

NCEP NOTES

Objective Guidance for Use in Setting Tropical Cyclone Conditions of Readiness

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ABSTRACT

The Department of Defense uses a Tropical Cyclone Conditions of Readiness (TC-CORs) system to prepare bases and evacuate assets and personnel in advance of adverse weather associated with tropical cyclones (TCs). TC-CORs are recommended by weather facilities either on base or at central sites and generally are related to the timing and potential for destructive (50 kt; 1 kt \approx 0.5144 m s⁻¹) sustained winds. Recommendations are then considered by base or area commanders along with other factors for setting the TC-CORs. Ideally, the TC-CORs are set sequentially, from TC-COR IV (destructive winds within 72 h), through TC-COR III (destructive winds within 48 h) and TC-COR II (destructive winds within 24 h), and finally to TC-COR I (destructive winds within 12 h), if needed. Each TC-COR, once set, initiates a series of preparations and actions. Preparations for TC-COR IV can be as unobtrusive as obtaining emergency supplies, while preparations and actions leading up to TC-COR I are generally far more costly, intrusive, and labor-intensive activities. The purpose of this paper is to describe an objective aid that provides TC-COR guidance for meteorologists to use when making recommendations to base commanders. The TC-COR guidance is based on wind probability thresholds from an operational wind probability product run at the U.S. tropical cyclone forecast centers. An analysis on 113 independent cases from various bases shows the skill of the objective aid and how well it compares with the operational TC-CORs. A sensitivity analysis is also performed to demonstrate some of the advantages and pitfalls of raising or lowering the wind probability thresholds used by this objective aid.

1. Introduction

The Department of Defense (DoD) uses a set of rules [see Operational Navy Instruction 3140.2 series (Department of the Navy 2012)] similar to those of the watches and warnings to prepare bases and regions, hereafter referred to as just bases, for high winds associated with tropical cyclones. East of the date line the rules are generally called Hurricane Conditions of Readiness

(HURCONs) while the same rules are called Tropical Cyclone Conditions of Readiness (TC-CORs) at bases west of the date line. Since tropical cyclone (TC) wind speeds reported in advisories and forecasts are in units of knots (1 kt \approx 0.5144 m s⁻¹), these units will be used hereafter. The rules are defined with slightly different verbiage at different bases, but fall into the general categories described in Table 1. The bases prefer to set their conditions sequentially (e.g., IV, III, II, I, all clear) rather than allow them to backtrack (e.g., IV, III, II, back to IV, III, II, I, all clear). There are also many subjective considerations used in setting these conditions. A base may prefer to delay a condition IV setting

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TABLE 1. TC-COR definitions and courses of action derived from a Kadena Air Base, Japan, typhoon fact sheet (available at www.kadena.af.mil).

TC-COR	Definition	Preparedness examples
IV	50-kt sustained winds possible within 72 h	Obtain flashlight with extra batteries, snacks, first aid supplies, bottled water
III	50-kt sustained winds possible within 48 h	Clean up around house, pick up loose items
II	50-kt sustained winds anticipated within 24 h	Secure outdoor property including picnic table, barbecue grill
I	50-kt sustained winds anticipated within 12 h	Schools close, fill available containers with water
I-CAUTION	34–49 kt occurring and are expected to reach 50 kt within 12 h	All outdoor activities except in support of urgent military missions discontinued
I-EMERGENCY	50-kt sustained winds occurring	All outside activity prohibited
I-RECOVERY	50-kt sustained winds no longer occurring	No outdoor activity authorized except by predesignated emergency crews
STORM WATCH	Still a possibility of danger	Normal activity resumes 2 h after declaration
ALL CLEAR	Local recovery operations complete	Be alert to possible damage and hazardous conditions on roads, etc.

to the morning since there is typically little urgency involved with longer lead times. Some bases may also prefer to upgrade from condition IV through condition II on a set schedule (e.g., first thing in the morning) so as not to disrupt or confuse those involved with preparing the base for the destructive winds (sustained winds of 50 kt or greater). Also, a base may often remain in a heightened condition even after a tropical cyclone because another is forecast to approach within a day or two. There may also be occasions when a base could modify conditions based on assets, holidays, or base experience in emergency preparedness. Figure 1 (bottom) shows a graphic used to provide guidance for TC-COR settings at U.S. Navy bases in Japan. This graphic, called the tropical prediction utility (TPU), provides a general overview of bases and regions that would be considered for TC-CORs as a TC approaches. The base closest to the current TC position (Kadena) is just outside the TC-COR I region while regions farther along the forecast track are in higher TC-CORs. In this specific case, both Sasebo and Yokosuka Naval Bases were in TC-COR III (50-kt sustained winds possible within 48 h) when the graphic was generated, which is consistent with guidance in the template.

