14A.1 AN INTRODUCTION TO THE STATISTICAL TYPHOON INTENSITY PREDICTION SCHEME (STIPS)

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1. INTRODUCTION

The prediction of tropical cyclone "intensity" or maximum sustained 1-minute surface winds remains a difficult task in all tropical cyclone basins. On average forecasts of intensity are slightly better than those produced based upon climatology and persistence (CLIPER approach). While there has been relatively steady improvement over the years in track forecasting skill, little improvement of intensity forecast skill has simultaneously occurred. The slow improvement of intensity forecasts is primarily due to the complexity of the tropical cyclone intensification process, which involves scale interactions between the environment, the storm and convection. Intensity forecasting is also made more difficult by the limited number of skillful NWP model intensity guidance.

An alternative methodology for forecasting intensity combines statistical techniques with environmental predictors derived from NWP model forecasts. This methodology is commonly called the statistical-dynamical approach. The Statistical Hurricane Prediction Scheme or SHIPS (DeMaria and Kaplan 1999), developed for use in the North Atlantic and eastern North Pacific, routinely produces skillful forecasts and is a good example of a statistical model developed using this approach.

In the western North Pacific, the Joint Typhoon Warning Center (JTWC) routinely produces intensity forecasts through 120 hours. These forecasts tend to be, as in other TC basins, slightly better than forecasts produced using statistical CLIPER-based techniques STIF (Chu, 1992) and ST5D (Knaff, et al, 2003). . Until 2002, intensity guidance used at JTWC included analogs, statistical techniques and a few NWP models – none of them demonstrating consistent skill. As a result, the intensity forecasting at JTWC remains a subjective, though only slightly skillful, endeavor.

This paper discusses the development of the Statistical Typhoon Intensity Prediction Scheme (STIPS), which was made operational at the JTWC in 2002.

2. DATASETS

Five and a half years of Navy Operational Global Atmospheric Prediction System (NOGAPS) analyses were used in the most recent formulation of STIPS. Temperature, wind, water vapor pressure and geopotential height data were collected twice daily for the period 21 July 1997 through 31 December 2002 at 100, 150, 200, 250, 300, 400, 500, 700, 850, 925, and 1000 hPa. NOGAPS skin temperature fields were also collected at the surface for the same period, which are used as sea surface temperature (SST). Surface type (i.e. land or ocean) is determined from a digitized land file that contains the continental areas and large islands in the western North Pacific. For operations, SST climatology is used if the real-time skin temperature is unavailable.

The tropical cyclone position and intensity information used in this study come from the JTWC's best track database, which is a post-season reanalysis of TC position and intensity. These six-hourly data contain time, date, position and intensity (to the nearest 5 kts) for all storms tropical depression strength or greater.

3. MODEL DEVELOPMENT

Development of the STIPS model closely follows the development of the SHIPS model for the Atlantic and Eastern Pacific tropical cyclone basins (DeMaria and Kaplan 1999). STIPS is a multiple linear regression model where the dependent variables are the intensity change from the initial forecast time at 12-hour intervals. As a result, there are 10 predictive equations for the 10 time periods, 12-h through 120-h forecasts. Potential predictors (independent variables) are created using current TC conditions, current TC trends, and the NOGAPS analyses. The predictors are evaluated for their combined ability to predict tropical cyclone intensity change.

The potential predictors used in STIPS development can be divided into two separate categories: 1) those related to climatology, persistence and trends of intensity - "CLIPER predictors" and 2) those related to current and future environmental and SST conditions – "synoptic predictors". All of these are derived along the tropical cyclone track. Predictors are developed using a "perfect prog" methodology where the NOGAPS analyses and tropical cyclone best tracks are used to create the statistical model. When applied operationally, the NOGAPS forecasts are used to create the predictors along the forecast tropical cyclone track. Finally, the inland tropical cyclone intensity decay at landfall is treated the same as in the SHIPS model.

The stepwise predictor selection procedure was performed on the predictor pool and resulted in 11 predictors being included in the final model formulation. There were 1921 cases available at 12-h and 608 cases at 120 hours in the developmental dataset. The 11 predictors chosen came from the 21-member predictor pool.

