SUBJECTIVE METHODS FOR ASSESSING TROPICAL CYCLOGENESIS AND INTENSITY CHANGE AT THE JOINT TYPHOON WARNING CENTER

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1. INTRODUCTION

Although numerical models have demonstrated an increased capability to forecast tropical cyclogenesis in recent years (Elliott 2010), forecasting the formation of a disturbance into a tropical cyclone has been primarily a subjective practice guided by the knowledge and experience of individual forecasters. In an effort to increase forecast consistency and accuracy, the Joint Typhoon Warning Center (JTWC) Techniques Development Branch recently developed a technique to predict tropical cyclogenesis from regularly observable factors associated with developing tropical cyclones. In conjunction with this effort, JTWC updated its 24 hour tropical cyclone formation classification system from “poor”, “fair”, and “good” to the more probabilistic “low”, “medium”, and “high”. The new classification levels are defined as follows:

> “Low” formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours.
>
> “Medium” formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.
>
> “High” formation potential describes an area that is being monitored for development and is either expected to develop within 24 hours or development has already started, but warning criteria have not yet been met. l Forecasters issue a “Tropical Cyclone Formation Alert” for all areas classified with a “High” development potential.

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Techniques Development plans to apply the tropical cyclogenesis forecasting method introduced in this paper to tropical cyclone rapid intensification and other forecast problems.

2. METHOD

This development effort focused on the second of three stages of genesis described by Simpson, et al (1997). These stages are categorized as establishment, pre-formation, and initial development. After suitable atmospheric conditions (Gray, 1968) are established in vicinity of a nascent tropical disturbance (stage 1), the pre-formation stage begins. The pre-formation stage may last hours to days before a disturbance either enters the initial development stage or dissipates. During this pre-formation period, JTWC forecasters analyze key observable phenomena known to influence tropical cyclone development. A list of these phenomena was compiled through in-person interviews with the forecasters. The list was then limited to include only those items quantified in datasets that are routinely available to forecasters in real-time. The data and phenomena studied hereafter will be referred to as “development factors.”

Key data values quantifying each of the development factors were collected for seventeen developing disturbances (03W – 19W) and seventeen non-developing disturbances from the 2010 western North Pacific tropical cyclone season. Developing disturbances (hereafter termed “developers”) were defined as cyclones that attained or exceeded a maximum sustained surface wind speed of 25 knots and were subject of JTWC tropical cyclone warnings. Data were interpreted and binned according to their observed values. The following criteria, also listed in Table 1, were evaluated: symmetry of the low level circulation center, 850 mb vorticity, Dvorak final T-number, global model development, outgoing longwave radiation (OLR) anomaly associated primarily with the

Madden-Julian Oscillation, vertical wind shear, and upper level outflow pattern. Each item was evaluated at every synoptic time (00Z, 06Z, 12Z, and 18Z) during the 48 hour period preceding first warning for the developer cases, and for an equivalent 48 hour period for the non-developer cases.

Of the eight development factors tested, only core temperature anomaly was eventually excluded as an unreliable predictor due to the data's limited availability, inconsistent representation, and a poor correlation to early development potential displayed in the thirty-four samples observed. All other development factors were determined to be readily available, easily evaluated, and useful for predicting tropical cyclone formation.

Development factor	**Dataset referenced**	**Value "bins"**
LLCC symmetry	ASCAT, visible and microwave satellite imagery, radar	Long axis diameter divided by short axis diameter: Between 1.5 and 2, Between 1.2 and 1.5, Less than 1.2 (~ symmetric)
850 mb vorticity	CIMSS vorticity product	$< 25\ s^{-1} \times 10^{-6}$ $25\text{-}50\ s^{-1} \times 10^{-6}$, $50\text{-}75\ s^{-1} \times 10^{-6}$, $>75\ s^{-1} \times 10^{-6}$
Dvorak T numbers	PGTW and KNES final T-numbers	1.0, 1.5 or greater
Global model development	NOGAPS, GFS, UKMET, JGSM, and ECMWF surface wind fields	Development Yes/No within 24 hours and within 48 hours
MJO OLR anomaly	Australian CAWCR OLR anomaly Hovmoller diagram	No or positive anomaly $< -4\ W/m^2$, $< -12\ W/m^2$
Vertical wind shear	CIMSS vertical wind shear product	< 15 kts, 15-20 kts, 20-30 kts, 30+ kts
Upper level outflow pattern	CIMSS upper-level feature track winds	Weak to no diffluence, Moderate to strong diffluence but no trough interaction, Moderate to strong diffluence with trough interaction
Core temperature anomaly	CIMSS AMSU	0°-0.5° C, 0.5°C – 1° C, 1°-2° C, >2° C