Costs involved in setting these TC-CORs vary. Bases generally have checklists of tasks to complete for each upgrade in TC-COR (Winters et al. 2006). As a general rule, the costs of the TC-CORs increase as the level drops from TC-COR IV to TC-COR I. TC-CORs can influence sortie decisions for both ships and aircraft, delay spacecraft launches, prompt evacuations, and necessitate overtime for essential employees. The ideal warning scenario is to set TC-CORs early while only setting them for the “hits,” never for misses. This ideal scenario allows plenty of lead time for preparation while avoiding unnecessary, costly actions in both monetary terms and forecaster credibility.

Applications for TC-COR settings have been developed for at least 35 yr (Brand and Brelloch 1975; Jarrell et al. 1978; Jarrell and Brand 1983; Jarrell 1987). The most recent application in the western North Pacific is the TPU (Fig. 1, bottom). The TPU, developed in 2006, ensures a level of consistency with TC-COR timelines at the bases (Wallace 2008). As with the wind probability guidance developed in this paper, the TPU is meant to be guidance for the forecasters and not intended to be used in place of human decisions. Wallace (2008) found the TPU predictions to be biased toward longer lead times than the operational TC-CORs (which in our opinion is better than it being biased toward shorter lead times). One limitation of the TPU is that it is limited to tropical cyclones that are forecast to be >50 kt, something we hope to address with our TC-COR algorithm.

The purpose of this paper is to describe an objective aid that provides TC-COR guidance for meteorologists to use when making recommendations to base commanders. Section 2 discusses a database gathered over several years for the evaluation. Section 3 describes development of the wind probability thresholds and algorithm used to produce TC-COR guidance. Section 4 evaluates results of the TC-COR guidance on the independent cases. Section 5 performs sensitivity tests on the wind probability thresholds developed in section 2. Section 6 discusses our conclusions and further research.

2. Data

The forecast and best-track data used for this study are taken from the Automated Tropical Cyclone Forecasting System (ATCF; Sampson and Schrader 2000) operational archives at the National Hurricane Center (NHC) and Joint Typhoon Weather Center (JTWC). There are 113 operational TC-COR cases (where a tropical

