NATIONAL HURRICANE CENTER FORECAST VERIFICATION REPORT

2024 HURRICANE SEASON

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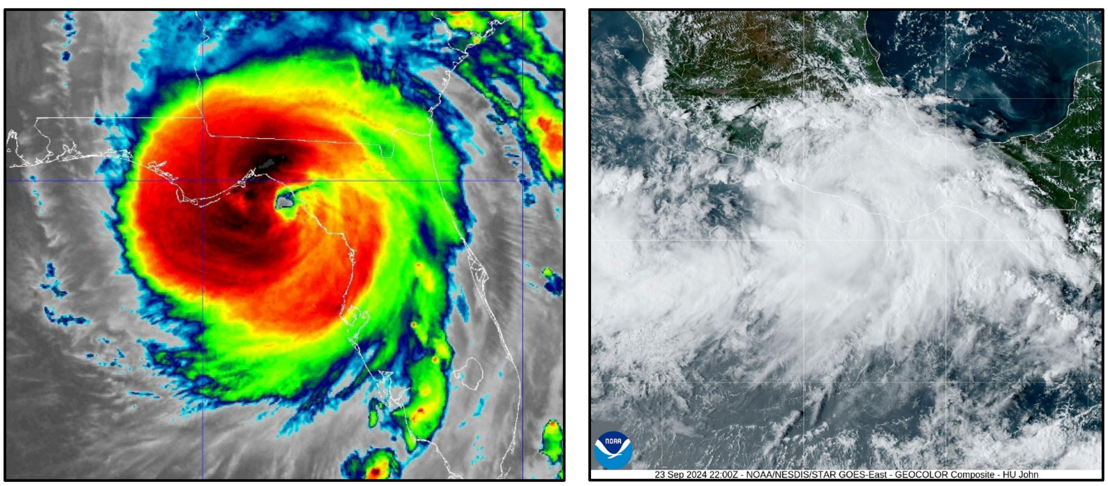

GOES-16 INFRARED IMAGE OF HELENE PRIOR TO LANDFALL IN FLORIDA AT 0200 UTC 27 SEPTEMBER (LEFT). GOES-16 GEOCOLOR IMAGE OF HURRICANE JOHN AT 2200 UTC 23 SEPTEMBER (RIGHT). IMAGES COURTESY OF NOAA/NESDIS/STAR.

ABSTRACT

There were 347 official forecasts issued during the 2024 Atlantic hurricane season, which is slightly above the long-term average number of forecasts. The mean NHC official track forecast errors set records for accuracy at every forecast time period in 2024. Official track forecast errors have decreased significantly over the long term, and are up to 75% smaller than they were a few decades ago. The official track forecasts were very skillful and beat all of the models at 96 and 120 h. The Government Performance and Results Act of 1993 (GPRA) track goal was met.

Mean official intensity errors for the Atlantic basin in 2024 were higher than the previous 5-yr means from 12 to 96 h, but lower at 120 h. Decay-SHIFOR errors in 2024 were significantly higher than their 5-yr means, implying that the season's storms were

notably more challenging than normal to predict. Although there is a considerable amount of year-to-year variability, the intensity forecast errors have been gradually decreasing over the past decade or so. The official forecasts beat all of the models at 12 h, and were comparable to the best models from 24 to 120 h. The GPRA intensity goal was missed, likely due to the high number of rapid intensification events.

There were only 189 official forecasts issued in the eastern North Pacific basin in 2024, which is about 40% below the average level of seasonal forecast activity. The mean NHC official track forecast errors in the eastern North Pacific basin were close to the previous 5-yr means from 12 to 36 h, but slightly lower than the means after that. No records for track accuracy were set in 2024. Track forecast errors have decreased considerably over the long term, but there has been little improvement in recent years. The official track forecasts mostly outperformed the individual models.

The official intensity forecast errors in the eastern North Pacific basin were higher than the previous 5-yr means at all forecast times, and 29% larger at 120 h. The Decay-SHIFOR errors were also significantly larger than their 5-yr means at all lead times, which suggests that forecasting the intensity of the season's storms was notably more challenging than average. No records for intensity accuracy were set in 2024. While NHC intensity forecasts have improved over the past couple of decades, there remains considerable year-to-year variability and errors went up in 2024. The official intensity forecasts were skillful and outperformed the individual models at most forecast times.

Quantitative probabilistic forecasts of tropical cyclogenesis are expressed in 48- and 168-h time frames in 10% increments and in terms of categories ("low", "medium", or "high"). In the Atlantic basin, the 48-h probabilistic forecasts had a low bias for the high probabilities, and low biases were also present at some probability ranges in the 168-h forecasts. In the eastern North Pacific basin, the 48-h forecasts were well calibrated, but a low bias existed in the 168-h forecasts for the low and medium probabilities.

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1. Introduction

For all operationally designated tropical or subtropical cyclones, or systems that could become tropical or subtropical cyclones and affect land within the next 48 h in the Atlantic and eastern North Pacific basins, the National Hurricane Center (NHC) issues an official forecast of the cyclone's center location and maximum 1-min surface wind speed. Forecasts are issued every 6 h, and contain projections valid 12, 24, 36, 48, 60, 72, 96, and 120 h after the forecast's nominal initial time (0000, 0600, 1200, or 1800 UTC)[1]. At the conclusion of the season, forecasts are evaluated by comparing the projected positions and intensities to the corresponding post-storm derived "best track" positions and intensities for each cyclone. A forecast is included in the verification only if the system is classified in the final best track as a tropical (or subtropical[2]) cyclone at both the forecast's initial time and at the projection's valid time. All other stages of development (e.g., tropical wave, [remnant] low, extratropical) are excluded[3]. For verification purposes, forecasts associated with special advisories do not supersede the original forecast issued for that synoptic time; rather, the original forecast is retained[4]. All verifications in this report include the depression stage.

It is important to distinguish between *forecast error* and *forecast skill*. Track forecast error, for example, is defined as the great-circle distance between a cyclone's forecast position and the best track position at the forecast verification time. Skill, on the other hand, represents a normalization of this forecast error against some standard or baseline. Expressed as a percentage improvement over the baseline, the skill of a forecast s_f is given by

$$s_f\,(\%) = 100 * (e_b - e_f) / e_b$$

where e_b is the error of the baseline model and e_f is the error of the forecast being evaluated. It is seen that skill is positive when the forecast error is smaller than the error from the baseline.

To assess the degree of skill in a set of track forecasts, the track forecast error can be compared with the error from CLIPER5, a climatology and persistence model that contains no information about the current state of the atmosphere (Neumann 1972, Aberson 1998)[5]. Errors from the CLIPER5 model are taken to represent a "no-skill" level of accuracy that is used as the baseline (e_b) for evaluating other forecasts[6]. If CLIPER5 errors are unusually low during a given season, for example, it indicates that the year's storms were inherently "easier" to forecast than

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[1] The nominal initial time represents the beginning of the forecast process. The actual advisory package is not released until 3 h after the nominal initial time, i.e., at 0300, 0900, 1500, and 2100 UTC.

[2] For the remainder of this report, the term "tropical cyclone" shall be understood to also include subtropical cyclones.

[3] Possible classifications in the best track are: Tropical Depression, Tropical Storm, Hurricane, Subtropical Depression, Subtropical Storm, Extratropical, Disturbance, Wave, and Low.

[4] Special advisories are issued whenever an unexpected significant change has occurred or when watches or warnings are to be issued between regularly scheduled advisories. The treatment of special advisories in forecast databases changed in 2005 to the current practice of retaining and verifying the original advisory forecast.

[5] CLIPER5 and SHIFOR5 are 5-day versions of the original 3-day CLIPER and SHIFOR models.

[6] To be sure, some "skill", or expertise, is required to properly initialize the CLIPER model.

normal or otherwise unusually well behaved. The current version of CLIPER5 is based on developmental data from 1931–2004 for the Atlantic and from 1949–2004 for the eastern Pacific.

Particularly useful skill standards are those that do not require operational products or inputs, and can therefore be easily applied retrospectively to historical data. CLIPER5 satisfies this condition, since it can be run using persistence predictors (e.g., the storm's current motion) that are based on either operational or best track inputs. The best-track version of CLIPER5, which yields substantially lower errors than its operational counterpart, is generally used to analyze lengthy historical records for which operational inputs are unavailable. It is more instructive (and fairer) to evaluate operational forecasts against operational skill benchmarks, and therefore the operational versions are used for the verifications discussed below.[7]

Intensity forecast error is defined as the absolute value of the difference between the forecast and best track intensity at the forecast verifying time. Skill in a set of intensity forecasts is assessed using Decay-SHIFOR5 (DSHIFOR5) as the baseline. The DSHIFOR5 forecast is obtained by initially running SHIFOR5, the climatology and persistence model for intensity that is analogous to the CLIPER5 model for track (Jarvinen and Neumann 1979, Knaff et al. 2003). The output from SHIFOR5 is then adjusted for land interaction by applying the decay rate of DeMaria et al. (2006). The application of the decay component requires a forecast track, which here is given by CLIPER5. The use of DSHIFOR5 as the intensity skill benchmark was introduced in 2006. On average, DSHIFOR5 errors are about 5–15% lower than SHIFOR5 in the Atlantic basin from 12–72 h, and about the same as SHIFOR5 at 96 and 120 h.

It has been argued that CLIPER5 and DSHIFOR5 should not be used for skill benchmarks, primarily on the grounds that they were not good measures of forecast difficulty. Particularly in the context of evaluating forecaster performance, it was recommended that a model consensus (see discussion below) be used as the baseline. However, an unpublished study by NHC has shown that on the seasonal time scales at least, CLIPER5 and DSHIFOR5 are indeed good predictors of official forecast error. For the period 1990–2009, CLIPER5 errors explained 67% of the variance in annual-average NHC official track forecast errors at 24 h. At 72 h, the explained variance was 40% and at 120 h the explained variance was 23%. For intensity, the relationship was even stronger: DSHIFOR5 explained between 50–69% of the variance in annual-average NHC official errors at all time periods. Given this, CLIPER5 and DSHIFOR5 appear to remain suitable, if imperfect, baselines for skill, in the context of examining forecast performance over the course of a season (or longer). However, they are probably less useful for interpreting forecast performance with smaller samples (e.g., for a single storm).

NHC also issues forecasts of the size of tropical cyclones; these "wind radii" forecasts are estimates of the maximum extent of sustained winds of various thresholds (34, 50, and 64 kt) expected in each of four quadrants surrounding the cyclone. Unfortunately, there are typically insufficient surface wind observations to allow the forecaster to accurately analyze the size of a tropical cyclone's wind field over much of the Atlantic and nearly all of the eastern Pacific

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7 On very rare occasions, operational CLIPER or SHIFOR runs are missing from forecast databases. To ensure a completely homogeneous verification, post-season retrospective runs of the skill benchmarks are made using operational inputs. Furthermore, if a forecaster makes multiple estimates of the storm's initial motion, location, etc., over the course of a forecast cycle, then these retrospective skill benchmarks may differ slightly from the operational CLIPER/SHIFOR runs that appear in the forecast database.

(Cangialosi and Landsea 2016). However, this report does provide some baseline statistics on this parameter, and there continues to be more thorough internal efforts to assess the state of tropical cyclone structure forecasts. Some of the size statistics are given in skill space with wind-radii CLIPER model (DRCL) being the used baseline (Knaff et. al. 2007).

Numerous objective forecast aids (guidance models) are available to help the NHC in the preparation of official track and intensity forecasts. Guidance models are characterized as either *early* or *late*, depending on whether or not they are available to the forecaster during the forecast cycle. For example, consider the 1200 UTC (12Z) forecast cycle, which begins with the 12Z synoptic time and ends with the release of an official forecast at 15Z. The 12Z run of the National Weather Service Global Forecast System (GFS) model is not complete and available to the forecaster until about 16Z, or about an hour after the NHC forecast is released. Consequently, the 12Z GFS would be considered a late model since it could not be used to prepare the 12Z official forecast. This report focuses on the verification of early models.

Multi-layer dynamical models are generally, if not always, late models. Fortunately, a technique exists to take the most recent available run of a late model and adjust its forecast to apply to the current synoptic time and initial conditions. In the example above, forecast data for hours 6–126 from the previous (06Z) run of the GFS would be smoothed and then adjusted, or shifted, such that the 6-h forecast (valid at 12Z) would match the observed 12Z position and intensity of the tropical cyclone. The adjustment process creates an "early" version of the GFS model for the 12Z forecast cycle that is based on the most current available guidance. The adjusted versions of the late models are known, mostly for historical reasons, as *interpolated* models[8]. The adjustment algorithm is invoked as long as the most recent available late model is not more than 12 h old, e.g., a 00Z late model could be used to form an interpolated model for the subsequent 06Z or 12Z forecast cycles, but not for the subsequent 18Z cycle. Verification procedures here make no distinction between 6- and 12-h interpolated models.

A list of models is given in Table 1. In addition to their timeliness, models are characterized by their complexity or structure; this information is contained in the table for reference. Briefly, *dynamical* models forecast by solving the physical equations governing motions in the atmosphere. Dynamical models may treat the atmosphere either as a single layer (two-dimensional) or as having multiple layers (three-dimensional), and their domains may cover the entire globe or be limited to specific regions. The interpolated versions of dynamical model track and intensity forecasts are also sometimes referred to as dynamical models. *Statistical* models, in contrast, do not consider the characteristics of the current atmosphere explicitly but instead are based on historical relationships between storm behavior and various other parameters. *Statistical-dynamical* models are statistical in structure but use forecast parameters from dynamical models as predictors. *Consensus* models are not true forecast models *per se*, but are merely combinations of results from various models. One way to form a consensus is to simply average the results from a collection (or "ensemble") of models, but other, more complex techniques can also be used. The Hurricane Forecast Improvement Program Corrected Consensus Approach (HCCA), for example, combines its individual components on the basis of past performance and attempts to correct for biases in those components (Simon et al. 2018). A

[8] When the technique to create an early model from a late model was first developed, forecast output from the late models was available only at 12 h (or longer) intervals. In order to shift the late model's forecasts forward by 6 hours, it was necessary to first interpolate between the 12 h forecast values of the late model – hence the designation "interpolated".

consensus model that considers past error characteristics can be described as a "weighted" or "corrected" consensus. Additional information about the guidance models used at the NHC can be found at http://www.nhc.noaa.gov/modelsummary.shtml.

The verifications described in this report are for all tropical cyclones in the Atlantic and eastern North Pacific basins. These statistics are based on forecast and best track data sets taken from the Automated Tropical Cyclone Forecast (ATCF) System on 20 March 2025 for the Atlantic basin, and on 20 February 2025 for the eastern North Pacific basin. Verifications for the Atlantic and eastern North Pacific basins are given in Sections 2 and 3 below, respectively. Section 4 discusses NHC's probabilistic genesis forecasts. Section 5 summarizes the key findings of the 2024 verification and previews anticipated changes for 2025.