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Table 1 lists the 11 predictors used in the model along with the forecast time in which they are most statistically significant to the model's forecast. Note the "Wind Shear" refers to the 200hPa minus 850hPa wind vector difference, and Maximum Potential Intensity (MPI) is determined empirically from West Pacific TC climatology and the SST field. The predictors can be thought of as (1-2) CLIPER, (3-7) intensity potential that is a function of current intensity and MPI or SST, (8-9) combined effects of vertical wind shear and (10-11) convective instability.

Table 1. A list of the final predictors used in STIPS along with the forecast hour they are most statistically significant.

Predictor	Most Important (Hour)
1. 12-h Δ Vmax	12
2. Storm Speed	60
3. Initial Vmax	12
4. Initial Vmax squared	12
5. MPI	24
6. MPI squared	24
7. MPI * VMAX	12
8. Wind shear	12
9. Zonal Wind Shear	60
10. Temp. 200 hPa	36
11. RH 500 to 300 hPa	24

4. MODEL PERFORMANCE

The performances in terms of percent variance explained and mean absolute error (MAE) of this model formulation can be estimated from the dependent data. Table 2 shows the developmental statistics associated with this model. Also note that in the developmental dataset biases are zero.

Table 2. The developmental statistics associated with the STIPS model. Shown are percent variance explained (R^2), and mean absolute error of the model estimate (MAE).

	12-h	24-h	36-h	48-h	72-h	96-h	120-h
R^2	40.0	49.4	54.6	57.7	61.2	64.8	67.8
MAE	5.6	9.3	12.1	14.7	18.6	20.7	21.8

While the developmental performance is important, there is no substitute for independent testing. The current STIPS model formulation (i.e., Table 1) became operational at JTWC on 13 June 2003. A homogeneous verification of STIPS and decay STIPS with respect to the 5-day statistical model ST5D (Knaff, et al, 2003) for forecasts made after 12 June 18 UTC was created using preliminary best tracks. A standard CLIPER diagram is shown in Fig. 1 and MAE, biases and the number of forecasts are shown in Table 3.

The current formulation of STIPS and decay STIPS models (installed on 12 June 18 UTC) both produced skillful forecasts with respect to ST5D. The STIPS based forecasts were also the most skillful intensity guidance available at the JTWC during that time.

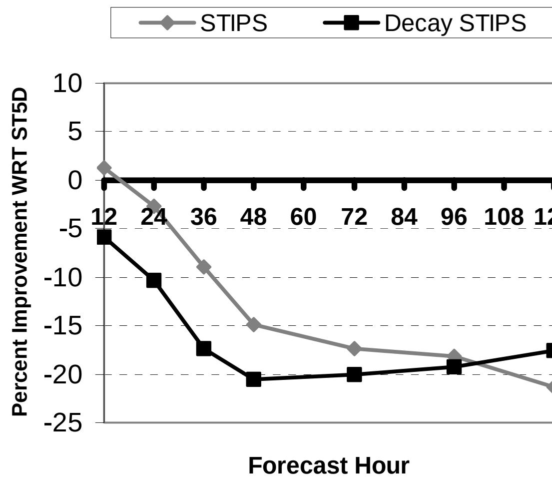

Figure 1. Figure showing the performance of the STIPS and the decay version of STIPS with respect to the 5-day CLIPER model ST5D (or the zero line). Negative values in this figure indicate skill.

Table 3. MAE (kt), Biases (kt) and number of cases associated with the homogeneous verification of decay STIPS.

	12-h	24-h	36-h	48-h	72-h	96-h	120-h
MAE	7.5	11.2	13.7	16.3	20.9	20.9	19.3
Bias	-1.1	-2.4	-4.0	-6.5	-10.7	-12.6	-8.5
N	390	357	330	301	242	142	93

5. FUTURE

The current version of the STIPS model will remain in JTWC's operational suite for the upcoming season and the coefficients used will be updated in early summer. This model could be improved by the use of satellite data, and ocean heat content as predictors. This would likely produce even more skillful forecasts. However, possibly the most efficient use of funding resources would be to develop a similar model formulation for JTWC's Indian Ocean and Southern Hemisphere areas of responsibility.

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