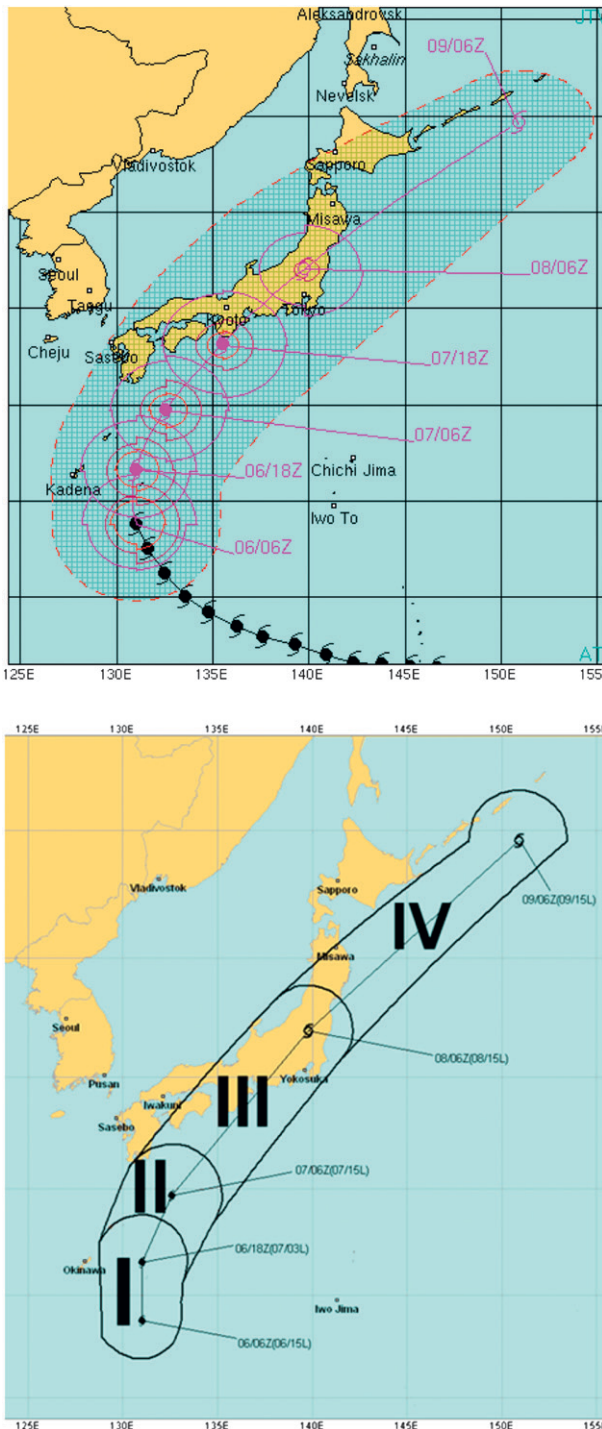


FIG. 1. Example of (top) JTWC warning graphic and (bottom) general TC-COR guidance for Typhoon Melor (2009) approaching Japan. Hatched area in JTWC warning indicates an area of uncertainty derived from the average track errors added to 34-kt wind radii.

TABLE 2. Summary of TC-COR cases used in this study.

Military base	Cases	50-kt sustained wind events
Andersen Air Force Base, Guam	11	2
Yokosuka Naval Base	18	2
Kadena Air Base	19	3
Yokota Air Base, Japan	14	0
Misawa Air Base, Japan	2	0
Atsugi Naval Air Facility, Japan	5	0
Sasebo Naval Base, Japan	6	0
Iwakuni Marine Corps Air Station, Japan	4	0
Patrick Air Force Base	15	3
Norfolk Naval Base	17	2
Stennis Space Center, Mississippi	1	1
Mayport Naval Station, Florida	1	0

cyclone approached close enough to a base to investigate TC-CORs) from tropical cyclone passages in the TC-COR database, and it includes 79 cases from eight bases in the western North Pacific, as well as 34 cases from four bases along the Eastern Seaboard and in the Gulf of Mexico (Table 2). The 113 TC-COR cases from 1997 through 2011 are gleaned from a variety of sources, including damage reports, base notes, e-mails, web pages, and verbal communications. Base wind and damage reports were also obtained from the bases, when possible, and were augmented by station observations gleaned from various web-based sources including the Weather Underground and *Stars and Stripes*.

Out of the 113 cases evaluated, it was determined that there were 13 hits (estimated 50 kt or greater 1-min sustained wind event at the base). Two of the hits had 48- and 49-kt sustained winds measured at the site, but damage reports and surrounding observations indicate that there were probably higher winds at the base. One site stopped transmitting before the arrival of 50-kt winds. Several other wind events have reported gusts that exceed 50 kt and sustained winds of 40 kt or greater. These were not included as hits, although the authors realize that 50-kt sustained winds may have been present during these wind events since the temporal and spatial resolutions of the observations are probably insufficient to capture the highest sustained winds. As such, the authors prefer that the guidance developed overforecasts the TC-COR settings to capture these wind events. Development of thresholds for the TC-COR settings will be discussed in the following section.

3. Methods

The operational wind speed probability algorithm (DeMaria et al. 2009; M. DeMaria et al. 2012, unpublished manuscript) used at National Hurricane Center

and Joint Typhoon Warning Center was employed to generate wind probabilities at sites for which we obtained observations, damage reports, or official TC-COR settings. For consistency we used the 2011 version of the wind probability algorithm, which includes a prediction of official forecast error to modify the track error spread [graphical predicted consensus error (GPCE); Goerss 2007], for the entire dataset.

The first step in the development of a TC-COR objective aid is to determine the wind speed probability thresholds that best correspond to times TC-COR should be issued. This methodology is analogous to the process used to develop objective aids for hurricane watches and warnings in the Atlantic (Schumacher et al. 2010). Even though the wind speed and timing criteria for hurricane warnings and TC-COR settings differ, minor changes to the methodology of Schumacher et al. (2010) should yield reasonable “first guess” approximations of the desired TC-COR probability thresholds. Then, probability thresholds can be tested and refined based on statistical verification (section 4).

The same sample of Atlantic tropical cyclones making landfall along the U.S. mainland from 2004 to 2010 used in Schumacher et al. (2010) was used here. Following their methodology, 64-kt wind speed probabilities were computed at 12, 24, 48, and 72 h prior to the arrival of the 64-kt winds to correspond to the time criteria for TC-COR settings I, II, III, and IV, respectively. Wind speed probabilities were generated using the 2010 developmental version of the Monte Carlo wind speed probability (MCWSP) product. Locations along the U.S. mainland coast where near-surface winds met or exceeded 64 kt were determined from tropical cyclone positions and the radius of 64-kt winds (R64) recorded in the ATCF. With these data, statistical metrics such as the probability of detection (POD), false alarm rate (FAR), and threat score (TS) can be calculated for any given probability threshold (see Wilks 2006).