2. Atlantic Basin

a. 2024 season overview – Track

The 2024 Atlantic hurricane season exhibited above normal levels of activity by nearly every metric (total number of tropical storms, hurricanes, major hurricanes, and values of Accumulated Cyclone Energy). A map of the 2024 Atlantic basin tropical storms and hurricanes is shown in Figure 1. As seen in the figure, the western portion of the basin was particularly active. Figure 2 and Table 2 present the results of the NHC official track forecast verification for the 2024 season, along with results averaged for the previous 5-yr period, 2019–2023. In 2024, the NHC issued 347 Atlantic basin tropical cyclone forecasts[9], a number slightly above the long term mean of around 325 (Fig. 3). Mean track errors ranged from 19 n mi at 12 h to 115 n mi at 120 h. The mean official track forecast errors in 2024 were below the 5-yr means at all times, and up to 39% smaller at 120 h. In fact, the mean track errors at every forecast interval (12, 24, 36, 48, 60, 72, 96, and 120 h) broke records for accuracy, meaning that NHC's 2024 track forecast performance was its best in history. The CLIPER errors for 2024 were slightly lower (3-11%) than their 5-yr means, which typically indicates that the storms' tracks were a little less difficult to predict than average. The official track forecast vector biases were small through 48 h, but a southward to south-southwestward bias (i.e., the official forecast tended to fall to the south/south-southwest of the verifying position) was present after that, and was fairly large at 120 h. Track forecast skill ranged from 54% at 12 h to 77% at 48 and 60 h (Table 2). Over the past couple of decades, the 24−72-h track forecast errors have been drastically reduced by about 75% (Fig. 4a). Track forecast error reductions of about 60-70% have occurred over the past 20 years for the 96- and 120-h forecast periods. An evaluation of track skill indicates that there has been a considerable amount of year-to-year variability, but a gradual increase in skill has occurred over the long term (Fig. 4b), and skill values were near all-time highs in 2024. Figure 5 indicates that on average the NHC track errors decrease as the initial intensity of a cyclone increases, and that relationship holds true through the entire 120-h forecast period. It has been seen in multiple cases during the past few years that the NHC track errors are notably lower than average for major hurricanes, including Helene and Milton in 2024.

Note that the mean official error in Figure 1 is not precisely zero at 0 h (the analysis time). This non-zero difference between the operational analysis of storm location and best track location, however, is not properly interpreted as just "analysis error". The best track is a subjectively smoothed representation of the storm history over its lifetime, in which the short-term variations in position or intensity that cannot be resolved in a 6-hourly time series are deliberately removed. Thus, the location of a strong hurricane with a well-defined eye might be known with great accuracy at 1200 UTC, but the best track may indicate a location elsewhere by 5–10 miles or more if the precise location of the cyclone at 1200 UTC was unrepresentative. Operational analyses tend to follow the observed position of the storm more closely than the best track analyses, since it is more difficult to determine unrepresentative behavior in real time.

[9] This count does not include forecasts issued for systems later classified to have been something other than a tropical cyclone at the forecast time.

Consequently, the t=0 “errors” shown in Figure 1 contain both true analysis error and representativeness error.

Table 3a presents a homogeneous[10] verification for the official forecasts along with a selection of early models for 2024. In order to maximize the sample size, a guidance model had to be available at least two-thirds of the time at both 48 and 120 h to be included in this comparison. The performance of the official forecasts and the early track models in terms of skill are presented in Figure 6. The official forecasts were highly skillful, and near the best models through 72 h, but NHC beat all of the guidance at 96 and 120 h. The best models were the consensus aids HCCA, TVCA, and FSSE. Among the individual models, GFSI, AEMI, and EMXI were the top performers, but GFSI was the best of the group at 96 and 120 h. The hurricane regional models (HWFI, HMNI, HFAI, HFBI) were generally less good, but HMNI was competitive with the best global model guidance at some forecast times. CMCI and EGRI lagged the aforementioned aids slightly, while NVGI was not competitive. An evaluation over the three years 2022–24 (Fig. 7) indicates that HCCA and TVCA were also the best models for this sample, with TVCA being superior at the longer lead times. The official forecasts had about the same skill levels as those models throughout the forecast period. EMXI was the best individual model, but it had about 5% lower skill than the official forecasts and consensus aids at some forecast times. GFSI, AEMI, EGRI, and HMNI all had about the same levels of skill as each other and were the next best models. HWFI and CMCI were slightly less skillful, while NVGI lagged at all forecast times.

Vector biases of the guidance models for 2024 are given in Table 3b. The table shows that the official forecast had similar biases to the consensus aids, which had a general south to southwest bias at the long-range forecast times. EMXI had a significant southward bias at 96 and 120 h, while GFSI had the smallest biases overall. A separate homogeneous verification of the primary consensus models for 2024 is shown in Figure 8. The figure shows that most of the consensus aids (FSSE, TVCA, HCCA, GFEX, TVCX, and TVDG) had about the same amount of skill. AEMI was notably less skillful though, but its skill levels were not far off from the best aids at 120 h.

Figure 9 provides a comparison of track error and consistency, or how much the official forecast and models changed from cycle to cycle, around the 96- and 120-h forecast time periods. It can be seen that for the 2022–24 sample the official forecasts had lower error and were notably more consistent than GFSI, EMXI, and EGRI. A closer inspection of NHC’s 2020–24 track error distribution is shown in Figure 10. This violin diagram shows the mean errors (colored dots) are higher than medians (horizontal lines) at all forecast times. The mean is being inflated by a small number of cases with significantly higher error, like for Philippe in 2023. Various percentiles (10, 25, 75, 90) can also be seen on the diagram along with kernel density estimates (KDEs) of the track forecast error probability density functions. These diagrams help show the distribution of the official forecast errors to better illustrate the range of NHC’s forecast abilities.

[10] Verifications comparing different forecast models are referred to as *homogeneous* if each model is verified over an identical set of forecast cycles. Only homogeneous model comparisons are presented in this report.

Atlantic basin 48-h official track error, evaluated for all tropical cyclones, is a forecast measure tracked under the Government Performance and Results Act of 1993 (GPRA). In 2024, the GPRA goal was 52 n mi, and the verification for this measure was met at 45.4 n mi.

b. 2024 season overview – Intensity

Figure 11 and Table 4 present the NHC Atlantic intensity forecast verification for the 2024 season, along with results averaged for the preceding 5-yr period. The intensity errors were higher than the 5-yr means from 12 to 96 h, but lower than the mean at 120 h. The Decay-SHIFOR forecast errors were significantly (up to 47%) larger than their 5-yr means at most lead times, which suggests the season's storms' intensities were considerably more difficult to forecast than normal. The official forecasts exhibited a slight low bias from 36 to 72 h and a slight high bias at 120 h. Figure 12 shows recent trends in intensity forecast accuracy and skill for the Atlantic basin. While there has been a modest decrease in error over the past couple of decades, there remains considerable year-to-year variability, and errors ticked up in 2024 compared to the all-time lows that were set a couple of years ago. On the other hand, intensity skill increased in 2024 and was near all-time highs. Overall, it appears that the intensity predictions are gradually improving as the forecasts are generally more skillful in the past 10-15 years than they were in the 1990s and the first decade of the 2000s (Cangialosi et al. 2020). Progress has also been made in predicting Rapid Intensification (RI), which is defined as increase in the storm's maximum winds of at least 30 kt over a 24 h period. A more detailed analysis on RI is shown below.

Table 5a presents a homogeneous verification for the official forecasts and the primary early intensity models for 2024. Intensity biases are given in Table 5b, and forecast skill is presented in Figure 13. The official forecasts were quite skillful, beating all of the models at 12 h and having comparable skill with the best models, IVCN, HCCA, and NNIC from 24 to 120 h. The hurricane regional models HWFI and HMNI were the next best for the short lead times, while the dynamical-statistical LGEM and DSHP were strong performers at 96 and 120 h. HFAI and HFBI were not as good as HWFI and HMNI at most time periods. GFSI had skill levels just below HFAI and HFBI, and EMXI was generally not competitive. An inspection of the intensity biases (Table 5b) indicates that most of the models had negative (low) biases, with the global models having the largest negative biases.

An evaluation over the three years 2022–24 (Fig. 14) indicates that the official forecasts have been consistently performing quite well, and had skill values close to the best aids IVCN and HCCA. HWFI and HMNI were the best individual models at most forecast times, followed by LGEM. DSHP and GFSI were slightly less good, while EMXI had little to no skill and was not competitive with the remainder of the guidance.

A closer inspection of NHC's 2020–24 intensity error distribution is shown in Figure 15. This diagram indicates that there is generally little bias in the official forecasts with the mean and median errors close to zero. However, it can also be seen that there is a fair amount of spread at all forecast times, indicating that there are cases that have both too high and too low predictions at each forecast time period. The distributions also become slightly left-skewed with forecast time, indicating an increasing negative (low) intensity forecast bias with time.

Although RI remains one of the biggest challenges at NHC, it is worth noting that advancements in hurricane modeling and understanding of the science are making a difference in improving forecasts for even the most challenging cases (DeMaria et al. 2021). Figure 16 shows NHC's intensity forecast bias for RI events binned in 5-yr spans. The intensity bias has been steadily decreasing from 26 kt too low in 2010-14 to 16 kt too low from 2020-24. Although there is still work to do, progress is clearly underway. Figure 17 shows the critical success index (CSI) of official and selected model forecasts for storms from 2022-24 that went through RI on a Roebber performance diagram. CSI is a skill score measuring the proportion of correct RI forecasts (hits) to the total number of times an RI event was forecast and/or observed. Therefore, CSI equally penalizes false alarms (RI was forecast but did not occur) and misses (RI occurred but was not forecast) while ignoring correct forecasts of non-RI occurrences. CSI values range from 0 to 1 with the best possible score being 1. It can be seen that NHC intensity forecasts (OFCL/black dot) had a higher probability of detection (vertical axis) and higher CSI (curved/shaded lines) for the subset of storms that underwent RI compared to the real time model guidance (other colored symbols).

The 48-h official intensity error, evaluated for all tropical cyclones, is another GPRA measure for NHC. In 2024, the GPRA goal was 10 kt, and the verification for this measure was missed at 11.4 kt. It should be noted that the primary reason the GPRA target was missed in 2024 was due to the high frequency of RI cases. In fact, there were 34 RI episodes in 2024, which was nearly twice as many as the average over the preceding 10 years (2014-23).

c. Wind Radii and Watch/Warning Verification

Even though the available data is often insufficient across much of the Atlantic basin to compose a comprehensive verification on tropical cyclone wind radii, this report provides an attempt to quantify some of NHC's errors and progress since wind radii forecasts were first post-analyzed and included in the best track dataset in 2004. Figure 18 shows recent trends in the 34- and 50-kt wind radii forecast accuracy averaged in all quadrants for the Atlantic basin. The trends in the 64-kt error are not shown due to relatively small sample sizes in some years. It can be seen that although there is notable year-to-year variability, the errors have been decreasing for both of these wind thresholds. Note, the 96- and 120-h wind radii predictions only began in 2024, so no trends are available for those lead times. An evaluation of NHC's prediction against the wind radii consensus model (RVCN) from 2022–24 indicates that NHC is more skillful than that consensus model for all wind radii thresholds (Fig. 19).

Perhaps the most actionable information from NHC are the storm surge, hurricane, and tropical storm watches and warnings that are issued. Figure 20 shows a comparison of the official track and intensity errors when U.S. watches and warnings were in effect compared to when they weren't. To ensure a sufficient sample, this analysis includes the most recent 5-yr period, 2020–24. It can be seen that track forecasts were more accurate when U.S. watches and warnings were in effect, especially at 96 and 120 h. Intensity forecast errors were also lower from 72 to 120 h for cases when U.S. watches and warnings were in effect. It is believed that the better forecasts when U.S. watches and warnings are in effect are due to more available observational data (e.g. reconnaissance aircraft) in those events. These data help the forecaster assess the structure of the tropical cyclone in real time, and advances models through data assimilation for better predictions of the future track and intensity.

Figure 21 displays NHC's 34-, 50-, and 64-kt wind radii best track of Hurricane Helene overlaid with the real-time hurricane and tropical storm warnings issued during the event. It can be seen that the tropical storm and hurricane warnings verified quite well, except for portions of the Florida Panhandle, Alabama, and western Georgia, where these warnings were an overestimate of what occurred. It should be noted that overwarning is expected since there is always some uncertainty in the track, intensity, and size predictions of tropical cyclones that is accounted for when those warnings are issued.

d. Verifications for individual storms

Forecast verifications for individual storms are given in Table 6. The official track forecast errors were generally low for most storms in 2024, but especially so for Debby, Ernesto, Leslie, and Milton. The largest errors occurred in Hurricane Isaac, but even then, it was for a small number of verifying 72- and 96-h forecasts. Figure 22 shows an illustration of the official track errors stratified by storm.

With regards to intensity, large forecast errors occurred for Hurricanes Milton and Rafael in capturing the magnitude of their RI episodes. Conversely, excellent intensity forecasts were issued for Debby, Francine, and Joyce. Figure 23 shows an illustration of the official intensity errors stratified by storm. Additional discussion on forecast performance for individual storms can be found in NHC Tropical Cyclone Reports available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2024&basin=atl.

3. Eastern North Pacific Basin

a. 2024 season overview – Track

The eastern North Pacific basin exhibited below normal levels of activity in 2024, and a map of the tropical storms and hurricanes is shown in Figure 24. The NHC track forecast verification for the 2024 season in the eastern North Pacific, along with results averaged for the previous 5-yr period, is presented in Figure 25 and Table 7. The level of activity in the eastern North Pacific basin was well below normal in 2024. In fact, there were only 189 forecasts issued, which is about 40% below the long-term mean for the basin and the second fewest number of forecasts since 1990 (Fig. 26). The mean track errors ranged from 25 n mi at 12 h to 117 n mi at 120 h. These errors were close to the previous NHC 5-yr mean errors from 12 to 36 h, but roughly 10-15% smaller than the 5-yr means after that. The CLIPER errors were also significantly lower than their 5-yr means at the latter forecast times, implying that the long-range track forecasts for the storms in the eastern North Pacific basin in 2024 were easier than normal. No records for track accuracy were set in 2024. The official track forecast vector biases were generally small through 96 h, but a pronounced north-northwest bias was present at 120 h.

Figure 27 shows recent trends in track forecast accuracy and skill for the eastern North Pacific. Over the long-term, 24- to 72-h track errors have been reduced by about 60–70% since 1990, however, the track errors have been generally steady over the past few years. At the 96- and 120-h forecast times, errors have dropped by 40–50% since 2001, but these decreasing error trends have also flattened out over the past few years. Likewise, NHC's track forecast skill is notably higher than it was decades ago, and it currently is about 60–70% better than climatology-persistence. However, the skill trends have also levelled off in recent years.

Table 8a presents a homogeneous verification for the official track forecasts and the early track models for 2024, with vector biases of the guidance shown in Table 8b. Skill comparisons of the official forecast and selected models are shown in Fig. 28. The official forecasts were very skillful, but were outperformed by the consensus model FSSE. NHC generally outperformed the other consensus aids. In terms of the individual models, EMXI was the best performer at the short lead times (12–36 h), and AEMI and GFSI were the best individual models from 48 to 120 h. In fact, GFSI and AEMI slightly outperformed the official forecasts at 72 and 96 h. The regional hurricane models were competitive with one another, but HFBI and HWFI were slightly better than the rest of the group. NVGI and EGRI were the least skillful models overall. The official forecasts had similar directional biases to HCCA and TVCE at all forecast times. The hurricane regional models had large westward to northwestward biases at the long lead times while EMXI generally had the smallest biases.

