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13. ABSTRACT *(Maximum 200 words)*

The primary objective of this project was to create and implement a 5-day Statistical Typhoon Intensity Prediction Scheme (STIPS) into the operational suite of products available to JTWC. The development of such a scheme builds on the success of the Statistical Hurricane Intensity Prediction Scheme (SHIPS) developed for the Atlantic and Eastern North Pacific and used by the National Hurricane Center (DeMaria and Kaplan 1999). In the process of developing STIPS, a comprehensive statistical analysis is performed which identifies the physical processes associated with tropical cyclone intensification in this basin along with their relative importance. The resulting statistical scheme, STIPS produces tropical cyclone intensity forecasts along a specified forecast track. The STIPS model also has a companion formulation Decay-STIPS which factors in the effect of interaction with land and decays the forecasted intensity accordingly.

A secondary objective was the development of simple 5-day statistical typhoon intensity forecast (STIFOR-5D) model which is based upon climatology and persistence (CLIPER). The development of this simple model was necessitated by the operational requirement to verify forecasts.

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Development and Implementation of a Statistical Typhoon Intensity Prediction Scheme for the Western North Pacific

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GOAL

The goal of this one-year project is to improve typhoon intensity prediction by the Joint Typhoon Warning Center (JTWC) in the western North Pacific region by providing new statistically based guidance schemes based upon climatology, persistence, thermodynamics and synoptic information derived from the Navy Operational Global Analysis and Prediction System (NOGAPS).

OBJECTIVE

The primary objective of this project was to create and implement a 5-day Statistical Typhoon Intensity Prediction Scheme (STIPS) into the operational suite of products available to JTWC. . The development of such a scheme builds on the success of the Statistical Hurricane Intensity Prediction Scheme (SHIPS) developed for the Atlantic and Eastern North Pacific and used by the National Hurricane Center (DeMaria and Kaplan 1999). In the process of developing STIPS, a comprehensive statistical analysis is performed which identifies the physical processes associated with tropical cyclone intensification in this basin along with their relative importance. The resulting statistical scheme, STIPS produces tropical cyclone intensity forecasts along a specified forecast track. The STIPS model also has a companion formulation Decay-STIPS which factors in the effect of interaction with land and decays the forecasted intensity accordingly.

A secondary objective was the development of simple 5-day statistical typhoon intensity forecast (STIFOR-5D) model which is based upon climatology and persistence (CLIPER). The development of this simple model was necessitated by the operational need to verify intensity forecasts beyond 72-hours, which is the capability of the current Statistical Typhoon Intensity Forecast (STIFOR) (Chu 1990).

Three new tropical cyclone intensity schemes, STIPS, Decay-STIPS, and STIFOR-5D will be implemented and made available to the forecasters at JTWC through the Automated Tropical Cyclone Forecasting System (ATCF) described in Sampson et al. (1999).

APPROACH

Three and a half years of NOGAPS (Baker, cited 2002, Hogan and Rosmond 1991) analyses were used in the development of STIPS. Specifically, temperature, wind, water vapor pressure and geopotential height data were collected twice daily for the period 12 July 1997 through 31 December 2000 at 100, 150, 200, 250, 300, 400, 500, 700, 850, 925, and 1000 hPa. Surface skin temperature fields were also collected 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 operational purposes a SST climatology (Levitus 1982) is used if real-time SST is not available.
The tropical cyclone position and intensity information came from the JTWC's "best track", which is a post-analysis product which uses additional information not available in the operational setting (JTWC, cited 2002). These files contain the six-hourly date, latitude, longitude and intensity to the nearest 5 knots for all storms designated by JTWC as being tropical depression strength or greater. The intensity archived in these historical datasets as well as operational intensity forecasts are estimated to the nearest 5 knots (2.58 ms^{-1}).

The development of the STIPS model closely follows the development of the SHIPS model in the Atlantic and Eastern Pacific tropical cyclone basins as described in DeMaria and Kaplan (1999). As a result, STIPS is a multiple linear regression model. The dependent variables used in STIPS (predictand) are the intensity change from the initial forecast time (DELV) at 12-hour intervals. This results in 10 predictive equations for the 10 time periods, 12-h through 120-h forecasts. Potential predictors (independent variables), or more precisely parameters that have been documented in the literature to be associated with tropical cyclone intensity change, are created. Then the potential model predictors, which are derived from environmental and climatological factors, are evaluated for their combined statistical ability to predict tropical cyclone intensity change The inland decay of tropical cyclone intensity at landfall is handled by the inland decay model discussed in Kaplan and DeMaria (1995) south of 36 N and that of Kaplan and DeMaria (2001) north of 40 N.