Table 1: Development factors, datasets used to evaluate these factors, and associated value bins for the low/medium/high classification study.

3. RESULTS

A series of logical relationships between development factors and development potential was generated from the collected data.

The series of logical relationships were determined as follows:

Classify as “low” if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 2 > 1.5
- 850 mb vorticity 25-50 $s^{-1} \times 10^{-6}$
- PGTW **AND** KNES final T = 1.0
- 2 or more global models indicate development within 48 hours
- Vertical wind shear less than 30 kts **AND** no upper level convergence over LLCC **AND** MJO-associated OLR anomaly < -4 W/m^2

Classify as “medium” if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 1.5 > 1.2 **AND** 850 mb vorticity 50-75 $s^{-1} \times 10^{-6}$
- PGTW final T = 1.5 **OR** KNES final T = 1.5
- 3 or more global models indicate development within 48 hours
- Vertical wind shear 20-30 kts **AND** divergence aloft over LLCC **AND** MJO-associated OLR anomaly < -4 W/m^2

Classify as “high” if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 1.2 **AND** 850 mb vorticity > 75 $s^{-1} \times 10^{-6}$
- PGTW final T = 1.5 **AND** KNES final T = 1.5
- 5 global models indicate development within 48 hours
- 3 or more global models indicate development within 24 hours
- Long axis diameter divided by short axis diameter < 1.2 **AND** vertical wind shear < 15 kts **AND** divergence aloft with outflow into an upper level trough
- At least four of the following are true: Long axis diameter divided by short axis diameter < 1.5 > 1.2, 850 mb vorticity 50-75 $s^{-1} \times 10^{-6}$, MJO-associated OLR anomaly < -12 W/m^2, vertical wind shear < 15 kts **OR** divergence aloft with outflow into an upper level trough, Long axis diameter divided by short axis diameter < 1.2, 850 mb vorticity > 75 s^{-1} x 10^{-6}
- Long axis diameter divided by short axis diameter < 1.5 > 1.2 **AND** 850 mb vorticity 50-75 $s^{-1} \times 10^{-6}$ **AND EITHER** PGTW final T = 1.5 **OR** KNES final T = 1.5

If no “low”, “medium”, or “high” criteria are met, the area will remain a “disturbance”.

Applying these relationships to the 2010 developer and non-developer data (17 cases each) yielded the results presented in figures1 through 6.

Figure 1 shows the percentage of disturbance areas classified as “low”, “medium”, or “high” at each six hour point during the 48 hours preceding first warning for all development cases. Overall, 71% of developers were classified with a “high” classification and 94% with at least a “medium” classification 24 hours prior to first warning. At least a “low” classification was assigned for nearly all developers 48 hours prior to first warning.

