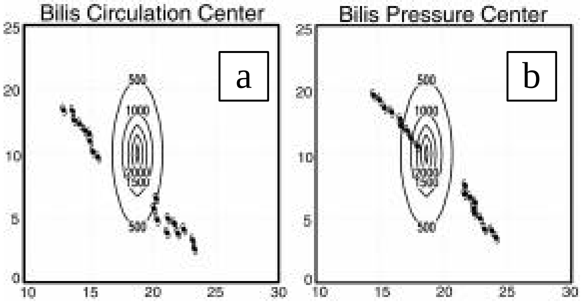

Fig. 3. GFDM model tracks of Circulation (a) and Pressure (b) for Bilis.

3.2 Nari simulation

First, a control run was made with no vortex. The mountain acts similar to a streamline body, with no eddy formation. Track deflections will be primarily due to the interaction of the vortex with the mountain.

In this simulation, a vortex was positioned such that the environmental flow would advect it into the northeast portion of the mountain. The strength of the inserted vortex was 20 ms^{-1}. The model results match reality surprisingly well. The, circulation and pressure centers move southeastward into the mountain. After landfall, the circulation center accelerates to the south, along the eastern edge of the mountain (Fig. 4a). This center seems to ride along the 1000 m height contour. However, the pressure field behaves quite differently (Fig. 4b). The primary pressure center deflects around the north end of the mountain, and then moves southward along the western side of the mountain. A secondary pressure center formed to the southeast of the mountain, with downslope wind causing this as well. Near the southern end of the 1000 m mountain height contour, a broad, elongated circulation becomes apparent. The southeastern end of this circulation is a continuation of the original center. The northwestern end coincides with the location of the main pressure center. Ultimately, the elongated center contracts into a circular vortex, at about the midpoint of the elongated vortex. The pressure centers was pulled south, toward the coalescing center.

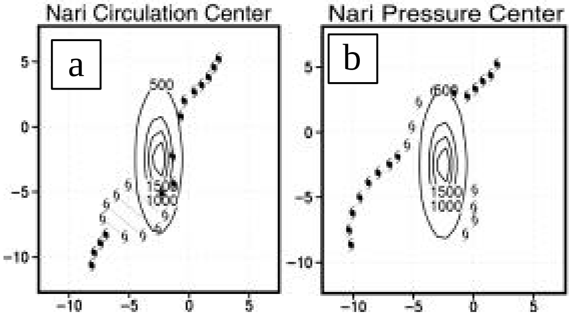

Fig. 4. GFDM model tracks of Circulation (a) and Pressure (b) for Nari. Tropical storm symbols indicate more than one center present at a certain time.

4. Conclusions

In this study a control parameter V_{max}/Nh is proposed to diagnose track continuity. The parameters for Bilis and Nari suggest a continuous and discontinuous track, respectively. Observations support the findings of the control parameters. A simple mesoscale model was able to reproduce observed storm tracks. This model could potentially be used to predict the track around complex terrain.

5. Acknowledgments

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6. References

Lin, Y.-L., J. Han, D. Hamilton, and C. Y. Huang, 1999. Orographic Influence on a Drifting Cyclone. *J. Atmos. Sci.*, **56**, 534-562.

Lin, Y-L, S. Chiao, T. A. Wang, M. L. Kaplan, and R. P. Weglarz, 2001: Some common ingredients of heavy orographic rainfall. *Weather and Forecasting*, **16**, 633-660.