Figure 29 shows an analysis of forecast skill over the past three seasons (2022–2024). The official forecasts compared well to the most skillful consensus models, but HCCA and FSSE slightly bested NHC at most forecast times. EMXI was the most skillful individual model through 60 h, but GFSI and AEMI were the best individual models at the longer forecast times. HMNI, HWFI, and CMCI trailed the top models, while EGRI and NVGI were the worst track models for this sample as well. A separate verification of the primary consensus aids for 2024 is given in Figure 30. TVCX and FSSE were the best aids at most forecast times, although the skill of the consensus models was tightly clustered. AEMI was not competitive with the multi-model consensus aids.

Figure 31 provides a comparison of track error and consistency, or how much the official forecast and models changed from cycle to cycle, around the 96-h and 120-h forecast time periods. It can be seen that for the 2022–24 sample the official forecasts had lower errors and were more consistent than GFSI, EMXI, and EGRI. A closer inspection of NHC's 2020–24 track error distribution is shown in Figure 32. This violin diagram shows the mean errors (colored dots) are higher than the medians (horizontal lines) at all forecast times. The mean is being inflated by a small number of cases with significantly higher error. Various percentiles (10, 25, 75, 90) can also be seen on the diagram along with kernel density estimates of the track forecast error probability density functions.

b. 2024 season overview – Intensity

Figure 33 and Table 9 present the NHC eastern North Pacific intensity forecast verification for the 2024 season, along with results averaged for the preceding 5-yr period. The mean intensity errors were higher than the 5-yr means at all forecast times. Notably, the official errors were 29% higher than the 5-yr means at 120 h. The Decay-SHIFOR forecast errors were significantly (up to 42%) larger than their 5-yr means at all lead times, which suggests the season's storms' intensities were considerably more difficult to forecast than normal. The official forecasts exhibited a low bias at all periods, which increased with forecast time. At 120 h, the intensity forecasts on average were about 17 kt too low. No records for intensity accuracy were set in 2024. Figure 34 shows recent trends in intensity forecast accuracy and skill for the eastern North Pacific. While there has been a modest decrease in error over the past couple of decades, there remains considerable year-to-year variability. In 2024, intensity errors increased at all forecast times. There has been little trend in intensity skill over the past several years, and in 2024, NHC intensity forecasts were generally 15–30% more skillful than climatology and persistence.

Table 10a presents a homogeneous verification for the official intensity forecasts and the early intensity guidance for 2024, with forecast biases provided in Table 10b. Skill comparisons of the official forecasts and selected models are shown in Fig. 35. The official forecasts were skillful at all lead times, but a few models performed better. The corrected consensus aids HCCA and NNIC were among the top performers, and were more skillful than the official forecasts at most lead times. Among the individual models, HFBI was a strong performer for the short forecast times and HMNI was quite skillful for the longer lead times. DSHP and GFSI were skillful, but not competitive with the hurricane regional models or consensus aids. Conversely, LGEM and EMXI had little to no skill in 2024. Every model had negative biases at all forecast times, likely a result of the instances of numerous rapid intensification that occurred during the 2024 season. HFAI and HFBI had the smallest biases while LGEM's predictions were significantly too low

A three-year (2022–2024) evaluation of forecast skill is shown in Fig. 36. The official forecasts were 20-30% more skillful compared to climatology-persistence and among the best-performing aids overall during this period. The consensus models NNIC and IVCN were top performers, while HCCA and FSSE verified well through 72 h, but showed declining skill at 96 and 120 h. HWFI and HMNI performed fairly well, especially at the longer lead times. DSHP, LGEM, and the global models (GFSI and EMXI) lagged the rest of the guidance.

A closer inspection of NHC's 2020–24 intensity error distribution is shown in Figure 37. This diagram indicates that the mean and median errors are close to zero at most forecast times. However, it can also be seen that there is a fair amount of spread, indicating that there are cases that have both too high and too low predictions at each forecast time period. The distributions also become more left-skewed with forecast time, indicating an increasing negative (low) bias with time.

As mentioned in the Atlantic intensity section, rapid intensification remains a significant challenge and an area of focus to evaluate. Figure 38 shows the critical success index of official and selected model forecasts for storms in 2024 that underwent RI. It can be seen that NHC intensity forecasts (OFCL/black dot) had a higher probability of detection (vertical axis) and higher critical success index (curved/shaded lines) for the subset of rapidly strengthening storms compared to the real time model guidance (other colored symbols). NHC still had a notable low bias, however, it provided more accuracy than the available models.

c. Wind Radii Verification

Although there is a lack of sufficient data to perform a comprehensive analysis on wind radii, especially in the eastern North Pacific basin, this is an attempt to provide some input on the performance trends of NHC since wind radii forecasts were first post-analyzed and included in the best track dataset in 2004. Figure 39 shows recent trends in the 34- and 50-kt wind radii forecast accuracy averaged in all quadrants for the eastern North Pacific. Trends in the 64-kt error are not shown due to small sample sizes in some years. It can be seen that although there is notable year-to-year variability, the errors have been decreasing for both of these wind thresholds. Note, the 96- and 120-h wind radii predictions only began in 2024, so no trends are available for those lead times. An evaluation of NHC's prediction against the wind radii consensus model (RVCN) from 2022–2024 indicates that NHC is more skillful for all wind radii thresholds compared to the multi-model consensus (Fig. 40).

d. Verifications for individual storms

Figure 41 illustrates the official track errors stratified by storm in the eastern North Pacific basin. The track errors for Hurricane Gilma and Hurricane Kristy were well below NHC's 5-yr means at all lead times. Conversely, very large track forecast errors were noted for Hurricane John that struck southern and southwestern Mexico. The early NHC forecasts and several of the models had a significant eastward bias for that hurricane.

Figure 42 shows the official intensity errors stratified by storm. Large intensity errors occurred for Hurricane Gilma due to NHC's predictions not anticipating the magnitude of the storm's two rapid intensification episodes, especially the latter one. The intensity of Hurricane John was also challenging to forecast. The timing of John's rapid intensification on 23 September was not well anticipated until just before landfall. On the other hand, excellent intensity forecasts were issued for Hector, Ileana, and Emilia.

Forecast verifications for individual storms are provided in Table 11. Additional discussion on forecast performance for individual storms can be found in NHC Tropical Cyclone Reports available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2024&basin=epac.

4. Genesis Forecasts

The NHC routinely issues Tropical Weather Outlooks (TWOs) every 6 h for both the Atlantic and eastern North Pacific basins. The TWOs are text products that discuss areas of disturbed weather and their potential for tropical cyclone development. Forecasters subjectively assign a probability of genesis (0 to 100%, in 10% increments) to each area of disturbed weather described in the TWO, where the assigned probabilities represent the forecaster's determination of the chance of tropical cyclone formation during the 48-h and 168-h periods following the nominal TWO issuance time. Note that the TWO was extended from 5 to 7 days in 2023.

Verification is based on NHC best-track data, with the time of genesis defined to be the first tropical cyclone point appearing in the best track.

Verifications of the 48-h outlook for the Atlantic and eastern North Pacific basins for 2024 are given in Table 12 and illustrated in Figure 43. In the Atlantic basin (Table 12a), a total of 936 genesis forecasts were made. These 48-h forecasts were generally well calibrated, but had a slight low (under-forecast) bias for the 70–90% probabilities. In the eastern Pacific (Table 12b), a total of 665 genesis forecasts were made. The forecasts in this basin were well calibrated at most probabilities. It should be noted that a 3-yr verification of the 48-h genesis forecasts from 2022–24 (not shown) are generally well calibrated in both basins and have little bias.

Verifications of the 168-h outlook for the Atlantic and eastern North Pacific basins for 2024 are given in Table 13 and illustrated in Figure 44. In the Atlantic basin (Table 13a), the 168-h forecasts had a slight low bias for most probability ranges. In the eastern North Pacific (Table 13b), the genesis forecasts also had a slight low bias at the low and medium probabilities. The diagrams also show the refinement distribution, which indicates how often the forecasts deviated from (a perceived) climatology. Sharp peaks at climatology indicate low forecaster confidence, while maxima at the extremes indicate high confidence; the refinement distributions shown in all of the diagrams suggest an intermediate level of forecaster confidence. Figure 45 shows composites of all 7-day tropical cyclone genesis areas depicted in the Graphical TWO during the 2024 season.

5. Looking Ahead to 2025

a. Track Forecast Cone Sizes

The NHC track forecast cone depicts the probable track of the center of a tropical cyclone, and is formed by enclosing the area swept out by a set of circles along the forecast track (at 12, 24, 36 h, etc.). The size of each circle is set so that two-thirds of historical official forecast errors over the most-recent 5-yr sample fall within the circle. The circle radii defining the cones in 2025 for the Atlantic and eastern North Pacific basins (based on error distributions for 2020–24) are given in Table 14. In the Atlantic basin, the cone circles will be slightly smaller (up to 6%) at most forecast times. In the eastern Pacific basin, the cone circles will be smaller (up to 10%) at most lead times compared to 2024.

b. Consensus Models

The set of NHC consensus model identifiers remain fixed from year to year. However, the specific members of these consensus models will be determined at the beginning of each season and may vary from year to year.

Some consensus models require all of their member models to be available in order to compute the consensus (e.g., GFEX, ICON), while others are less restrictive, requiring only two or more members to be present (e.g., TVCA, IVCN). The terms “fixed” and “variable” can be used to describe these two approaches, respectively. In a variable consensus model, it is often the case that the 120-h forecast is based on a different set of members than the 12-h forecast. While this approach greatly increases availability, it does pose consistency issues for the forecaster.

The consensus model composition for 2025 is given in Table 15. The consensus models are unchanged from their compositions in 2024.

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List of Tables

Table 1. National Hurricane Center forecasts and models.

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
OFCL	Official NHC forecast			Trk, Int
HFSA	Hurricane Analysis and Forecast System – A	Multi-layer regional dynamical	L	Trk, Int
HFSB	Hurricane Analysis and Forecast System – B	Multi-layer regional dynamical	L	Trk, Int
HWRF	Hurricane Weather and Research Forecasting Model	Multi-layer regional dynamical	L	Trk, Int
HMON	Hurricanes in a Multi-scale Ocean-coupled Non-hydrostatic model	Multi-layer regional dynamical	L	Trk, Int
GFSO	NWS/Global Forecast System (formerly Aviation)	Multi-layer global dynamical	L	Trk, Int
AEMN	GFS ensemble mean	Consensus	L	Trk, Int
UKM	United Kingdom Met Office model, automated tracker	Multi-layer global dynamical	L	Trk, Int
EGRR	United Kingdom Met Office model with subjective quality control applied to the tracker	Multi-layer global dynamical	L	Trk, Int
UEMN	UKMET ensemble mean	Consensus	L	Trk, Int
NVGM	Navy Global Environmental Model	Multi-layer global dynamical	L	Trk, Int
CMC	Environment Canada global model	Multi-level global dynamical	L	Trk, Int
NAM	NWS/NAM	Multi-level regional dynamical	L	Trk, Int
CTX	COAMPS-TC using GFS initial and boundary conditions	Multi-layer regional dynamical	L	Trk, Int
EMX	ECMWF global model	Multi-layer global dynamical	L	Trk, Int
EEMN	ECMWF ensemble mean	Consensus	L	Trk
TABS	Beta and advection model (shallow layer)	Single-layer trajectory	E	Trk
TABM	Beta and advection model (medium layer)	Single-layer trajectory	E	Trk

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
TABD	Beta and advection model (deep layer)	Single-layer trajectory	E	Trk
CLP5	CLIPER5 (Climatology and Persistence model)	Statistical (baseline)	E	Trk
SHF5	SHIFOR5 (Climatology and Persistence model)	Statistical (baseline)	E	Int
DSF5	DSHIFOR5 (Climatology and Persistence model)	Statistical (baseline)	E	Int
OCD5	CLP5 (track) and DSF5 (intensity) models merged	Statistical (baseline)	E	Trk, Int
TCLP	Trajectory-CLIPER model	Statistical (baseline)	E	Trk, Int
SHIP	Statistical Hurricane Intensity Prediction Scheme (SHIPS)	Statistical-dynamical	E	Int
DSHP	SHIPS with inland decay	Statistical-dynamical	E	Int
OFCI	Previous cycle OFCL, adjusted	Interpolated	E	Trk, Int
HFAI	Previous cycle HAFS-A, adjusted	Interpolated-dynamical	E	Trk, Int
HFBI	Previous cycle HAFS-B, adjusted	Interpolated-dynamical	E	Trk, Int
HWFI	Previous cycle HWRF, adjusted	Interpolated-dynamical	E	Trk, Int
HMNI	Previous cycle HMON, adjusted	Interpolated-dynamical	E	Trk, Int
CTCI	Previous cycle CTCX, adjusted	Interpolated-dynamical	E	Trk, Int
GFSI	Previous cycle GFS, adjusted	Interpolated-dynamical	E	Trk, Int
UKMI	Previous cycle UKM, adjusted	Interpolated-dynamical	E	Trk, Int
EGRI	Previous cycle EGRR, adjusted	Interpolated-dynamical	E	Trk, Int
NVGI	Previous cycle NVGM, adjusted	Interpolated-dynamical	E	Trk, Int
EMXI	Previous cycle EMX, adjusted	Interpolated-dynamical	E	Trk, Int
CMCI	Previous cycle CMC, adjusted	Interpolated-dynamical	E	Trk, Int

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
AEMI	Previous cycle AEMN, adjusted	Consensus	E	Trk, Int
UEMI	Previous cycle UEMN, adjusted	Consensus	E	Trk, Int
FSSE	FSU Super-ensemble	Corrected consensus	E	Trk, Int
GFEX	Average of GFSI and EMXI	Consensus	E	Trk
RVCN	Average of AHNI, EHHI, CHCI, HWRF, ECMWF, COAMPS-TC	Consensus	E	Radii
TVCN	Average of at least two of GFSI EGRI HFAI HFBI EMXI CTCI HWFI HMNI EMNI	Consensus	E	Trk
TVCA	Average of at least two of GFSI EGRI HFAI HFBI EMXI CTCI HWFI HMNI EMNI	Consensus	E	Trk
TVCE	Average of at least two of GFSI EGRI HFAI HFBI EMXI CTCI EMNI HWFI HMNI	Consensus	E	Trk
TVCX	EMXI and average of at least two of GFSI EGRI HFAI HFBI HWFI HMNI	Consensus	E	Trk
TVCC	Version of TVCN corrected for model biases	Corrected consensus	E	Trk
TVDG	GFSI (double weight) EMXI (double weight) EGRI (double weight) CTCI HFAI HFBI HWFI HMNI	Corrected consensus	E	Trk
HCCA	Weighted average of AEMI, GFSI, CTCI, DSHP, EGRI, EMNI, EMXI, HWFI, HMNI LGEM	Corrected consensus	E	Trk, Int
ICON	Average of DSHP LGEM HFAI HFBI CTCI HWFI HMNI	Consensus	E	Int
IVDR	CTCI (double weight) HWFI (double weight) HMNI (double weight) HFAI (double weight) HFBI (double weight) GFSI DSHP LGEM	Consensus	E	Int
IVCN	Average of at least two of DSHP LGEM HFAI HFBI CTCI HWFI HMNI	Consensus	E	Int
NNIC	Average of at least two of HWFI GFSI DSHP LGEM	Corrected consensus	E	Int