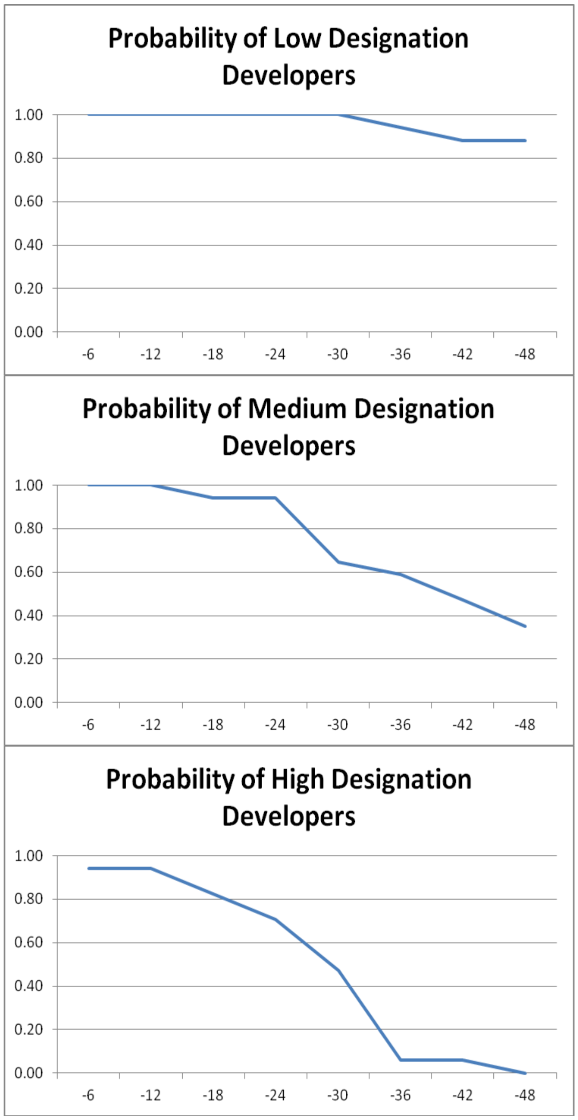

Figure 1: Probability that developing disturbances would be classified as “low” (top), “medium” (middle), and “high” (bottom) at various lead times (0 to 48 hours prior to first warning) using the logical relationships among development factors derived in this study.

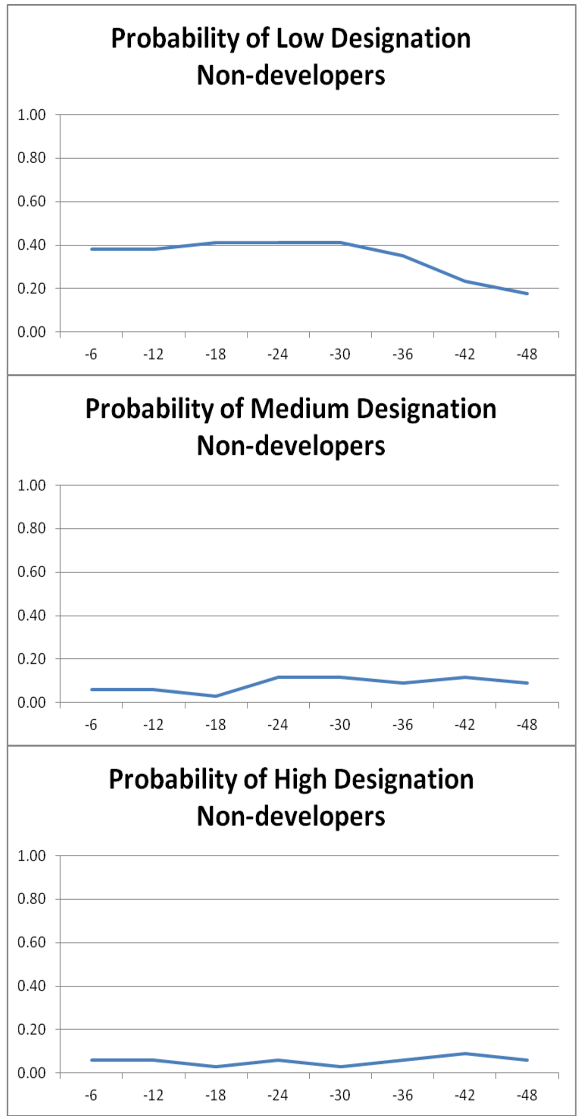

Figure 2: Probability that non-developing disturbances would be classified as “low” (top), “medium” (middle), and “high” (bottom) at various times over a 48 hour monitoring period using the logical relationships among development factors derived in this study.

Figure 2 shows the percentage of non-developers classified as “low”, “medium”, and “high” at each synoptic time over a 48 hour monitoring period. Note that “medium” and “high” classifications were infrequently assigned for the non-developers. Even “low” designations were relatively infrequent for non-developers compared with the developer cases. This suggests that disturbances classified as “low” using the derived logical relationships are more likely to eventually develop into significant tropical cyclones than to dissipate.

