PREDICTIONS OF TROPICAL CYCLONES USING DIFFERENT CONVECTIVE PARAMETERIZATION SCHEMES

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1. INTRODUCTION

As computer resource increases along with the advancement of modern technology, the resolutions in global forecast systems have been increasing steadily to levels that can be reached only by regional models in the past. The global forecast models now can provide reliable forecast of synoptic and sometimes mesoscale phenomena in the five to seven day range. An alternative method to evaluate the prediction skill of global forecast systems is the tracking of tropical cyclones in the model in which synthetic data are included to represent the cyclone. The U. S. Navy Operational Global Atmospheric Prediction System (NOGAPS) has demonstrated its capability of predicting tropical cyclone motions and is providing guidance for Navy's tropical cyclone prediction mission (Fiorino et al. 1993, Goerss and Jeffries 1994).

The main source of energy for tropical cyclones comes from underlying warm oceans and is released through latent heat of condensation. Therefore, one of the most important sub-grid physical parameterizations for the simulation of tropical cyclone is the convective parameterization. The A-S scheme has been the one chosen for the operational NOGAPS. The Arakawa and Schubert scheme (Arakawa and Schubert 1974, denoted as A-S scheme) is unique in its determination of the spectrum of the cloud base mass flux by demanding that the convection dissipates instability at the same rate as which it is generated by large-scale forcing. The main deficiency of the scheme is the lack of downdraft in its origin design. Recently, the Emanuel scheme (Emanuel 1991) has been implemented in NOGAPS as an alternative scheme for convective parameterization. The Emanuel scheme, which is designed based on aircrafts observations that reveal a large degree of inhomogenerity in individual convective cloud, treats the updraft and downdraft in sub-cloud scale of the order of 100m. Emanuel scheme takes the approach of buoyancy sorting in determining the subsequent ascent or decent of individual air parcel to reach a level where the liquid water potential temperature equals to that of its environment.

During the testing period for the month of August 1998, the forecasts with Emanuel scheme showed an improved skill than the forecasts using the A-S scheme. The 500 mb height anomaly correlation for the northern hemispheric at the 120 h forecast is increased from 0.75 of the control runs using the A-S scheme to 0.77 using the Emanuel Scheme during that period. Furthermore, the average forecast distance error of the six tropical cyclones occurring during that period was also reduced by using the Emanuel scheme. In this study we analyze and compare the forecasts of the six storms by NOGAPS using these two different convective parameterization schemes.

2. PREDICTIONS OF TROPICAL CYCLONES

For the month of August in 1998, there were six tropical cyclones that had reached cyclone strength, they include Bonnie and Danielle in the Atlantic that made recurvature; Howard, Estelle, and Georgette in the eastern Pacific that moved west by northwest; and Rex in the Western Pacific that had an unusual north-south oscillation in its overall eastward movement. The average 120h forecast distance error from the forecasts using A-S scheme is 416 NM for 35 cases verse 354 NM from the 27 cases using the Emanuel scheme.

For the two recurving hurricanes in the Atlantic, the intensity of the mid-latitude trough over the U. S. Continent is over-predicted by the A-S scheme and bias is improved by the Emanuel scheme. This leads to better prediction of the tracks for Hurricane Bonnie and Danielle by the Emanuel scheme. For the three more westward moving hurricanes in the eastern Pacific, there appears to be no significant synoptic system near-by that affects the movement of the storm. The more realistic structure of the storm by Emanuel scheme may contribute to the better track prediction. The most challenging task is for Typhoon Rex in the western Pacific. Even though the Emanuel scheme produces smaller forecast distance error, the irregular motion of Rex is not captured by either scheme. The mechanism associated with Rex's oscillatory motion remains undetermined.

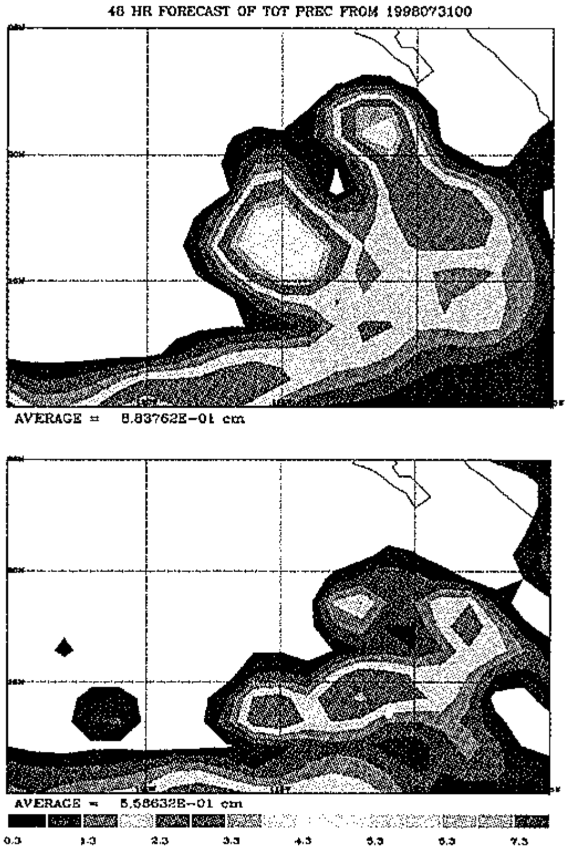

Figure 1. 12h accumulated rainfall amount at 48h for Hurricane Estelle on 31 July 1998: a) A-S scheme, and b) Emanuel scheme.