Table 2. Homogenous comparison of official and CLIPER5 track forecast errors in the Atlantic basin in 2024 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2024 mean OFCL error (n mi)	19.2	28.0	36.1	45.4	55.8	66.9	89.6	115.3
2024 mean CLIPER5 error (n mi)	41.7	88.4	145.7	199.0	245.1	281.1	343.6	388.5
2024 mean OFCL skill relative to CLIPER5 (%)	54.0	68.3	75.2	77.2	77.2	76.2	73.9	70.3
2024 mean OFCL bias vector (°/n mi)	013/001	229/002	215/005	205/009	191/015	176/019	190/032	198/062
2024 number of cases	311	276	244	214	185	157	112	79
2019-2023 mean OFCL error (n mi)	23.9	36.5	49.3	63.4	79.2	93.4	132.9	190.4
2019-2023 mean CLIPER5 error (n mi)	45.7	97.1	153.0	205.4	254.9	297.8	372.7	439.1
2019-2023 mean OFCL skill relative to CLIPER5 (%)	47.7	62.4	67.8	69.1	68.9	68.6	64.3	56.6
2019-2023 mean OFCL bias vector (°/n mi)	357/003	333/003	329/003	339/004	004/006	006/007	358/005	033/007
2019-2023 number of cases	1792	1588	1401	1243	1092	948	714	530
2024 OFCL error relative to 2019-2023 mean (%)	-19.7	-23.3	-26.8	-28.4	-29.5	-28.4	-32.6	-39.4
2024 CLIPER5 error relative to 2019-2023 mean (%)	-8.8	-9.0	-4.8	-3.1	-3.8	-5.6	-7.8	-11.5

Table 3a. Homogenous comparison of Atlantic basin early track guidance model errors (n mi) for 2024. Errors smaller than the NHC official forecast are shown in bold-face.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	19.3	27.8	35.5	45.0	56.3	67.3	88.9	115.3
OCD5	42.0	89.0	147.0	201.0	246.7	281.3	342.3	388.5
GFSI	20.2	32.5	43.1	55.0	69.3	82.1	114.5	157.5
EMXI	20.3	30.8	39.3	50.1	62.5	76.3	108.3	164.1
CMCI	23.2	37.1	50.0	64.2	81.2	102.3	146.0	177.4
HWFI	22.2	35.4	49.9	66.3	82.2	99.3	135.4	165.1
HMNI	21.6	33.5	45.8	60.3	72.4	84.2	125.7	172.3
HFAI	23.8	36.6	48.2	59.5	76.9	92.4	128.8	177.4
HFBI	22.1	34.4	47.1	62.2	78.8	90.6	138.1	201.7
AEMI	20.9	33.2	44.3	56.9	70.6	81.2	113.9	152.8
HCCA	**18.4**	**26.9**	**35.2**	45.0	56.8	68.7	93.0	136.2
TVCA	**18.6**	**27.7**	36.6	46.4	57.1	68.4	98.2	140.2
Forecasts	305	271	239	208	178	150	110	79

Table 3b. Homogenous comparison of Atlantic basin early track guidance model bias vectors (º/n mi) for 2024.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	010/001	229/002	215/005	205/009	191/015	178/013	193/032	198/062
OCD5	211/009	248/028	248/047	253/056	248/058	240/051	243/078	235/133
GFSI	340/002	288/003	260/004	230/005	189/009	158/013	160/026	161/044
EMXI	276/001	223/004	196/008	189/015	177/024	169/033	183/057	187/103
CMCI	287/005	278/009	275/013	264/013	245/012	211/007	190/014	187/024
HWFI	343/002	281/005	251/012	232/020	219/030	210/045	213/072	208/086
HMNI	291/004	270/008	256/013	248/017	236/015	211/018	203/033	201/041
HFAI	226/001	217/006	219/002	223/018	221/026	218/033	229/047	224/052
HFBI	344/001	239/006	235/014	232/024	226/035	222/041	223/063	216/085
AEMI	305/002	257/005	240/008	224/011	202/016	184/023	188/044	185/075
HCCA	180/001	196/003	200/007	203/011	198/019	193/024	219/039	231/067
TVCA	216/001	244/004	230/009	222/015	209/022	200/030	204/049	203/076
Forecasts	305	271	239	208	178	150	110	79

Table 4. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the Atlantic basin for the 2024 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2024 mean OFCL error (kt)	5.4	8.0	9.9	11.4	12.1	13.1	13.7	12.8
2024 mean Decay-SHIFOR5 error (kt)	8.3	13.4	18.5	22.9	24.0	25.3	27.9	19.2
2024 mean OFCL skill relative to Decay-SHIFOR5 (%)	34.9	40.3	46.5	50.2	49.6	48.2	50.9	33.3
2024 OFCL bias (kt)	0.5	-0.1	-1.5	-2.5	-3.0	-2.7	-0.2	4.4
2024 number of cases	311	276	244	214	185	157	112	79
2019-23 mean OFCL error (kt)	5.0	7.3	8.5	9.7	10.4	10.9	12.9	15.5
2019-23 mean Decay-SHIFOR5 error (kt)	6.6	10.2	13.1	15.6	17.2	18.6	21.8	22.6
2019-23 mean OFCL skill relative to Decay-SHIFOR5 (%)	24.2	28.4	35.1	37.8	39.5	41.4	40.8	31.4
2019-23 OFCL bias (kt)	0.4	0.3	0.5	0.5	0.5	0.5	-0.9	-4.8
2019-23 number of cases	1792	1588	1401	1243	1092	948	714	530
2024 OFCL error relative to 2019-23 mean (%)	8.0	9.6	16.5	17.5	16.3	20.2	6.2	-17.4
2024 Decay-SHIFOR5 error relative to 2019-23 mean (%)	25.8	31.3	41.2	46.8	39.5	36.0	28.0	-15.0

Table 5a. Homogenous comparison of selected Atlantic basin early intensity guidance model errors (kt) for 2024. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	5.4	8.0	9.9	11.4	12.0	13.3	13.8	12.8
OCD5	8.3	13.4	18.4	22.7	23.8	25.4	28.1	19.2
HWFI	7.5	9.7	11.4	12.3	12.8	**13.2**	15.8	17.7
HMNI	7.2	9.1	11.1	12.1	12.5	**13.0**	14.9	15.6
HFAI	7.4	10.2	12.4	13.9	14.8	16.3	18.6	17.5
HFBI	7.3	10.1	11.4	14.3	15.8	16.8	16.2	18.8
DSHP	7.2	10.3	13.0	14.0	14.8	16.3	15.5	15.3
LGEM	7.5	10.5	13.1	14.0	13.6	14.3	14.6	14.1
IVCN	6.3	8.4	10.1	11.5	12.0	**12.6**	**13.3**	**12.2**
HCCA	6.0	**7.8**	**9.6**	**11.3**	12.1	**12.9**	14.4	14.8
GFSI	7.6	11.0	13.7	15.6	16.8	17.8	18.7	17.6
EMXI	8.6	12.8	16.3	18.8	20.3	21.3	21.5	21.6
Forecasts	306	272	240	210	181	153	111	79

Table 5b. Homogenous comparison of selected Atlantic basin early intensity guidance model biases (kt) for 2024. Biases smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	0.4	-0.2	-1.5	-2.4	-2.9	-2.7	-0.2	4.4
OCD5	-1.0	-2.3	-3.6	-5.4	-6.6	-7.5	-4.6	**-3.5**
HWFI	-3.7	-5.5	-7.1	-7.4	-6.3	-4.3	1.9	11.3
HMNI	-2.6	-4.8	-6.9	-8.2	-8.2	-8.6	-6.0	**-3.9**
HFAI	-3.4	-5.6	-6.6	-7.0	-7.0	-7.1	-8.7	-5.8
HFBI	-2.0	-3.8	-4.5	-5.2	-5.0	-5.1	-6.1	**2.4**
DSHP	-0.5	-0.7	**-1.4**	-2.4	-3.2	-4.7	-4.3	**2.2**
LGEM	-1.6	-3.2	-3.8	-4.1	-4.1	-4.7	-3.3	**2.4**
IVCN	-1.9	-3.8	-5.1	-5.8	-5.8	-5.8	-4.1	**1.6**
HCCA	-1.2	-2.7	-3.9	-5.4	-5.7	-6.0	-2.1	**2.5**
GFSI	-2.4	-5.4	-8.0	-10.2	-11.3	-12.4	-12.8	-9.4
EMXI	-3,1	-5.7	-8.2	-10.6	-11.8	-13.5	-15.3	-15.2
Forecasts	306	272	240	210	181	153	111	79

Table 6. Official Atlantic track and intensity forecast verifications (OFCL) for 2024 by storm. CLIPER5 (CLP5) and SHIFOR5 (SHF5) forecast errors are given for comparison and indicated collectively as OCD5. The number of track and intensity forecasts are given by NT and NI, respectively. Units for track and intensity errors are n mi and kt, respectively.

Verification statistics for: AL012024 ALBERTO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	15.9	15.9	5	1.0	1.0
012	3	41.8	81.8	3	3.3	10.3
024	1	28.4	61.3	1	5.0	5.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL022024 BERYL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	43	5.9	5.9	43	1.6	1.7
012	41	18.8	30.7	41	6.8	10.7
024	39	27.6	61.1	39	9.5	14.4
036	37	36.5	94.5	37	12.3	21.0
048	35	50.3	125.5	35	15.3	26.1
060	33	69.7	151.6	33	18.5	31.1
072	31	84.7	180.3	31	18.7	36.5
096	27	125.4	211.5	27	14.4	40.8
120	23	147.8	207.1	23	11.3	23.1

Verification statistics for: AL032024 CHRIS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	3	31.5	31.5	3	1.7	1.7
012	1	25.6	43.4	1	5.0	3.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL042024 DEBBY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	7.2	7.2	24	3.1	3.1
012	22	17.9	43.0	22	5.0	7.4
024	20	19.8	95.9	20	6.0	10.9
036	18	28.7	160.2	18	8.1	12.5
048	16	35.8	229.7	16	6.9	14.7
060	14	46.6	298.3	14	4.6	11.4
072	12	54.1	351.8	12	5.4	12.8
096	8	64.0	386.8	8	4.4	14.1
120	4	51.1	405.9	4	12.5	9.8

Verification statistics for: AL052024 ERNESTO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	32	5.5	5.7	32	0.9	0.9
012	30	19.1	44.0	30	3.3	5.7
024	28	29.0	107.4	28	7.7	9.0
036	26	39.3	187.1	26	11.2	11.3
048	24	43.4	259.8	24	12.1	13.0
060	22	52.1	313.4	22	12.3	13.4
072	20	58.7	355.0	20	13.2	14.7
096	16	69.0	516.1	16	16.2	16.1
120	12	61.6	775.8	12	17.1	13.4

Verification statistics for: AL062024 FRANCINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	13	7.3	7.3	13	0.4	0.4
012	11	22.8	55.1	11	7.7	9.5
024	9	25.9	104.2	9	7.2	14.7
036	7	32.0	189.0	7	5.7	13.7
048	5	52.2	320.3	5	5.0	22.8
060	3	71.9	376.1	3	5.0	8.0
072	1	47.2	361.8	1	5.0	30.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL072024 GORDON

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	4.1	4.1	24	0.2	0.2
012	22	20.4	33.0	22	2.3	3.5
024	20	31.0	68.7	20	4.0	6.8
036	18	32.2	118.5	18	4.4	10.3
048	16	37.9	178.4	16	2.8	13.9
060	14	39.3	252.2	14	1.4	18.5
072	12	51.2	324.6	12	3.3	23.0
096	8	90.4	462.3	8	10.0	33.4
120	4	157.2	571.6	4	13.8	33.8

Verification statistics for: AL082024 EIGHT

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	0	-999.0	-999.0	0	-999.0	-999.0
012	0	-999.0	-999.0	0	-999.0	-999.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL092024 HELENE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	13	2.4	3.0	13	1.5	1.9
012	11	22.8	62.6	11	7.7	11.9
024	9	40.6	157.9	9	8.3	19.9
036	7	52.4	267.4	7	6.4	30.7
048	5	59.9	432.6	5	11.0	40.0
060	3	55.5	581.1	3	18.3	31.0
072	1	45.9	630.2	1	0.0	24.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL102024 ISAAC

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	17	6.2	6.2	17	0.9	0.9
012	15	14.8	46.5	15	5.0	7.4
024	13	26.0	115.8	13	8.5	14.3
036	11	37.5	160.3	11	11.4	18.6
048	9	46.3	176.0	9	13.3	20.0
060	7	51.0	238.0	7	10.7	17.4
072	5	99.7	241.5	5	7.0	9.0
096	1	209.4	289.0	1	0.0	12.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL112024 JOYCE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	14	10.1	10.1	14	0.0	0.0
012	12	19.3	25.4	12	2.9	5.4
024	10	36.2	50.7	10	3.0	11.1
036	8	50.3	76.8	8	3.8	17.2
048	6	55.9	101.6	6	3.3	24.2
060	4	55.8	149.5	4	3.8	31.2
072	2	42.6	219.0	2	2.5	34.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL122024 KIRK

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	31	5.8	5.8	31	0.8	0.8
012	29	21.6	40.2	29	5.7	7.8
024	27	31.1	79.9	27	7.6	12.9
036	25	37.7	129.0	25	10.4	18.6
048	23	44.4	169.2	23	10.0	24.2
060	21	51.9	189.5	21	7.9	29.7
072	19	58.1	200.7	19	9.5	33.8
096	15	97.0	239.8	15	13.0	37.6
120	11	187.9	375.5	11	9.1	30.0

Verification statistics for: AL132024 LESLIE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	40	5.0	5.0	40	2.1	2.4
012	38	15.3	36.9	38	5.1	7.7
024	36	25.7	72.6	36	7.6	12.0
036	34	39.5	107.6	34	8.2	14.8
048	32	51.5	134.9	32	8.9	16.9
060	30	61.0	170.8	30	10.5	16.0
072	28	63.9	201.4	28	14.3	14.4
096	24	54.9	232.8	24	16.5	15.2
120	20	68.9	238.0	20	16.0	14.4

Verification statistics for: AL142024 MILTON

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	21	5.2	5.2	21	2.1	2.4
012	19	25.8	51.5	19	9.7	15.7
024	17	43.0	113.1	17	17.9	26.2
036	15	52.5	202.2	15	19.7	38.5
048	13	69.8	289.8	13	27.7	52.5
060	11	78.5	396.4	11	26.4	51.0
072	9	87.9	464.2	9	22.8	51.6
096	5	77.6	524.9	5	17.0	47.4
120	1	82.7	618.6	1	0.0	16.0

Verification statistics for: AL152024 NADINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	9.7	9.7	5	3.0	3.0
012	3	17.5	61.2	3	6.7	7.0
024	1	0.0	126.4	1	0.0	8.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL162024 OSCAR