The probability that a disturbance designated as “low”, “medium”, or “high” following the logical relationships would develop into a significant tropical cyclone within the following 24 hour period (from both developer and non-developer data) is shown in Figure 3. Approximately 70% of disturbances classified “high” and 20% of disturbances classified “medium” developed into a tropical cyclone within 24 hours. The percentage of medium-classified disturbances developing within 24 hours was low because most disturbances that eventually developed into tropical cyclones were classified as high at least 24 hours prior to the first warning issued by JTWC (12 of 17). It is worth noting that 17 out of 21 disturbances classified as “medium”, or “high” and approximately two-thirds of disturbances designated as “medium” (only), did eventually develop. This result is consistent with the definition of “medium” development potential, which indicates “elevated potential to develop, but (that) development will likely occur beyond 24 hours.”

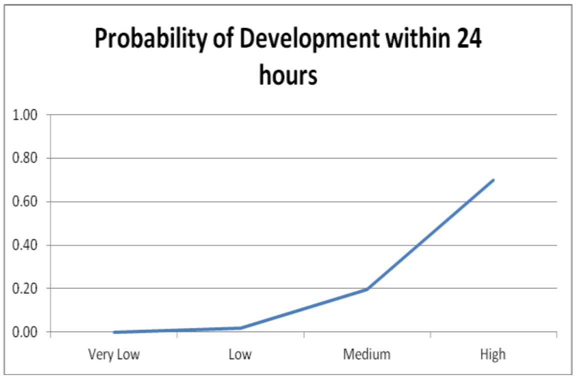

Figure 3: Probability that a disturbance area classified as “very low (no classification)”, “low”, “medium”, and “high” would develop into a warnable tropical cyclone within the 24 hour forecast period, using the logical relationships among development factors derived in this study.

Figure 4 compares the average operational “poor”, “fair”, and “good” classification lead times with the average “low”, “medium”, and “high” classification lead times determined through this study. Mean lead-times using the logical relationships are significantly longer than the operational classification timelines.

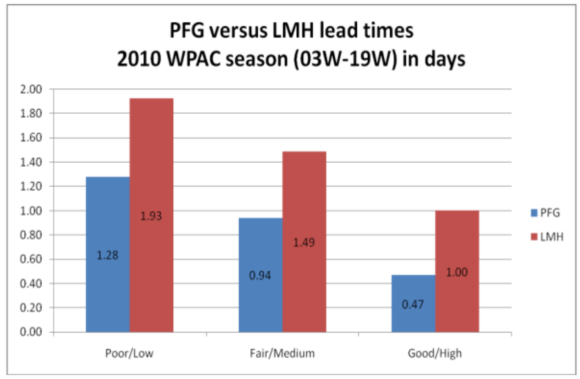

Figure 4: Operational “poor”, “fair”, “good” versus derived “low”, “medium”, “high” mean lead times for 2010 western North Pacific season tropical cyclones.

Figure 5 compares classification lead-times for each developing cyclone using the operational “poor”, “fair”, “good” method to the “low”, “medium”, “high” (logical relationship) method applied during the study. Although lead-times were extended using the logical relationship method for most cyclones, there were several cases in which the classification proceeded directly from “low” to “high” from one synoptic time to the next. This is a weakness of the current methodology that we hope to correct with further data gathering and testing.

Figure 6 also suggests that fewer “low” classifications than “poor” classifications preceded development for the studied developer cases. However, the lack of “low” classifications can be almost wholly attributed to the limited time period studied (48 hours) as it is likely that low recommendations would have preceded the 48 hour study period in many developer cases.