Working under the assumptions that 1) missed TC-CORs can have extreme negative consequences (e.g., loss of life) and 2) false alarms are also costly, a selection scheme for our first-guess TC-COR probability thresholds was specified so that 1) $\text{POD} \geq 0.99$ and 2) FAR is minimized—implying the cost-to-loss ratio is very small (Wilks 2006, 321–324). The thresholds that we derived are 12%, 8%, 6%, and 5% cumulative probability of 50-kt winds at 12, 24, 48, and 72 h, which correspond to TC-COR I, II, III, and IV, respectively. These thresholds appear at first glance to be quite low, but they are defined to minimize the missed cases ($\text{POD} \geq 0.99$). If it is acceptable to miss 50-kt wind events (i.e., the cost-to-loss ratio was close to one), these thresholds could be raised to minimize the FAR and improve statistical skill

scores (e.g., Peirce’s skill score or threat score) discussed in Wilks (2006).

There are other applications that apply the wind probabilities to operational tasks such as warning coordination, ship sorties, ship routing, and space shuttle launches (M. DeMaria et al. 2012, unpublished manuscript). One application for Patrick Air Force Base (Roeder and Szpak 2011), Florida, separates the wind probabilities into five qualitative categories (very low, low, moderate, high, and very high) based on prior evaluation of the wind probabilities (Splitt et al. 2010). It is noteworthy that the average 50-kt cumulative wind probability “low” category thresholds in Roeder and Szpak (2011) are similar to our TC-COR guidance thresholds, even though their thresholds were derived independently (and subjectively).

Our TC-COR algorithm uses the thresholds developed above. Applying the thresholds at each site along with a couple of consistency checks provides TC-COR guidance. There is a check against the last condition set at a site in order to keep the condition from moving backward, as in operations they generally move from TC-COR IV toward TC-COR I. There is also a check to ensure that the cumulative probabilities for the critical forecast times have increased, which prevents the longer-term TC-CORs from being set for shorter-term probabilities (e.g., TC-COR IV being set for a cumulative probability at 72 h of 6% when the cumulative probability for the same case is 6% at 36 h).

This TC-COR objective aid has been run and provided in real time to various bases in the western North Pacific since 2009, and is now also being run at NHC and Fleet Weather Center, Norfolk, Virginia. The output is at the end of the wind probability text product, which includes a caveat about the guidance being for 50-kt or greater wind events only (no waves, rain, surge, etc.). The product should be considered “strategic guidance” in that it does not account for the complex interaction between tropical cyclones and the orography near the bases, nor does it consider the complex interplay between asset protection and meteorology, nor does it provide guidance on storm surge that may affect preparedness at bases. The product states that “each base has its own sensitivities, which these TC-COR settings do not address.” The purpose of this is to ensure that military decision makers understand that this product is not a replacement for the TC-COR process, but is treated as guidance to be used in that process.

4. Results

Figure 2 presents an overview of the performance of the objective TC-COR aid against all “discernible wind

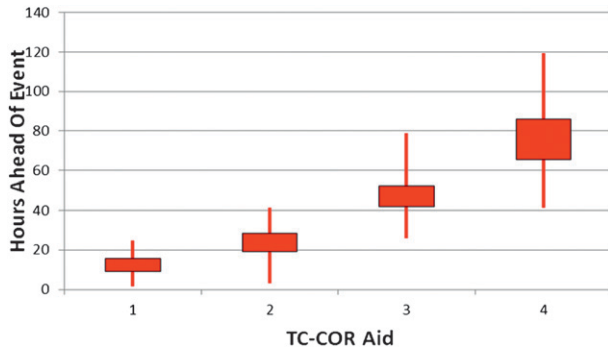


FIG. 2. TC-COR aid timing for discernible tropical cyclone wind events. Thick red bars indicate second and third quartiles, and thin red bars indicate first and fourth quartiles. The numbers of discernible wind events are 33, 43, 53, and 54 for TC-COR I, II, III, and IV, respectively.

events” recorded at the bases. These discernible wind events are not only the actual hits, but a set of measurable tropical cyclone passes by/over bases. While the times for hits are at the onset of 50-kt winds at the base, the times for discernible wind events that did not reach 50 kt are taken at the time of maximum wind at the base or nearby site. The purpose of including all these discernible wind events in Fig. 2 is to evaluate the timing of the objective TC-COR aid. From Fig. 2, it is apparent that the initial time of the TC-COR is generally within an acceptable range (see Table 1).