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	13	4.9	4.4	13	1.9	1.9
012	11	20.4	51.1	11	6.8	9.0
024	9	30.3	119.5	9	6.7	13.3
036	7	37.6	188.6	7	12.1	25.0
048	5	46.9	237.3	5	11.0	35.6
060	3	32.4	243.1	3	11.7	47.0
072	1	25.2	287.2	1	5.0	26.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL172024 PATTY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	9	13.4	13.4	9	1.1	1.7
012	7	22.8	81.3	7	3.6	6.7
024	5	27.4	159.2	5	4.0	7.0
036	3	21.9	371.3	3	3.3	11.7
048	1	48.2	492.7	1	0.0	13.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL182024 RAFAEL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	24	4.3	4.3	24	1.2	1.2
012	22	15.2	38.4	22	6.1	10.4
024	20	16.1	94.6	20	10.8	19.2
036	18	16.0	183.8	18	11.4	27.2
048	16	23.9	299.9	16	14.7	31.5
060	14	42.7	423.6	14	17.1	35.9
072	12	62.7	538.3	12	19.2	32.6
096	8	116.8	703.9	8	11.9	26.2
120	4	151.4	800.5	4	6.2	5.2

Verification statistics for: AL192024 SARA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	4.8	5.2	16	0.9	0.9
012	14	14.0	30.9	14	3.2	5.3
024	12	21.4	59.1	12	5.0	11.7
036	10	23.8	94.0	10	7.5	12.2
048	8	23.0	126.1	8	9.4	12.2
060	6	39.9	79.2	6	10.0	4.7
072	4	75.8	76.7	4	11.2	7.2
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Table 7. Homogenous comparison of official and CLIPER5 track forecast errors in the eastern North Pacific basin in 2024 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2024 mean OFCL error (n mi)	24.6	37.2	44.8	48.8	59.8	78.0	102.8	116.5
2024 mean CLIPER5 error (n mi)	41.5	79.0	116.8	148.9	171.5	194.3	234.6	281.7
2024 mean OFCL skill relative to CLIPER5 (%)	40.7	52.9	61.6	67.2	65.1	59.9	56.2	58.6
2024 mean OFCL bias vector (°/n mi)	087.003	085/003	059/007	038/010	026/009	057/016	030/017	337/058
2024 number of cases	161	134	109	89	71	61	44	31
2019-2023 mean OFCL error (n mi)	22.6	34.4	45.9	57.5	69.6	83.4	112.1	137.0
2019-2023 mean CLIPER5 error (n mi)	38.2	75.5	117.0	159.9	203.4	247.7	329.5	404.7
2019-2023 mean OFCL skill relative to CLIPER5 (%)	40.8	54.4	60.8	64.0	65.8	66.3	66.0	66.1
2019-2023 mean OFCL bias vector (°/n mi)	275/001	186/002	176/005	163/008	151/012	145/016	130/024	117/025
2019-2023 number of cases	1320	1141	979	834	708	595	406	267
2024 OFCL error relative to 2019-2023 mean (%)	8.8	8.1	-2.4	-15.1	-14.1	-6.5	-8.2	-15.0
2024 CLIPER5 error relative to 2019-2023 mean (%)	8.6	4.6	-0.2	-6.9	-15.6	-21.6	-28.8	-30.3

Table 8a. Homogenous comparison of eastern North Pacific basin early track guidance model errors (n mi) for 2024. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	18.8	24.7	32.1	38.7	52.7	63.4	91.7	111.0
OCD5	35.8	67.8	96.6	126.3	163.3	181.7	224.7	284.6
GFSI	19.9	30.6	43.0	54.4	58.8	**60.9**	**88.5**	112.7
EMXI	18.8	26.4	36.6	46.5	60.2	67.7	110.6	147.9
EGRI	26.6	42.9	61.8	83.8	102.1	107.5	151.8	196.3
CMCI	27.1	41.9	52.3	61.3	69.7	87.9	148.3	182.0
NVGI	28.5	43.4	57.6	71.2	88.9	101.3	153.0	259.3
HWFI	21.3	30.2	43.3	58.0	73.6	70.3	**91.0**	130.4
HMNI	22.4	33.1	44.7	58.9	79.0	85.9	114.0	141.9
HFAI	20.5	32.7	45.6	55.5	68.9	80.3	111.7	162.8
HFBI	22.3	34.6	45.9	51.8	61.6	75.6	106.5	153.1
AEMI	21.0	30.2	38.9	45.6	52.8	**60.4**	**90.2**	137.2
HCCA	**17.8**	**22.4**	**32.0**	43.1	53.2	**60.7**	99.4	130.6
FSSE	**18.3**	**22.7**	**30.2**	**38.1**	**46.7**	**54.4**	**85.5**	**99.3**
TVCE	**18.0**	**24.5**	33.4	42.2	54.4	**61.8**	**90.0**	119.0
Forecasts	96	84	74	66	57	45	32	22

Table 8b. Homogenous comparison of eastern North Pacific basin early track guidance model bias vectors (º/n mi) for 2024.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	054/003	037/005	010/009	343/013	333/011	328/014	330/024	321/077
OCD5	080/003	133/008	118/011	079/013	084/040	057/071	048/137	043/186
GFSI	071/009	073/018	068/027	056/033	058/029	043/019	020/023	313/051
EMXI	003/004	331/007	316/011	308/014	283/008	073/002	088/024	025/040
EGRI	303/007	292/021	293/039	290/059	278/070	271/069	263/093	280/143
CMCI	080/004	094/006	022/004	324/009	289/006	269/010	274/053	277/143
NVGI	314/006	290/013	296/022	308/035	315/040	319/063	341/089	013/164
HWFI	096/003	109/003	278/003	282/011	290/008	338/028	328/038	300/092
HMNI	062/005	050/006	017/005	331/010	339/008	339/022	314/048	307/101
HFAI	085/005	051/007	356/011	324/017	304/017	282/024	279/057	279/127
HFBI	109/005	105/006	046/002	298/009	250/008	207/014	238/039	261/125
AEMI	064/009	063/016	048/020	026/023	014/021	351/026	330/040	323/089
HCCA	060/003	013/004	345/009	332/016	329/013	359/014	031/028	356/056
FSSE	054/004	047/007	035/012	024/014	030/010	026/013	025/016	326/041
TVCE	051/004	025/005	346/009	320/016	304/015	305/019	296/034	294/091
Forecasts	96	84	74	66	57	45	32	22

Table 9. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the eastern North Pacific basin for the 2024 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
2024 mean OFCL error (kt)	6.3	10.6	11.9	14.9	17.6	19.3	21.1	23.4
2024 mean Decay-SHIFOR5 error (kt)	8.3	13.6	17.3	21.4	25.4	27.1	26.7	26.5
2024 mean OFCL skill relative to Decay-SHIFOR5 (%)	24.1	22.1	31.2	30.4	30.7	28.8	21.9	11.7
2024 OFCL bias (kt)	-0.4	-1.2	-3.0	-5.3	-6.1	-7.8	-11.8	-17.3
2024 number of cases	161	134	109	89	71	61	44	31
2019-23 mean OFCL error (kt)	5.5	8.7	10.8	12.7	14.5	15.6	17.1	18.1
2019-23 mean Decay-SHIFOR5 error (kt)	7.2	12.2	15.9	18.6	19.8	20.0	19.7	18.7
2019-23 mean OFCL skill relative to Decay-SHIFOR5 (%)	23.6	28.7	32.1	31.7	26.8	22.0	13.2	3.2
2019-23 OFCL bias (kt)	0.7	0.8	0.9	0.9	1.0	1.5	1.8	-0.4
2019-23 number of cases	1320	1141	979	834	708	595	406	267
2024 OFCL error relative to 2019-23 mean (%)	14.5	21.8	10.2	17.3	21.4	23.7	23.4	29.2
2024 Decay-SHIFOR5 error relative to 2019-23 mean (%)	15.3	11.5	8.8	15.1	28.3	35.5	35.5	41.7

Table 10a. Homogenous comparison of eastern North Pacific basin early intensity guidance model errors (kt) for 2024. Errors smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	6.4	10.7	12.6	15.2	18.0	19.8	20.0	22.9
OCD5	8.8	14.4	18.5	22.3	26.3	28.2	26.1	26.4
HWFI	7.8	10.8	12.8	**14.6**	**17.4**	**18.0**	**19.9**	**20.8**
HMNI	7.1	**10.4**	13.3	15.8	18.5	**19.0**	**17.3**	**16.8**
HFAI	7.8	11.7	14.2	17.2	18.9	20.1	20.9	**18.7**
HFBI	7.9	**10.6**	**12.2**	**14.7**	**17.0**	**19.7**	22.6	**15.7**
DSHP	8.1	12.0	14.8	17.9	21.3	23.0	24.2	26.7
LGEM	8.1	12.7	16.5	19.8	23.5	26.7	30.5	33.7
HCCA	7.1	**9.9**	**11.6**	**13.3**	**16.0**	**18.7**	**19.1**	**19.1**
IVCN	6.7	**10.0**	**12.5**	15.4	**17.8**	20.2	20.9	**20.6**
FSSE	6.4	**9.3**	**11.8**	**14.7**	**16.2**	**17.2**	**19.1**	24.0
GFSI	8.5	12.4	15.1	18.6	21.2	21.9	21.2	24.2
EMXI	8.8	14.6	19.4	24.4	27.6	29.6	26.8	30.3
Forecasts	133	114	94	80	64	54	41	29

Table 10b. Homogenous comparison of eastern North Pacific basin early intensity guidance model biases (kt) for 2024. Biases smaller than the NHC official forecast are shown in boldface.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	0.1	-0.1	-2.6	-4.8	-6.2	-7.6	-10.5	-17.8
OCD5	-1.6	-2.8	-6.8	-10.0	-13.3	-16.6	-17.1	**-17.6**
HWFI	-6.1	-6.2	-7.4	-8.5	-9.0	-9.1	**-10.3**	**-14.2**
HMNI	-2.5	-4.1	-6.3	-8.2	-8.7	**-7.5**	**-8.6**	**-10.9**
HFAI	-4.1	-3.3	-3.7	-5.0	**-6.1**	**-6.8**	**-8.2**	**-8.7**
HFBI	-1.2	-0.1	**-0.7**	**-2.2**	**-3.4**	**-5.8**	**-8.9**	**-6.8**
DSHP	-2.6	-4.1	-7.4	-11.2	-14.5	-16.7	-17.5	-22.0
LGEM	-3.1	-6.2	-11.2	-15.5	-19.6	-22.5	-24.5	-32.1
HCCA	-1.8	-1.6	-3.9	-5.0	**-4.5**	**-4.2**	**-9.3**	**-12.7**
IVCN	-3.1	-4.0	-6.3	-8.6	-10.4	-11.6	-13.5	**-16.4**
FSSE	-2.4	-2.7	-4.6	-6.2	-7.9	-9.4	-12.0	-17.9
GFSI	-4.3	-5.6	-7.7	-9.8	-11.6	-13.4	-14.0	-20.7
EMXI	-4.3	-5.2	-8.8	-12.1	-15.0	-17.6	-19.3	-25.5
Forecasts	133	114	94	80	64	54	41	29

Table 11. Official eastern North Pacific track and intensity forecast verifications (OFCL) for 2024 by storm. CLIPER5 (CLP5) and SHIFOR5 (SHF5) forecast errors are given for comparison and indicated collectively as OCD5. The number of track and intensity forecasts are given by NT and NI, respectively. Units for track and intensity errors are n mi and kt, respectively.

Verification statistics for: EP012024 ALETTA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	8.8	8.8	6	0.8	0.8
012	4	28.2	54.1	4	2.5	5.2
024	2	58.7	92.4	2	5.0	12.5
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP022024 BUD

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	6.3	6.3	6	4.2	5.0
012	4	25.6	17.8	4	11.2	9.5
024	2	57.9	20.7	2	10.0	0.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP032024 CARLOTTA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	22	5.7	5.7	22	2.5	2.5
012	20	15.6	27.5	20	4.8	5.9
024	18	24.8	50.3	18	7.2	8.2
036	16	29.6	68.0	16	8.4	13.4
048	14	35.0	97.3	14	9.3	16.6
060	12	47.9	134.3	12	10.0	15.8
072	10	60.3	164.0	10	13.5	12.8
096	6	125.5	209.2	6	20.8	9.0
120	2	210.3	163.4	2	22.5	4.0

Verification statistics for: EP042024 DANIEL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	10	7.1	7.1	10	0.0	0.0
012	8	30.0	62.0	8	1.2	4.5
024	6	41.0	143.6	6	5.8	8.0
036	4	54.5	263.9	4	6.2	13.5
048	2	71.3	424.1	2	2.5	19.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP052024 EMILIA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	17	14.5	14.5	17	0.6	0.6
012	15	34.0	72.5	15	4.0	5.2
024	13	44.3	145.6	13	6.2	7.4
036	11	65.6	211.4	11	5.9	10.5
048	9	65.5	250.6	9	5.0	13.6
060	4	62.9	363.7	4	6.2	14.5
072	2	60.1	356.8	2	7.5	20.5
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP062024 FABIO

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	9	12.8	12.8	9	1.7	1.7
012	7	45.3	69.9	7	7.9	8.7
024	5	81.6	165.3	5	13.0	14.6
036	3	111.5	289.8	3	6.7	11.7
048	1	145.3	561.0	1	10.0	20.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP072024 GILMA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	36	9.6	9.7	36	2.2	2.2
012	36	14.0	25.2	36	8.3	11.3
024	36	24.1	47.8	36	12.6	18.4
036	36	32.4	70.6	36	14.0	20.9
048	36	43.4	98.3	36	17.4	22.3
060	36	55.3	127.9	36	19.3	25.3
072	34	65.8	153.8	34	21.9	28.6
096	30	82.4	201.4	30	23.3	31.1
120	26	108.3	257.9	26	24.2	31.1

Verification statistics for: EP082024 HECTOR

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	12	19.0	19.0	12	1.7	1.7
012	10	23.0	34.5	10	4.0	3.1
024	8	22.1	47.6	8	3.8	3.9
036	6	21.1	53.0	6	3.3	4.5
048	4	26.6	58.2	4	5.0	7.0
060	2	57.1	22.1	2	10.0	15.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP092024 ILEANA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	11	5.0	5.0	11	2.7	2.7
012	9	23.0	33.8	9	4.4	6.9
024	7	40.8	54.6	7	5.7	5.9
036	5	59.5	84.4	5	5.0	5.6
048	3	68.4	114.7	3	6.7	9.7
060	1	68.4	186.9	1	0.0	5.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP102024 JOHN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	18	7.1	7.1	18	0.3	0.3
012	14	35.8	39.5	14	10.4	11.9
024	11	69.6	85.3	11	23.6	25.5
036	8	92.0	137.0	8	17.5	19.1
048	5	118.0	182.4	5	23.0	17.4
060	3	195.8	244.8	3	38.3	30.3
072	4	268.7	210.4	3	18.3	13.0
096	1	561.8	90.0	1	45.0	36.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP112024 ELEVEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	22.0	22.0	8	3.8	3.8
012	6	65.4	100.5	6	0.8	2.5
024	4	112.2	170.4	4	6.2	6.5
036	2	135.8	219.6	2	7.5	7.5
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP122024 KRISTY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	23	2.3	2.3	23	0.9	0.9
012	21	15.6	36.8	21	7.6	12.0
024	19	21.0	83.7	19	13.4	19.5
036	17	28.4	145.7	17	20.3	28.3
048	15	33.8	213.0	15	23.7	36.6
060	13	50.4	272.2	13	21.2	39.9
072	11	65.9	311.4	11	19.1	40.5
096	7	105.1	419.4	7	8.6	21.6
120	3	124.9	567.2	3	16.7	1.3

Verification statistics for: EP132024 LANE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	7	4.6	4.6	7	0.7	0.7
012	5	25.5	29.3	5	7.0	6.8
024	3	42.4	58.2	3	6.7	6.3
036	1	59.2	97.6	1	0.0	13.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP142024 FOURTEEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	4	12.9	12.9	4	0.0	0.0
012	2	38.0	65.3	2	5.0	6.0
024	0	-999.0	-999.0	0	-999.0	-999.0
036	0	-999.0	-999.0	0	-999.0	-999.0
048	0	-999.0	-999.0	0	-999.0	-999.0
060	0	-999.0	-999.0	0	-999.0	-999.0
072	0	-999.0	-999.0	0	-999.0	-999.0
096	0	-999.0	-999.0	0	-999.0	-999.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Table 12a. Verification of 48-h probabilistic genesis forecasts for the Atlantic basin in 2024.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	4	466
10	6	195
20	17	78
30	26	58
40	36	42
50	45	31
60	56	18
70	100	12
80	89	19
90	100	14
100	100	3

Table 12b. Verification of 48-h probabilistic genesis forecasts for the eastern North Pacific basin in 2024.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	1	330
10	8	109
20	26	69
30	25	52
40	50	22
50	53	17
60	55	11
70	74	27
80	85	13
90	87	15
100	-	0

Table 13a. Verification of 168-h probabilistic genesis forecasts for the Atlantic basin in 2024.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	0	27
10	18	272
20	28	169
30	32	120
40	62	112
50	60	70
60	71	49
70	75	40
80	95	38
90	100	36
100	100	3

Table 13b. Verification of 168-h probabilistic genesis forecasts for the eastern North Pacific basin in 2024.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	6	18
10	18	160
20	42	119
30	46	114
40	54	63
50	58	38
60	71	34
70	66	35
80	68	38
90	93	46
100	-	0

Table 14. NHC forecast cone circle radii (n mi) for 2025. Change from 2024 values expressed in n mi and percent are given in parentheses.