A comparison with the NCEP analysis of the rain gauge data indicates that the Emanuel scheme produces superior precipitation over land. In addition, the rainfall pattern generated by A-S scheme surrounding a cyclone is concentric with its maximum near the storm center, while the rainfall amounts using Emanuel scheme show more of an asymmetric annulus with a minimum at the center and several maxims surrounding it. The 12h-accumulated rainfall amounts at 48 h forecast for Estelle on July 31 are depicted in Fig. 1 for illustration. The overall intensities of the storms are weaker in the experiments using the Emanuel scheme compared to those using the A-S scheme.

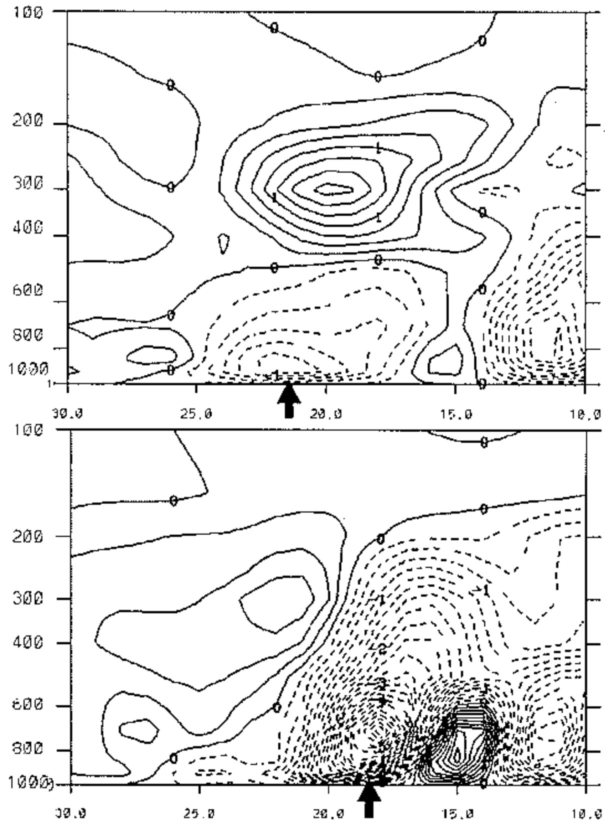

Figure 2. Vertical motion across the center of the storm for Estelle using the A-S scheme at 96h. Dashed lines indicate upward motion and solid lines indicate downward motion. The center of the storm is marked by an arrow.

In the simulation of the eastern Pacific hurricanes during that period, the vertical motion in the downward branch of the vertical circulation surrounding the storm breaks into two parts in the simulations by A-S scheme. At a later stage, the upper part of the downward motion propagates to the storm center and caps the storm by a large downward motion. One example is shown in Fig. 2 for Hurricane Estelle. The large descending motion above the storm center causes distortion of the horizontal circulation at upper levels (Fig. 3) and decoupling of the circulation centers in the vertical. On the other hand, the cyclone simulated using the Emanuel scheme has a well-organized vertical (Fig.2b) and horizontal circulation (Fig.3b) so that the circulation centers remain barotropic in the vertical. This may suggest that it is the better treatment of the micro-cloud physics in the Emanuel scheme that proves to be superior to the A-S scheme. The superior performance of Emanuel scheme leads to the adoption of it in NOGAPS for operational test.

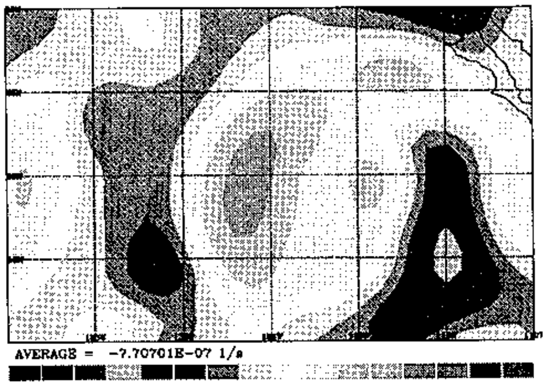

Figure 3. Relative vorticity at 500 mb for Estelle at 96h simulated using: a) the A-S scheme; and b) the Emanuel scheme.

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