The initial TC-COR I settings all occur between 1 and 25 h prior to the discernible wind event, with the median being 12 h. The best-case scenario for the objective aid would be for it to predict TC-COR I approximately 12 h ahead of the wind event for all cases, giving operational forecasters time to use the guidance. This availability is not always possible, and for this evaluation there are a couple of very short lead times for TC-COR I. Further investigation indicates that the shortest lead time (1.4 h) is for a hit, and the time would have been extended another 6 h if the TC-COR I wind probability threshold was slightly (1%) lower. This case highlights an issue with forecast latency as TC-COR wind probability thresholds are raised. This issue will be discussed in more detail later in the sensitivity tests (section 4).

The initial TC-COR II settings all occur between 15 and 42 h prior to the discernible wind event, with the median at 24.5 h. The shortest lead time (15.9 h) would have been extended by 6 h if the TC-COR II wind probability threshold was slightly lower. The longest lead time (41.85 h) occurs for a system that was forecast to rapidly recurve and move away from the threatened site, but it slowed down instead. This result is not considered a critical problem since it is more desirable to set these TC-CORs early rather than late.

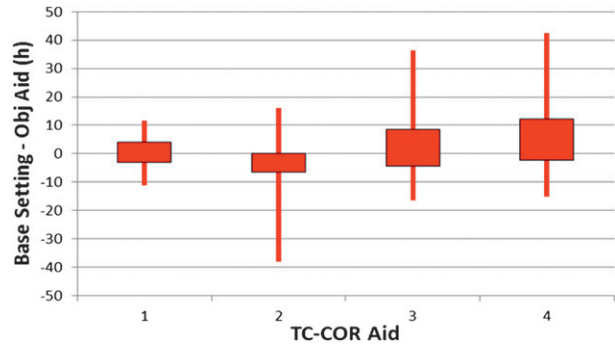


FIG. 3. TC-COR aid times compared with official TC-COR times for discernible tropical cyclone wind events. Thick red bars indicate second and third quartiles, and thin red bars indicate first and fourth quartiles. The numbers of discernible wind events are 25, 30, 43, and 36 for TC-COR I, II, III, and IV, respectively.

The initial TC-COR III settings all occur between 26 and 87 h prior to the discernible wind event, with a median of 49.9 h. The shortest lead time (26 h) is for a hit with significant consequences for both navy meteorologists and a navy base, and it could have been extended another 12 h with a slightly (1%) lower threshold. The longest lead time (87 h) is for a case (Fay of 2008) with a series of very difficult forecasts traversing a coastline. Given the difficulty of the forecast track, intensity, and timing, the TC-COR guidance performance is acceptable and probably desirable.

The initial TC-COR IV settings occur between 41 and 120 h prior to the discernible wind event, with a median of 72.75 h. The shortest lead time is for a tropical storm (Gabrielle of 2007) as it approached the Eastern Seaboard. Forecast winds for Gabrielle were only as high as 55 kt, and the wind probabilities remained low (near the TC-COR IV threshold). The wind event itself was only 20 kt with gusts to 24 kt—a minor event. Given these conditions, the TC-COR IV timing seems appropriate. The next shortest lead time is for 41.85 h, and was associated with Hurricane Dennis (1999) looping off the Eastern Seaboard, which presented difficult track forecast scenarios for the National Hurricane Center. The time between TC-COR IV and the wind event is short for this particular tropical cyclone, as is the TC-COR III and TC-COR II (there is no TC-COR I and the wind event verified as 37-kt sustained winds).

Figure 3 shows an evaluation of the differences between the objective TC-COR aid guidance and the operational TC-COR settings at the bases for the discernible wind events. Ideally, we would prefer that the distribution of these differences be tightly packed around the zero line, but operational settings are influenced by a number of weather and nonweather factors. For example, certain times of day (e.g., morning) may be preferred for initial

TC-COR settings or a base could set a TC-COR early for an intense TC that is forecast to pass directly over the base. There are cases where a base set a TC-COR and the objective aid did not and vice versa. For example, one operational TC-COR I decision (a false alarm by strict measures) involved Halloween, a weekend, and a new base commander. It was decided that these sensitivities warranted the TC-COR I at the base.

The differences between the initial base and initial objective aid TC-COR I settings are within approximately 12 h of each other, which seems reasonable. The quartiles are centered on the zero line, with 50% of the differences falling between -3 (objective aid later than base setting by 3 h) and 4 (objective aid earlier than base setting by 4 h). The least desirable cases are those where the objective aid trails the base setting (negative values). The largest negative value (-11 h) is for a hit where the base TC-COR I setting is approximately 24 h prior to the discernible wind event, probably because base commanders desire to set the COR early in the day instead of in the middle of the night.