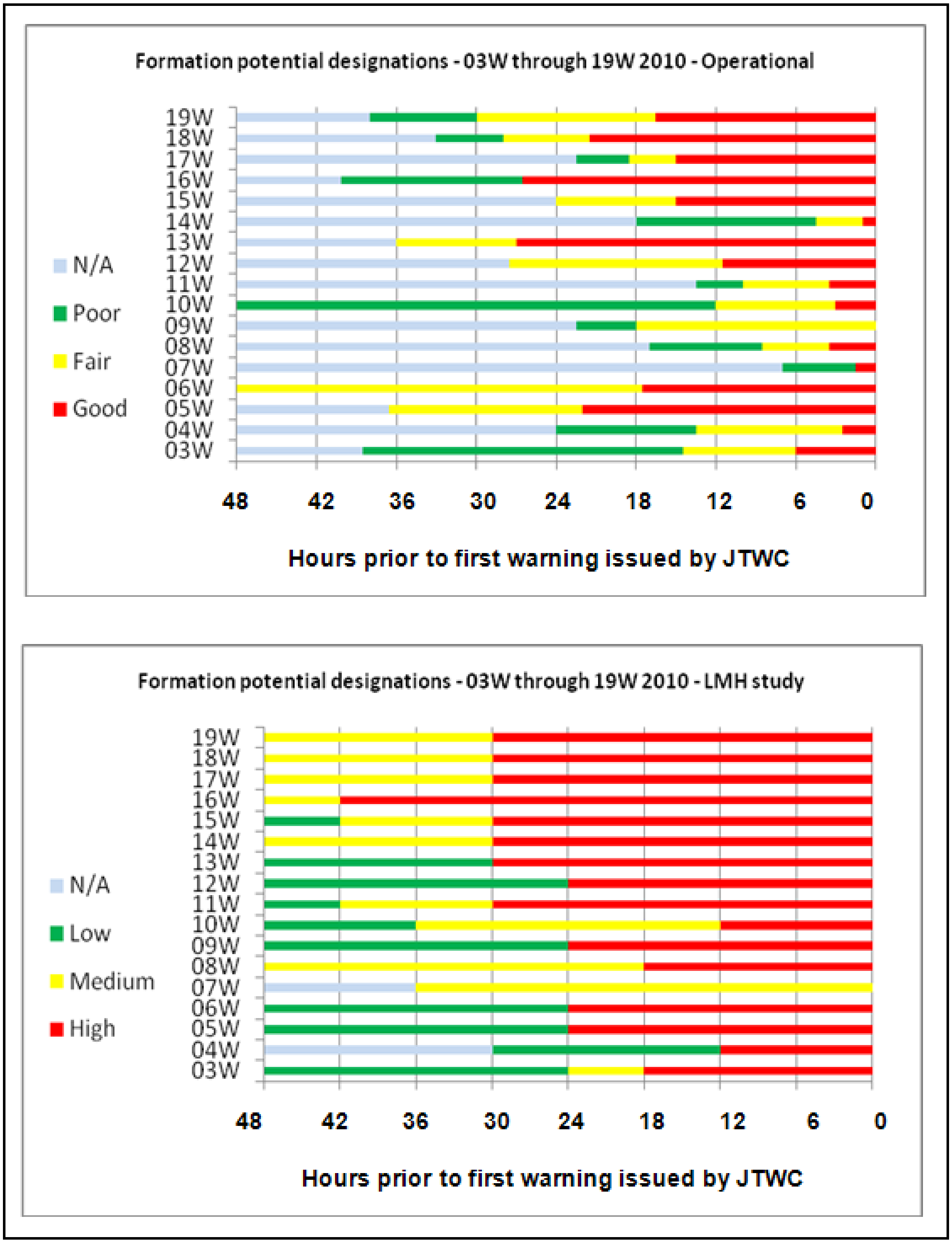

Figure 5: Designated development potential in the 48 hour period preceding first warning for cyclones 03W – 19W (2010): operational poor/fair/good classifications versus low/medium/high classifications derived from the logical relationships among development factors.