2025 Track Forecast Cone Two-Thirds Probability Circles (n mi)		
Forecast Period (h)	**Atlantic Basin**	**Eastern North Pacific Basin**
3	16 (0: 0%)	16 (0: 0%)
12	26 (0: 0%)	26 (0: 0%)
24	39 (-2: -5%)	38 (-1: -3%)
36	52 (-3: -5%)	50 (-3: -6%)
48	67 (-3: -4%)	59 (-6: -9%)
60	83 (-5: -6%)	71 (-5: -7%)
72	100 (-2: -2%)	83 (-9: -10%)
96	142 (-9: -6%)	113 (-6: -5%)
120	213 (-7: -3%)	146 (-6: -4%)

Table 15. Composition of NHC consensus models for 2025.

NHC Consensus Model Definitions For 2025			
Model ID	**Parameter**	**Type**	**Members**
GFEX	Track	Fixed	GFSI EMXI
ICON	Intensity	Fixed	DSHP LGEM HFAI HFBI CTCI HWFI HMNI
TVCA**	Track	Variable	GFSI EGRI HFAI HFBI EMXI CTCI HWFI HMNI EMNI
TVCE	Track	Variable	GFSI EGRI HFAI HFBI EMXI CTCI EMNI HWFI HMNI
TVDG	Track	Variable	GFSI (double weight) EMXI (double weight) EGRI (double weight) CTCI HFAI HFBI HWFI HMNI
TVCX	Track	Variable	EMXI (double weight) GFSI EGRI HFAI HFBI HWFI HMNI
IVCN	Intensity	Variable	DSHP LGEM HFAI HFBI CTCI HWFI HMNI
IVDR	Intensity	Variable	CTCI (double weight) HWFI (double weight) HMNI (double weight) HFAI (double weight) HFBI (double weight) GFSI DSHP LGEM

** TVCN will continue to be computed and will have the same composition as TVCA. GPCE circles will continue to be based on TVCN.

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37. Violin diagram of NHC official intensity forecasts for the eastern North Pacific basin for 2020–2024. The mean is shown by the colored dot, median by the horizontal line, 25-75th percentiles by the box edges, and 10-90th percentiles by whiskers. Dashed lines represent 5-yr means.

38. Roebber performance diagram of NHC official forecast and selected early intensity models of rapidly strengthening storms in 2024 in the eastern Pacific basin. Probability of detection is given by the ratio of hits to the total number of times the events occurred. False Alarm Ratio (FAR) is given by the ratio of false alarms to the total number of forecast events.

39. Recent trends in NHC 34- (top) and 50-kt (bottom) wind radii official forecast error for the eastern North Pacific basin. The results represent a quadrant average.

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41. 2024 NHC eastern North Pacific official track errors by tropical cyclone at 24, 48, 72, 96, and 120 h.

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44. As described for Fig. 43, except for 168-h forecasts.

45. Composites of 7-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks for the Atlantic and East Pacific basins during the 2024 season for (a) all probabilistic genesis categories, (b) low (<40% category), (c) medium (40–60%) category, and (d) high (> 60% category).

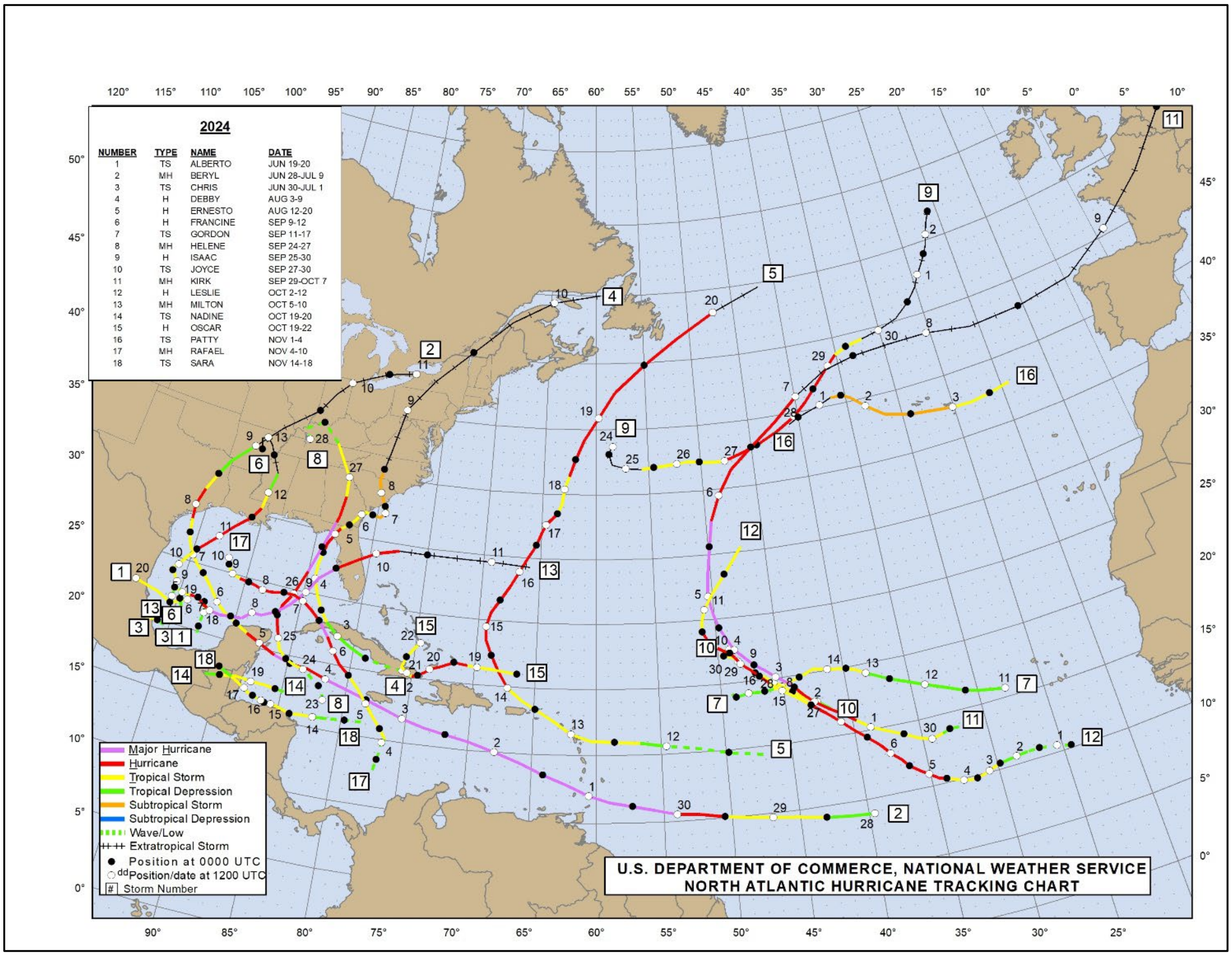


Figure 1. Map of the 2024 Atlantic basin tropical storms and hurricanes.

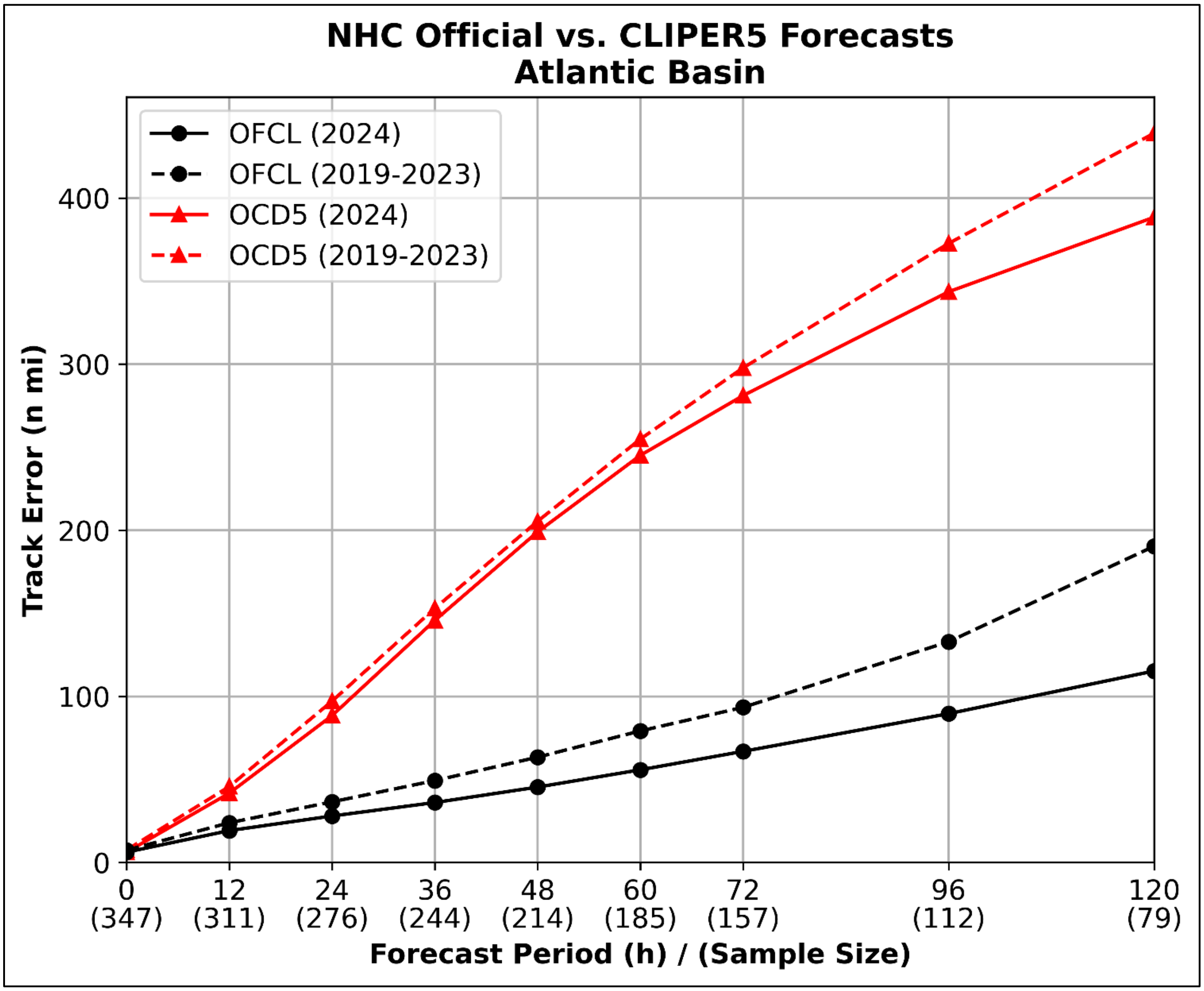


Figure 2. NHC official and CLIPER5 (OCD5) Atlantic basin average track errors for 2024 (solid lines) and 2019–2023 (dashed lines).