TC-COR II differences are between -38 and 16 h, with 50% of the differences falling between 0 and -7 h. The largest negative value (-38 h) is for the very same case as the largest negative TC-COR I difference. The objective aid TC-COR II guidance for this case is approximately 27 h before the discernible wind event, so it is suspected that the operational TC-COR II is set to coincide with waking hours and possibly provide additional lead time for preparations in advance of a category 4 hurricane. The second largest negative difference (-35 h) is also for a hit. In this case, the objective guidance predicts a TC-COR II approximately 25 h prior to the event. Another large negative difference is for a miss in which the objective guidance predicts a TC-COR II approximately 31 h prior to the event, well within reason.

TC-COR III differences are between -17 and 37 h, with 50% of the differences falling between -5 and 9 h. The largest negative difference (-16.5 h) is for a near miss where the objective guidance predicts TC-COR III 66.7 h prior to the discernible wind event. The base TC-COR III setting for this case corresponds to early daylight hours.

TC-COR IV differences are between -15 and 43 h, with 50% of the differences falling between -3 and 13 h. The largest negative difference (-15 h) is well within the expected range of differences, and it appears that the base TC-COR IV was set to coincide with early daylight hours. The largest positive difference (42.5 h) is for Hurricane Bonnie (1998), which was forecast to approach the Eastern Seaboard sooner than it actually arrived. The objective aid forecast TC-COR IV occurred 119.25 h prior to the event.

5. Sensitivity analysis

The objective TC-COR guidance times are impacted by forecast track (as discussed below, large errors in the track can significantly delay the objective TC-COR times at sites impacted by TCs), but also the forecast intensity. For a given tropical cyclone track, the objective TC-COR guidance times are a function of the intensity (e.g., TC-COR IV lead times for Irene 2011 approaching Norfolk Naval Base can be increased 6 h if the TC is forecast to intensify to 135 kt in 72 h and decreased 6 h if forecast to decay to 50 kt in 72 h) and the size (e.g., TC-COR IV lead times can be increased 6 h if the TC initial size is double the analyzed size and decreased 6 h if the TC initial size is half the analyzed size). The sensitivity to forecast intensity could be larger, but the forecast intensities in the wind probability realizations are capped at the high end (150 kt) such that the average intensity tends to decrease with forecast length for very intense TCs.

Although the objective TC-COR aid has been running in real time at JTWC for 3 yr with some success, it is important to test the sensitivities of this algorithm to changes in the wind probability thresholds. These are not tests on independent data; rather, they provide an indication of how well we selected our thresholds. Tests were constructed with all the thresholds (TC-COR I through IV) 50% lower, 50% higher, and double thresholds.

The resulting hits, misses, false alarms, and correct no forecasts from these tests are shown in Fig. 4. We consider the misses to be the most important parameter for our evaluation since we prefer that value to be zero. In all four tests we fail to get to zero misses. Even the 50% lower thresholds contain one miss of a TC-COR II. Further inspection reveals that this is an extremely important event and that the 50% lower thresholds miss the TC-COR II setting only because we rounded the threshold up. Nonetheless, it demonstrates that this particular case (Ma-On of 2004) had very low probabilities even though it caused significant damage at Yokosuka Naval Base, Japan. Increasing the thresholds by 50% appears to improve scores, especially for the TC-COR III and IV cases, while doubling the original thresholds results in TC-COR I and II misses at Patrick Air Force Base (Charley of 2004). From this simple test, we could conclude that we could either increase the thresholds by 50% to improve the false alarm rate and correct no forecasts or decrease the thresholds by approximately 50% (rounding down this time) to ensure we have no misses.

It is common practice to construct an appropriate score from the hits, misses, false alarms, and correct no forecasts. In this case we computed Peirce skill scores