When developing a multiple regression model one must use a method to select predictors based upon their combined ability to predict the dependent variable . For this study we choose to use a stepwise procedure to select variables from the predictor pool at each forecast time using a 99% statistical significance level (based upon an F-test) for inclusion and a 98% level for exclusion once included. Because this stepwise methodology results in different predictors being used at different forecast times, , a set of predictors consisting of all of the predictors chosen for any forecast period using a stepwise selection procedure are included in a final group. The predictors are combined in the manner to improve the consistency of the forecasts at different time intervals when the scheme is applied to independent cases. Using this final group of predictors, a single multiple regression model is created using a single backward step (i.e. all of the predictors in the final group are included in the model) for each forecast interval.

WORK PERFORMED

STIPS and STIFOR-5d were developed and implemented in the ATCF at the Joint Typhoon Warning Center. On-site training at JTWC on the use of these models was performed in May 2002.

RESULTS

The predictor selection procedure resulted in 12 predictors being included in the final model formulation. There were 1433 cases available at 12-h and 549 cases at 120 hours in the developmental dataset . Contrary to a popularly held believe that upper-level troughs impact tropical cyclone intensification, the predictor selection procedure suggests that the relative eddy flux convergence, which are most often related to upper-level trough interactions with the tropical cyclone is not significant at any time period. This result agrees with the findings of Fitzpatrick (1997).

Table 1 lists the 12 predictors used in the model along with the forecast time in which they are most important (statistically significant) to the model's forecast. Not surprisingly the predictors related to current conditions, namely the CLIPER predictors, were most important to the model at the 12-hour period, with the exception of zonal storm speed. During the 24-hour period and 36-hour forecasts the factors related to vertical wind shear, divergence and MPI become most important. The 200 hPa zonal wind and the RHHI have the greatest impact on the forecasts at 48-hours and are likely related to the encroachment of mid-latitude westerly winds and dry upper-level conditions. There are two predictors that have the most significance during the108-h forecast. Both the SPDX and SHRG* sin(LAT) are most important at 108-h.

Table 1: List of the final predictors used in STIPS along with a brief description and the forecast hour they are most statistically significant.

Predictor	Description	Most Important Forecast Hour
1. DVMX	12-hour change in Intensity	12
2. SPDX	Zonal Storm Motion	108
3. VMAX	Current Intensity	12
4. $VMAX^2$	Current Intensity squared	12
5. MPI	Empirical Maximum Potential Intensity (MPI)	24
6. MPI^2	MPI squared	24

7. MPI * VMAX	MPI times the initial intensity	12
8. SHRG	Generalized 200 to 850 hPa vertical wind shear	36
9. SHRG * sin (LAT)	Generalized wind shear times the sine of the latitude	108
10. U200	Area average (200 km to 800 km) zonal wind at 200 hPa	48
11. D200	Area average (0 km to 1000 km) 200 hPa divergence	24
12. RHHI	Area averaged (200 km to 800 km) relative humidity 500 – 300 hPa	48

The multiple regression procedure also provides thresholds values of the individual predictors as they relate to intensity change in the STIPS dependent data. These threshold values can determine when a predictor has a positive versus negative affect on intensity change. Table 2 lists the threshold values for the synoptic predictors at all of the forecast times, excluding MPI and quadratic terms. All of these predictors have positive coefficients in the model, except SHRG. As a result, values of these predictors greater than the threshold lead to intensification, except for SHRG where values smaller than the thresholds would lead to intensification.

Table 2: Threshold predictor values associated with tropical cyclone intensification in the western North Pacific. All wind values are in terms of knots and divergence terms are divergence times 10^7.

	12-h	24-h	36-h	48-h	60-h	72-h	84-h	96-h	108-h	120-h
SHRG	16.1	15.8	15.4	15.1	14.9	14.7	14.7	14.5	14.5	14.5
U200	-1.4	-1.7	-2.1	-2.4	-2.5	-2.5	-2.3	-2.2	-2.1	-2.1
δ200	53.8	54.8	55.6	56.5	57.3	58.3	59.5	60.9	62.5	64.1
RHHI	58.1	58.2	58.3	58.5	58.5	58.6	58.6	58.7	58.8	58.9

The development and implementation of STIFOR-5D in July of 2001 also produced an interesting outcome. STIFOR-5D produced dramatically better forecasts for the 2001 season than its 72-hour predecessor STIFOR, resulting in a significant improvement in the thresholds by which intensity forecasts in the West Pacific are measured.

IMPLICATIONS

Based upon results found in other tropical cyclones basins, the use of these new guidance models should result in significantly improved forecasts of tropical cyclone intensity in the western North Pacific. Overall improvements should be on the order of 10% of the error relative to climatology and persistence (i.e. STIFOR-5D).

TRANSITIONS

The software to run these statistical models has been transitioned to the operational ATCF at the JTWC. An evaluation of the operational performance of the models will be performed by JTWC after a sufficient sample of cases has been obtained.

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