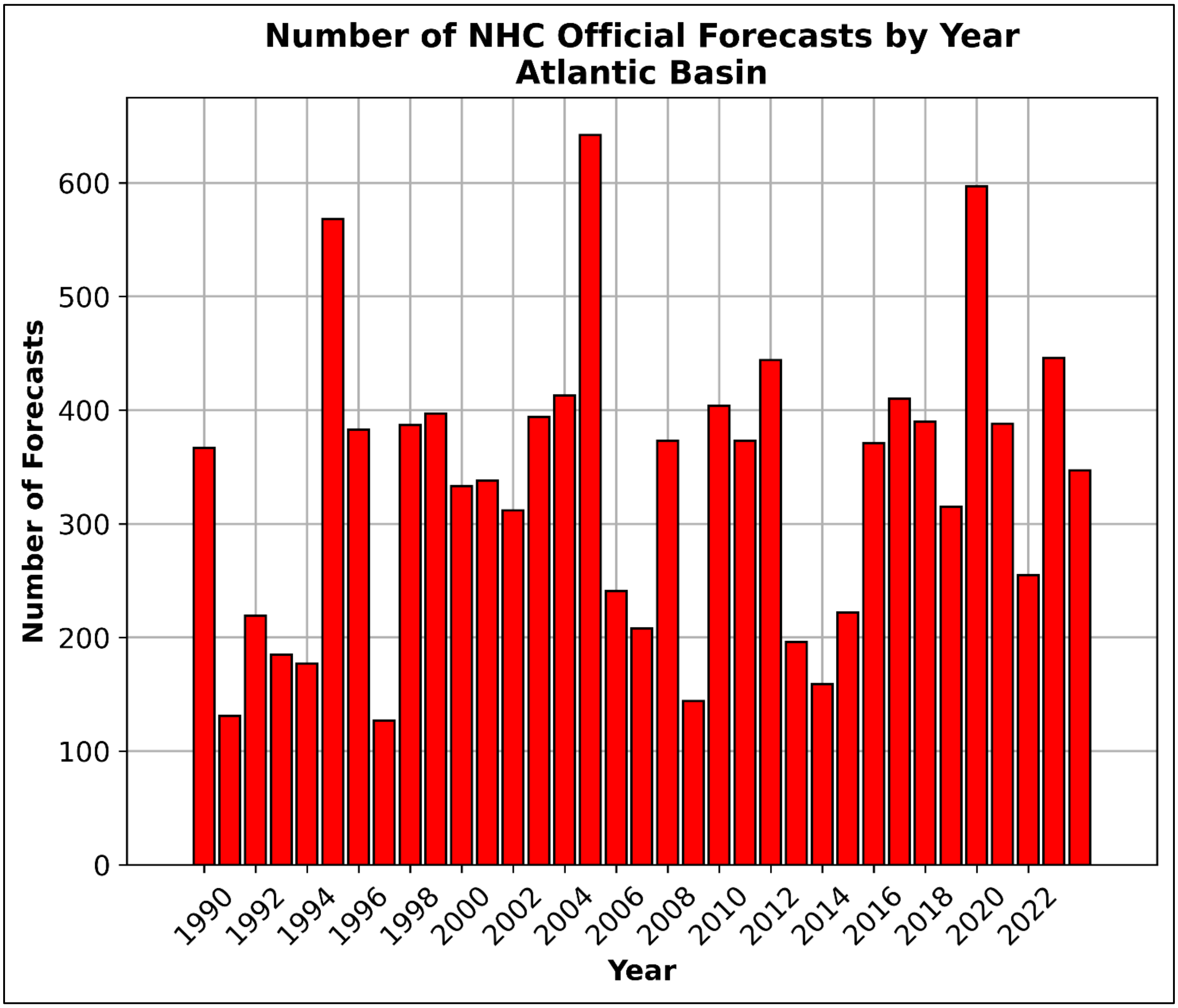
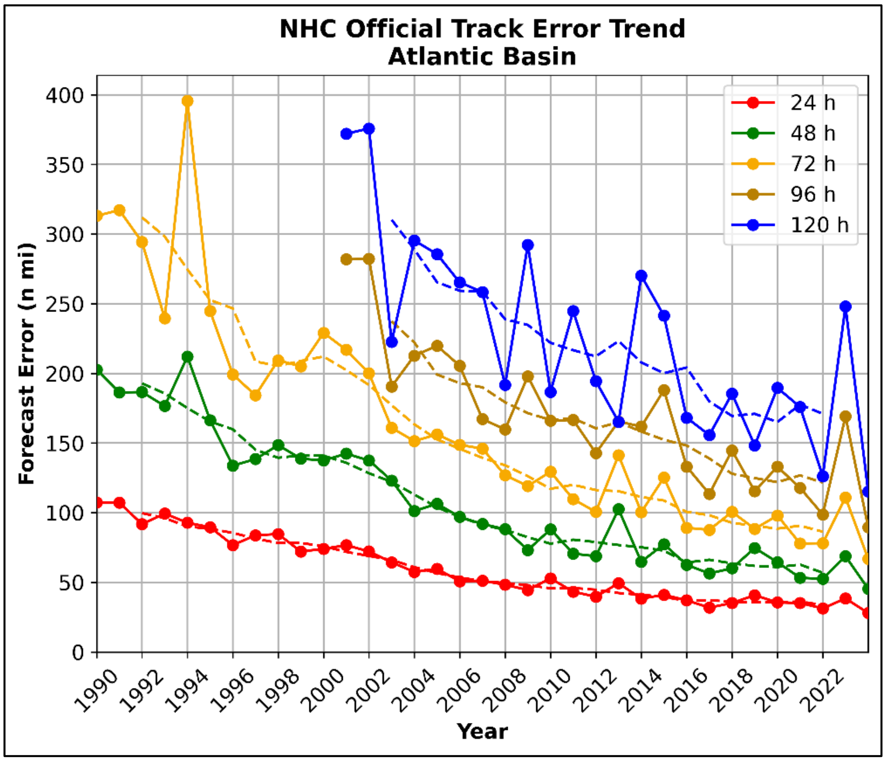


Figure 3. Number of NHC official forecasts for the Atlantic basin stratified by year from 1990–2024.



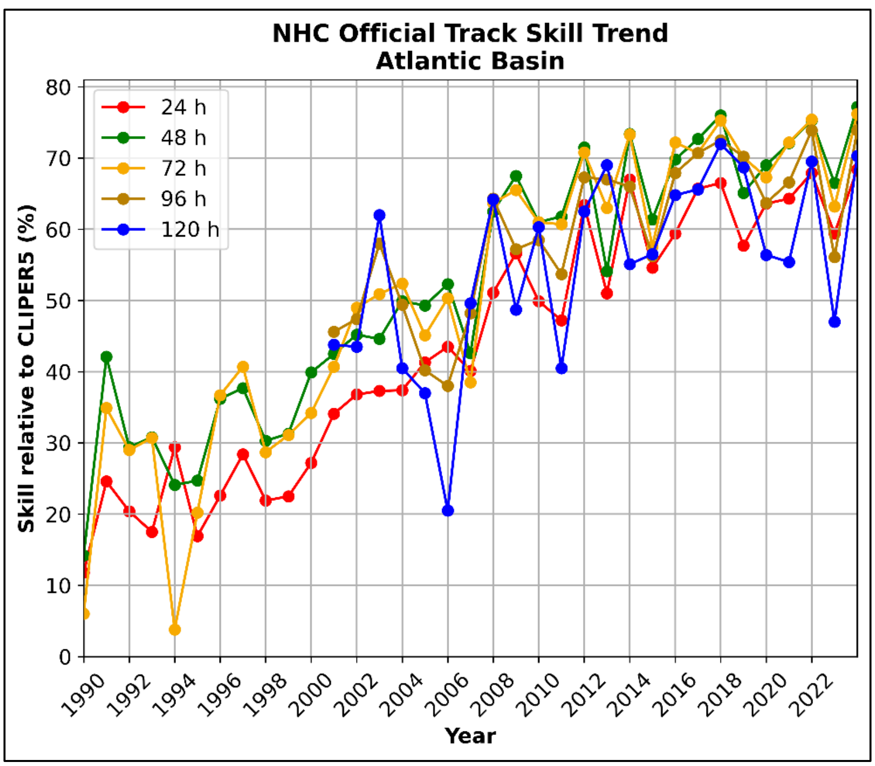


Figure 4. Recent trends in NHC official track forecast error (top) and skill (bottom) for the Atlantic basin. Dashed lines in error trend represent a 5-yr running mean.

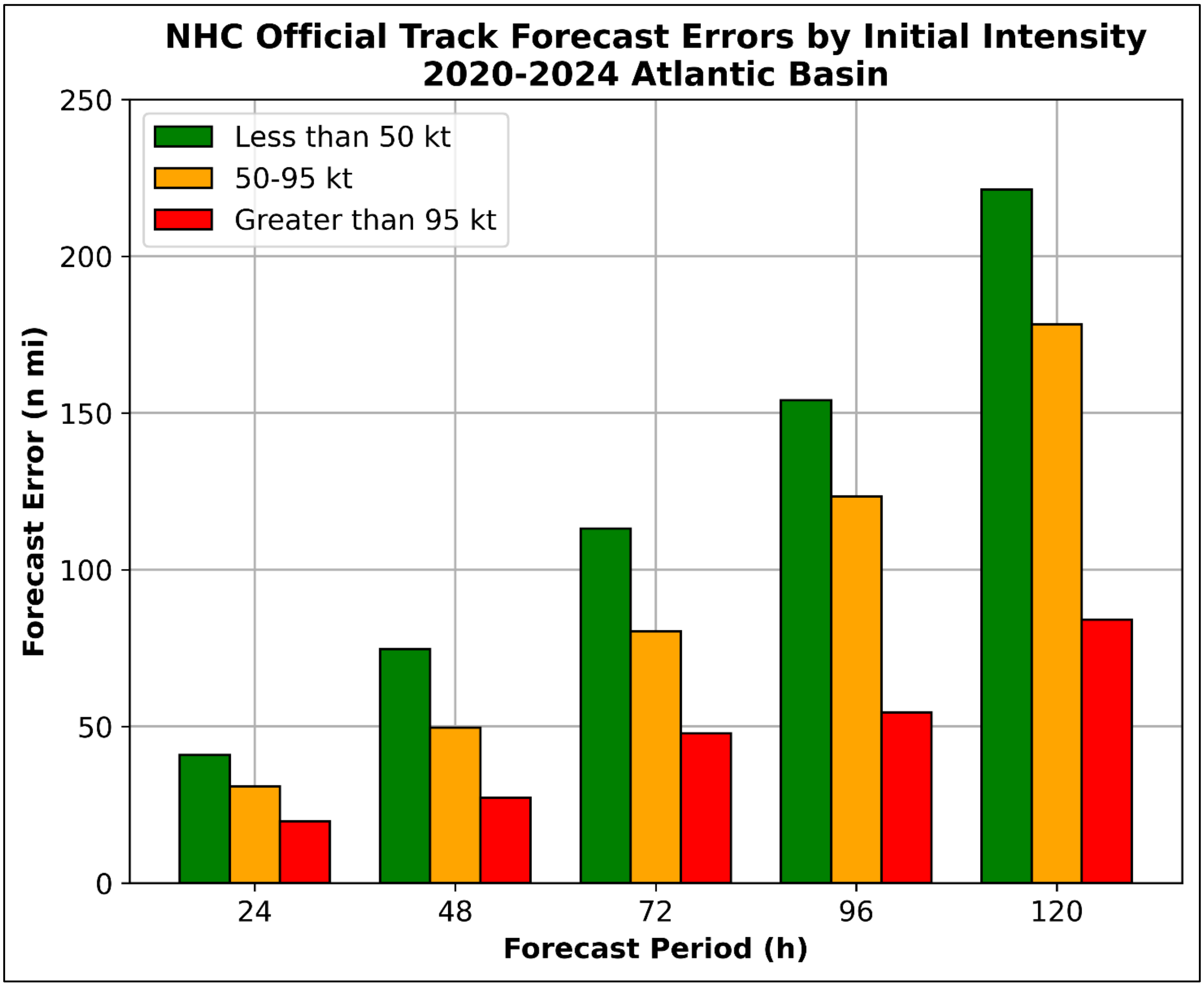


Figure 5. 2020–24 NHC official track forecast error binned by initial intensity for the Atlantic basin.

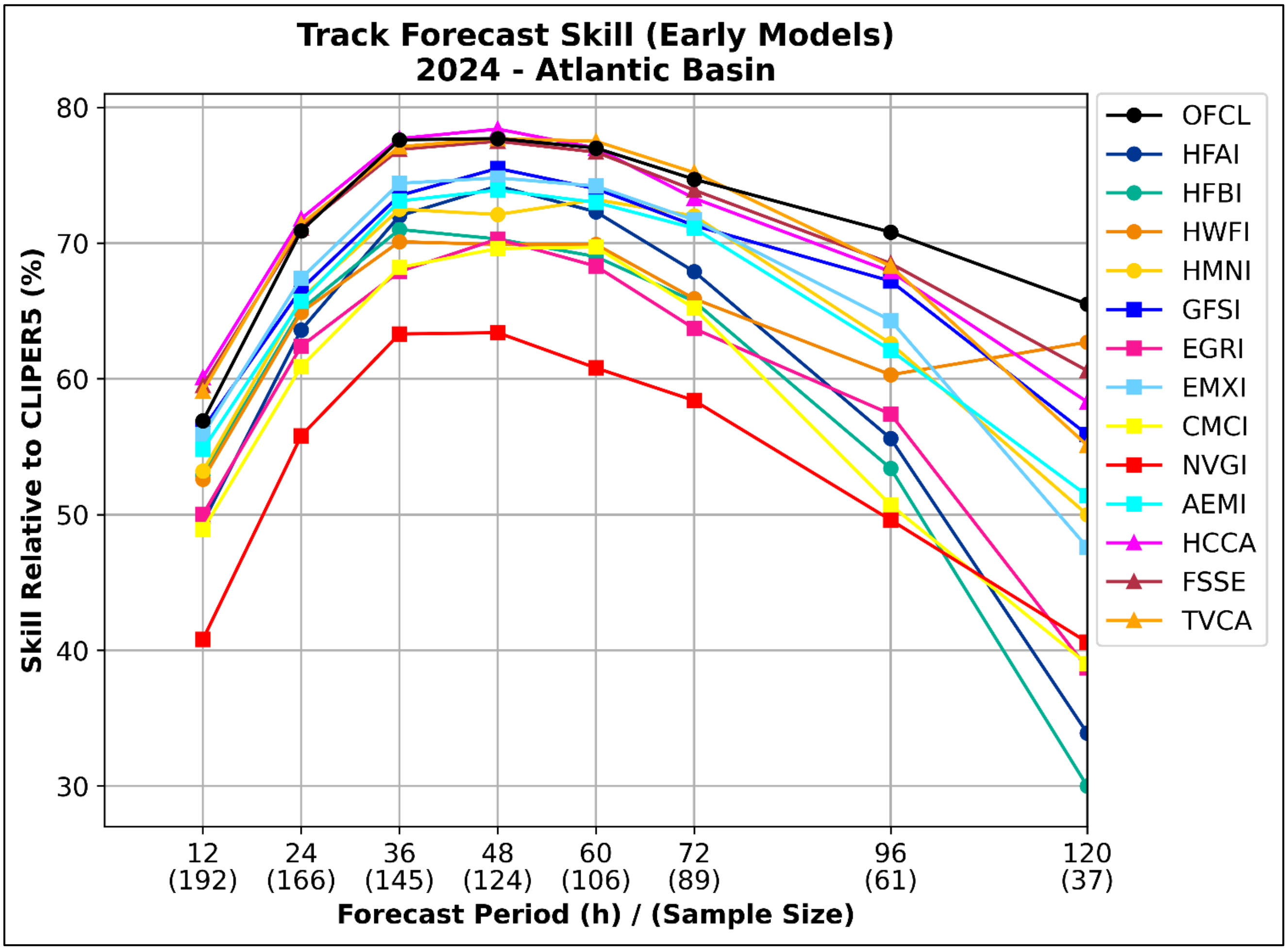


Figure 6. Homogenous comparison for selected Atlantic basin early track models for 2024. This verification includes only those models that were available at least 2/3 of the time (see text).