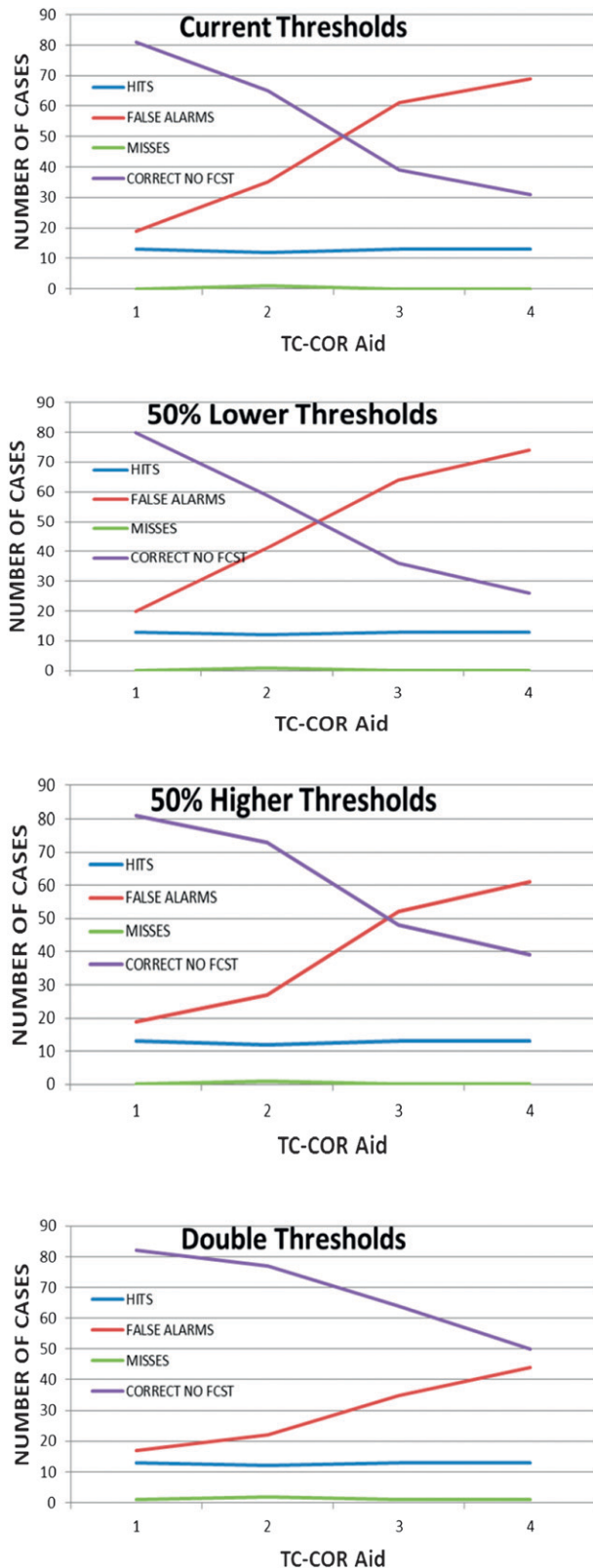


FIG. 4. Hits, false alarms, misses, and correct no forecasts provided by the objective aid predictions of TC-COR I, II, III, and IV.

(Wilks 2006), which can be interpreted as the hit ratio – false alarm ratio. Scores greater than zero indicate forecast skill. Figure 5 shows the Peirce skill scores for the all the thresholds for all the TC-CORs. The 50% higher thresholds outperform the others for TC-COR I and II while the double thresholds outperform the others for TC-COR III and IV. If thresholds are determined strictly by this measure, we could increase the thresholds at least 50%, possibly doubling them for TC-COR III and IV; however, there are consequences for doing so.

The first consequence is that we would need to accept misses, which may be acceptable with a base (depending on its sensitivities). One problem with designing an objective aid to include misses is that the objective aid needs to have estimates of the cost of these misses. Monetary costs incurred for preparedness and missed forecasts are difficult to predict, and there are other costs involved (e.g., loss of life, loss of forecast credibility, and schedule delays). Another consequence of raising the thresholds is that it reduces lead times for the TC-CORs. Fig. 6 shows both the number of lead times reduced and the average time lead times were reduced (for all cases) when we double the thresholds. TC-COR guidance is more useful when it predicts TC-CORs slightly ahead of when the base commanders need to make their decisions, rather than affirming the decision *ex post facto*. One forecaster suggested we attempt to forecast TC-COR times 12 or 24 h ahead of schedule (e.g., “TC-COR forecasted in 24 h”) so that the guidance could be used as a short-term prediction. As forecasts improve through the years (DeMaria et al. 2007), this becomes a more feasible approach.

6. Summary and conclusions

An objective aid for use in setting TC-CORs has been developed and described. This objective aid uses cumulative wind probabilities from the operational wind speed probability product produced every 6 h at the U.S. tropical cyclone forecast centers. The wind speed probability thresholds were determined using hurricane watch and warning data gathered along the Atlantic Seaboard and Gulf of Mexico, with a concerted effort to prevent misses and set TC-CORs at appropriate times. In the evaluation against independent data we found that the objective aid performs as expected. For the 13 recorded 50-kt wind events or “hits” at the bases examined, the objective aid predicted TC-CORs (IV, III, II, and I) for all but one TC-COR II. The initial TC-COR times for the objective aid are within expected ranges and median times are near the longest lead time (72, 48, 24, and 12 h for TC-COR IV, III, II, and I, respectively).