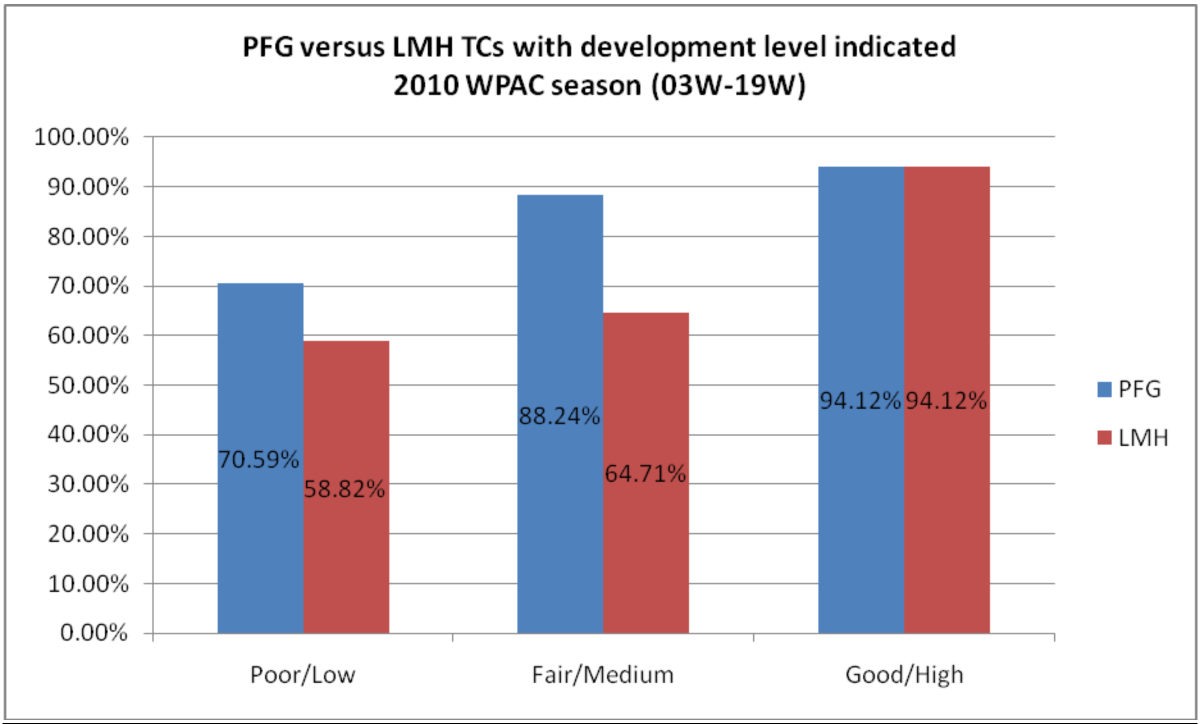

Figure 6: Percentage of developing cyclones for which development was preceded by specified classifications (PFG=poor/fair/good, LMH=low/medium/high) within the 48 hour period preceding issuance of the first tropical cyclone warning.

4. OPERATIONAL APPLICATION

In August 2011, JTWC forecasters began to evaluate tropical disturbances in the western, central, and eastern North Pacific Ocean using a "low/medium/high" (LMH) worksheet based on the results of this study. Additionally, an experimental version of the worksheet has been adapted to evaluate Indian Ocean and South Pacific disturbances. The JTWC Geophysical Technician (GT) and Typhoon Duty Officer (TDO) complete these worksheets at all synoptic times (every six hours). Graphical depictions of genesis potential have also been developed to aid in data interpretation and selection of the appropriate value bins on the LMH worksheet.

The logical relationships applied in the LMH worksheet will be updated as more data is collected. Future versions may incorporate experimental parameters such as a genesis potential index (Fu et al. 2011), Deviation Angle Variance (DAV) values (Piñeros et al. 2010), and Statistical Typhoon Intensity Prediction (STIPS) model trends (Knaff et al. 2005).

The LMH worksheet is designed as an input to the tropical cyclone genesis forecast process. Classifying development potential will ultimately remain at the forecaster's discretion. However, the goal of this effort is implement procedures that are reliable and consistent, and outperform a purely subjective determination of TC formation potential in all quantifiable terms.

5. CONCLUSION

JTWC has developed a process to forecast tropical cyclone formation probabilities as "low", "medium", or "high." This process also provides a framework for developing future guided forecasting techniques. Subsequently, JTWC Techniques Development will investigate how to apply this method to forecasting tropical cyclone rapid intensification (RI).

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7. REFERENCES

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