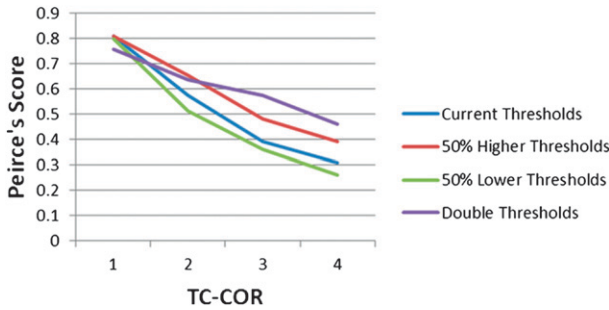


FIG. 5. Peirce skill scores for objective aid TC-COR I, II, III, and IV predictions.

Sensitivity studies show that the Peirce skill score was improved by increasing thresholds, but those improved scores come at the expense of misses and reduced lead times for TC-COR settings. Doubling the current thresholds results in one more TC-COR II and one more TC-COR I miss (both for Charley of 2004 passing through Patrick Air Force Base). Doubling the current thresholds also reduced lead times, especially for TC-COR IV (an average reduction of 7-h lead time). The current thresholds are reasonable for the 2011 version of the wind probability algorithm (M. DeMaria et al. 2012, unpublished manuscript) and bases with low tolerances for missed 50-kt wind events, but should be revisited regularly as the algorithm and the operational forecast errors improve (DeMaria et al. 2007). Higher thresholds could be developed for bases with higher tolerance to missed 50-kt wind events, shorter TC-COR lead time requirements, and high false alarm costs.

Future work on the TC-COR algorithm could include a forecast mode, which would produce 24-h forecasts for the bases. Another thrust is to explore site-specific TC-COR guidance that includes some of the sensitivities at each base, similar to what has been done in Winters et al. (2006) for space shuttle launches. Guidance could also include terrain effects such as are included in Jarrell (1987) for bases in the western North Pacific. In some cases, the bases may be able to tolerate more misses in exchange for a lower false alarm rate. This is especially true for bases where the cost of a miss is approximately equal to that of a hit so that one could use maximum Peirce skill scores to obtain the thresholds. Doubling or even tripling the wind probability thresholds could accomplish this, but it would also come with decreased lead times. One possible compromise (A. J. Reiss 2011, personal communication) is to add comments based on different wind probability thresholds to the TC-COR guidance, which would help mitigate the issues of timing and false alarm rates. This would be a solution similar in concept to what is done in Roeder and Szpak (2011).

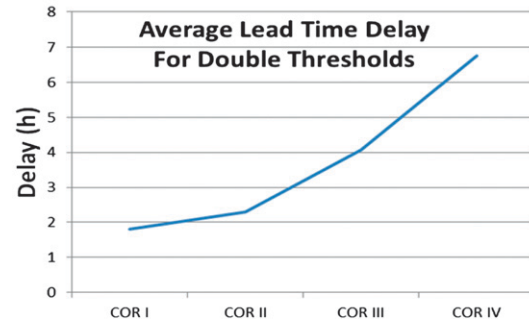
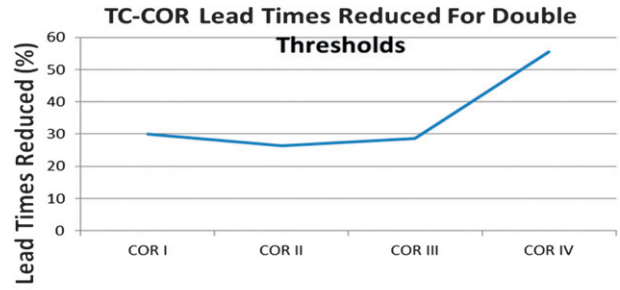


FIG. 6. (top) Percentage of lead times reduced and (bottom) the average number of hours the lead time was delayed for all the cases when the wind probability thresholds associated with the TC-CORs were doubled.

The U.S. Navy is also attempting to develop ship sortie guidance using consistent wind and wave probabilities near tropical cyclones. This is done by running a WAVEWATCH III (Tolman 1991) ensemble with input from the wind probability algorithm; similar to what is done in Sampson et al. (2010) to insert official forecasts into NWP model background wind fields.

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of the authors and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. government position, policy, or decision.

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