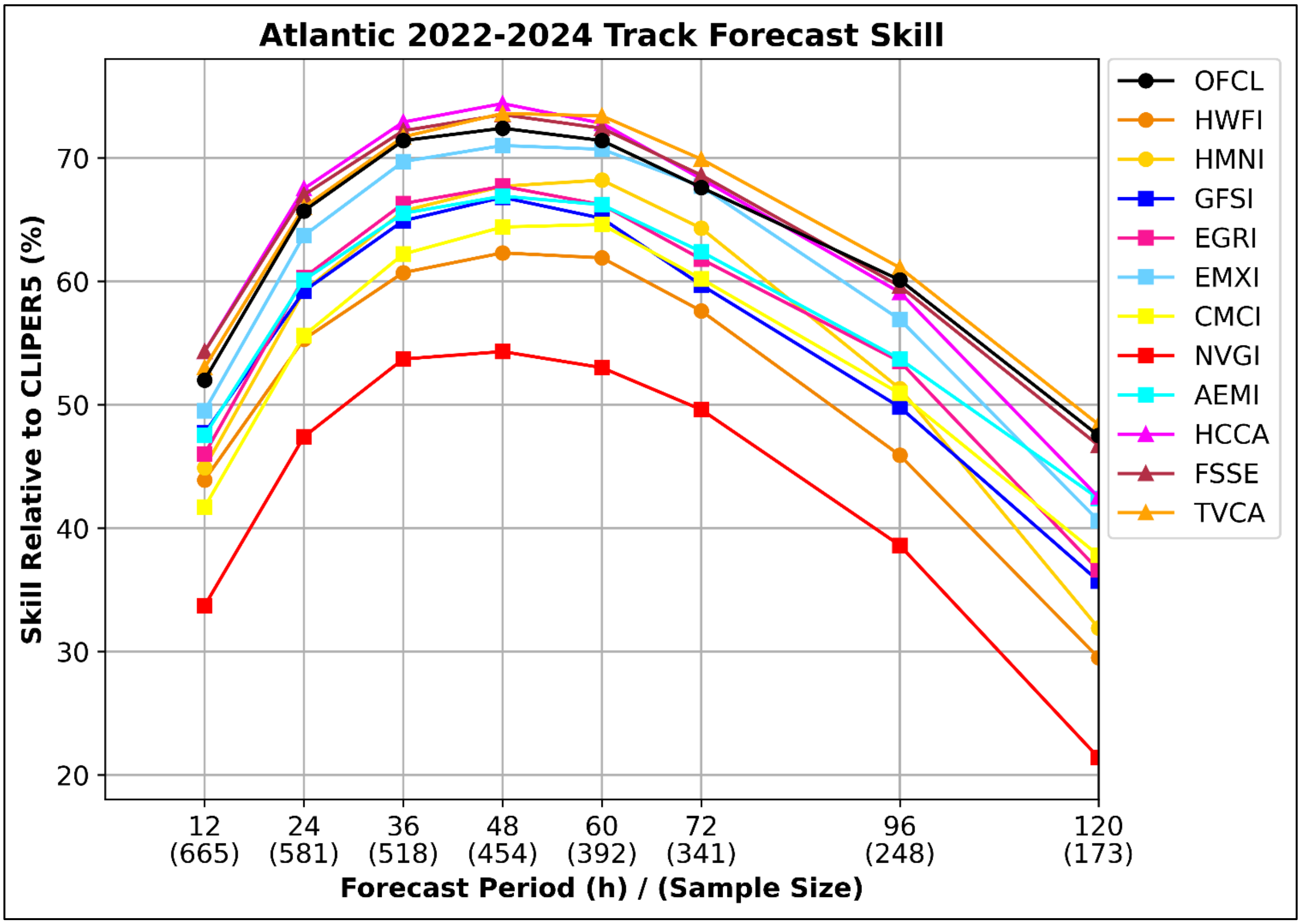


Figure 7. Homogenous comparison for selected Atlantic basin early track models for 2022–2024.

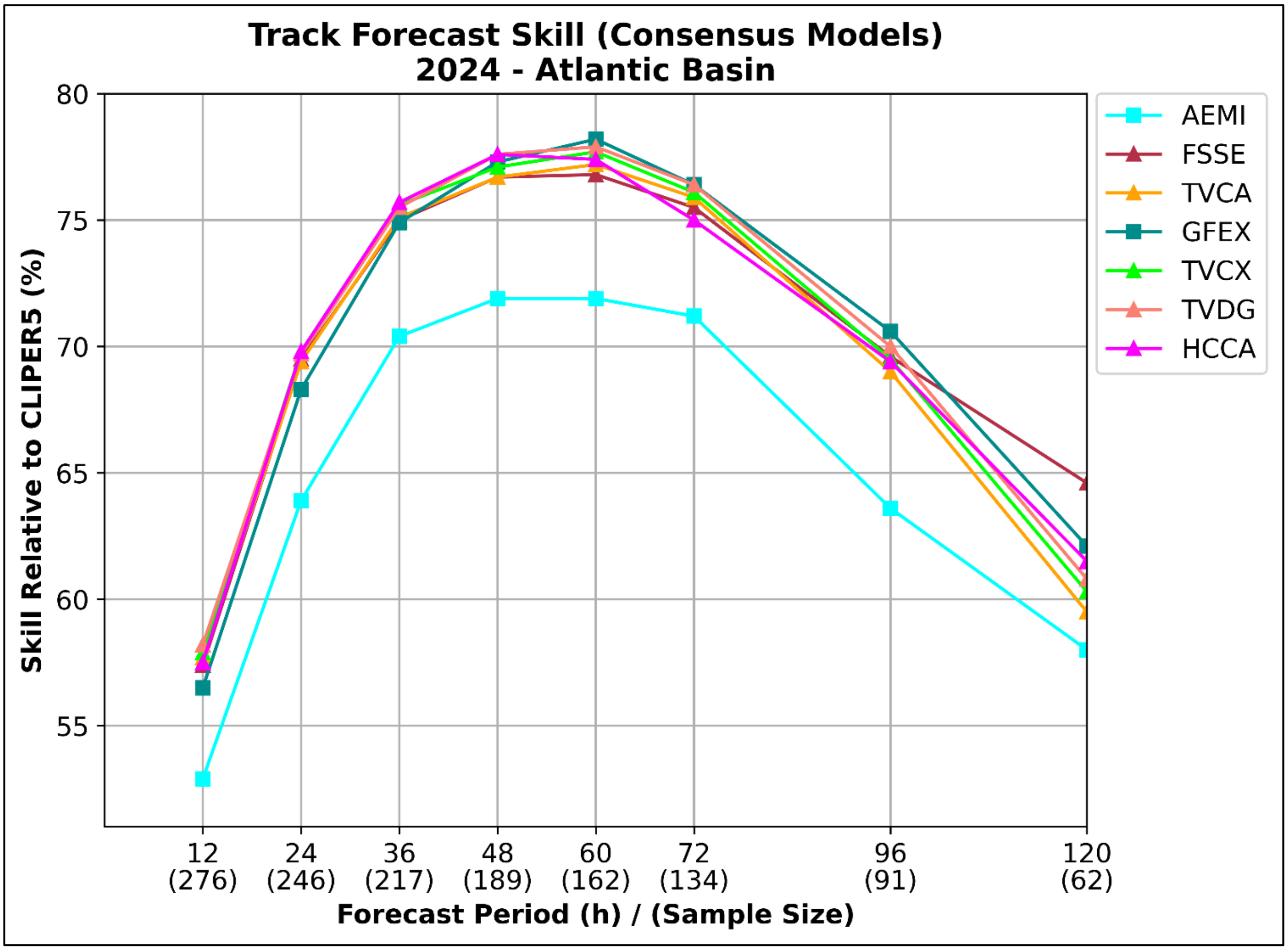
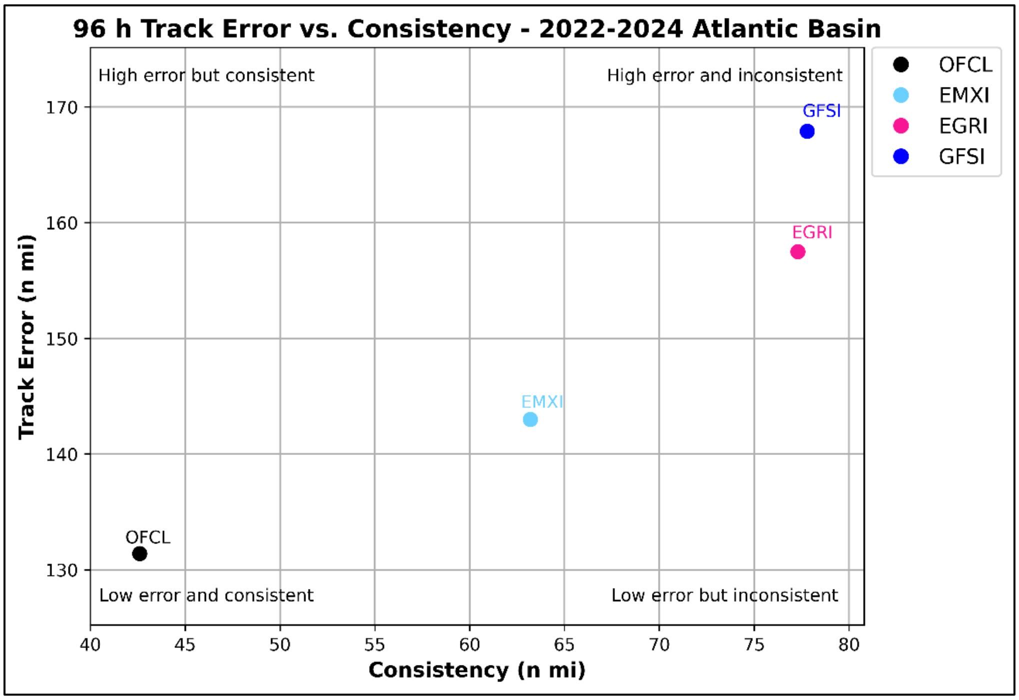


Figure 8. Homogenous comparison of the primary Atlantic basin track consensus models for 2024.



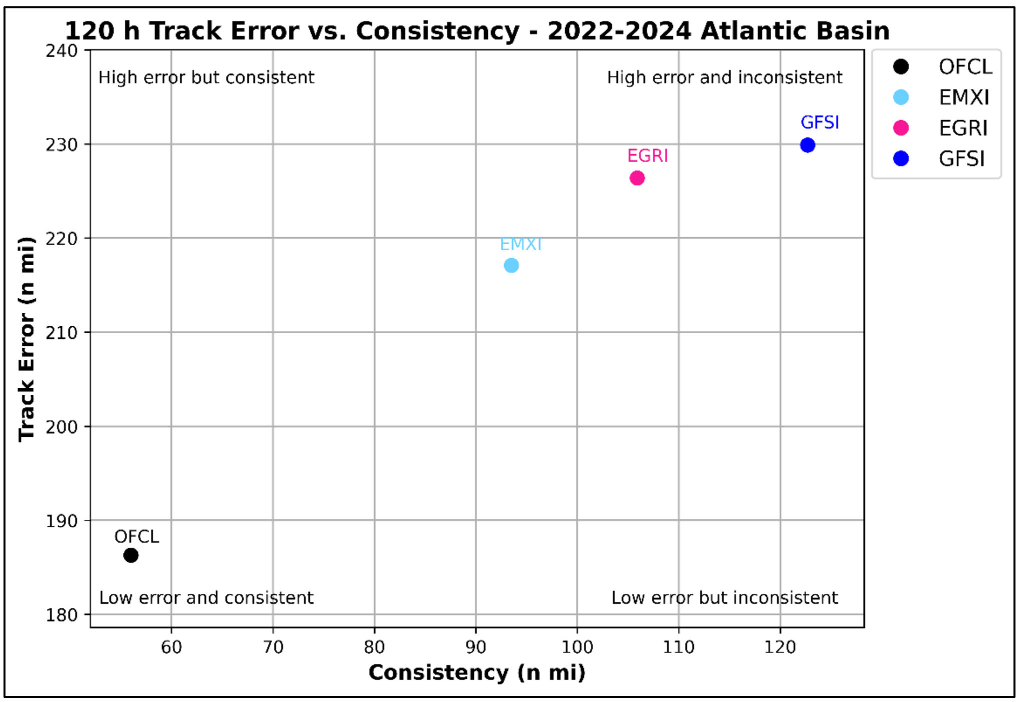


Figure 9. Track error vs. consistency around the 96- (top) and 120-h (bottom) forecast periods in the Atlantic basin of GFSI, EMXI, EGRI, and OFCL (NHC) from 2022–24.

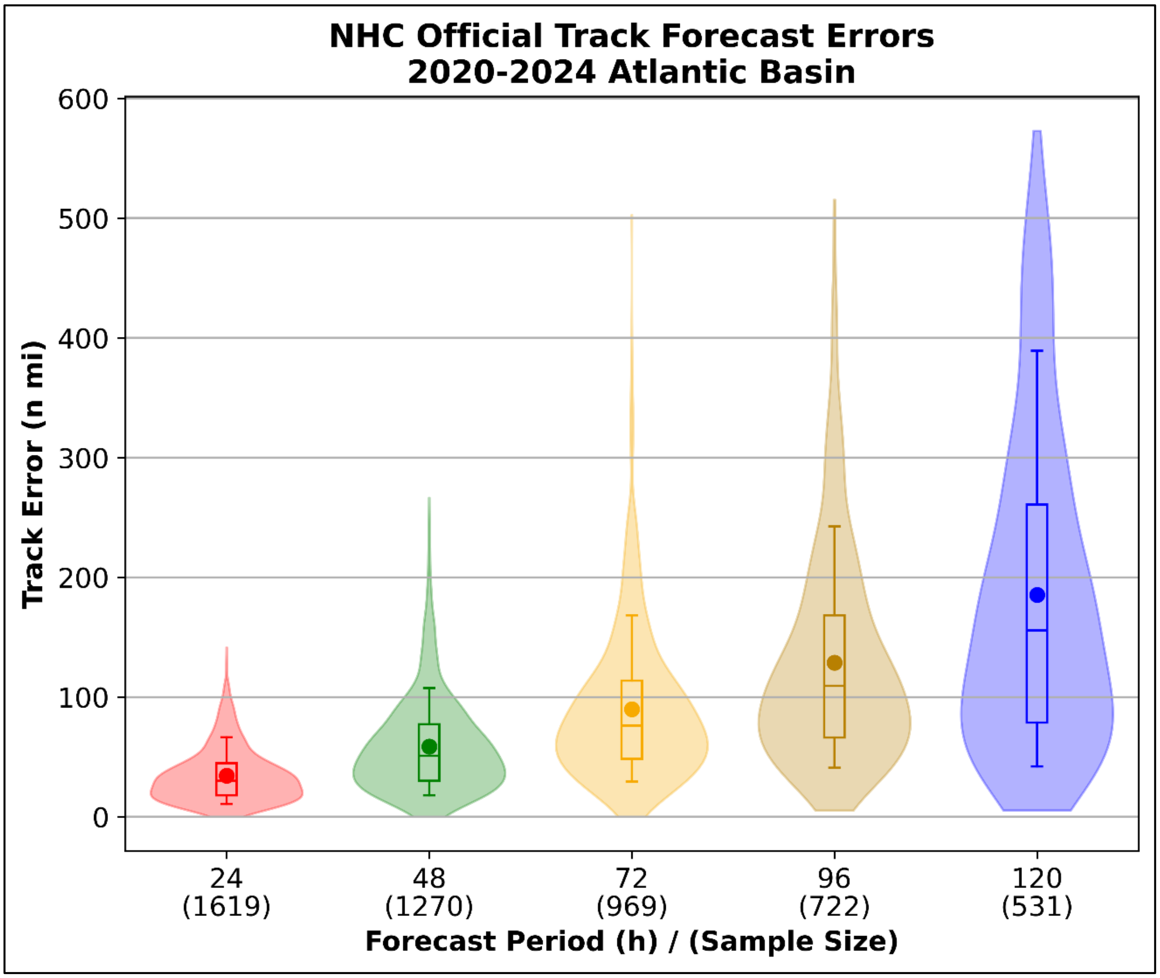


Figure 10. Violin diagram of NHC official track forecasts for the Atlantic basin for 2020–2024. The mean is shown by the colored dot, median by the horizontal line, 25-75th percentiles by the box edges, and 10-90th percentiles by whiskers. Kernel density estimates (KDEs, shaded) of the probability density function are constructed from Gaussian kernels comprising 100 data points.

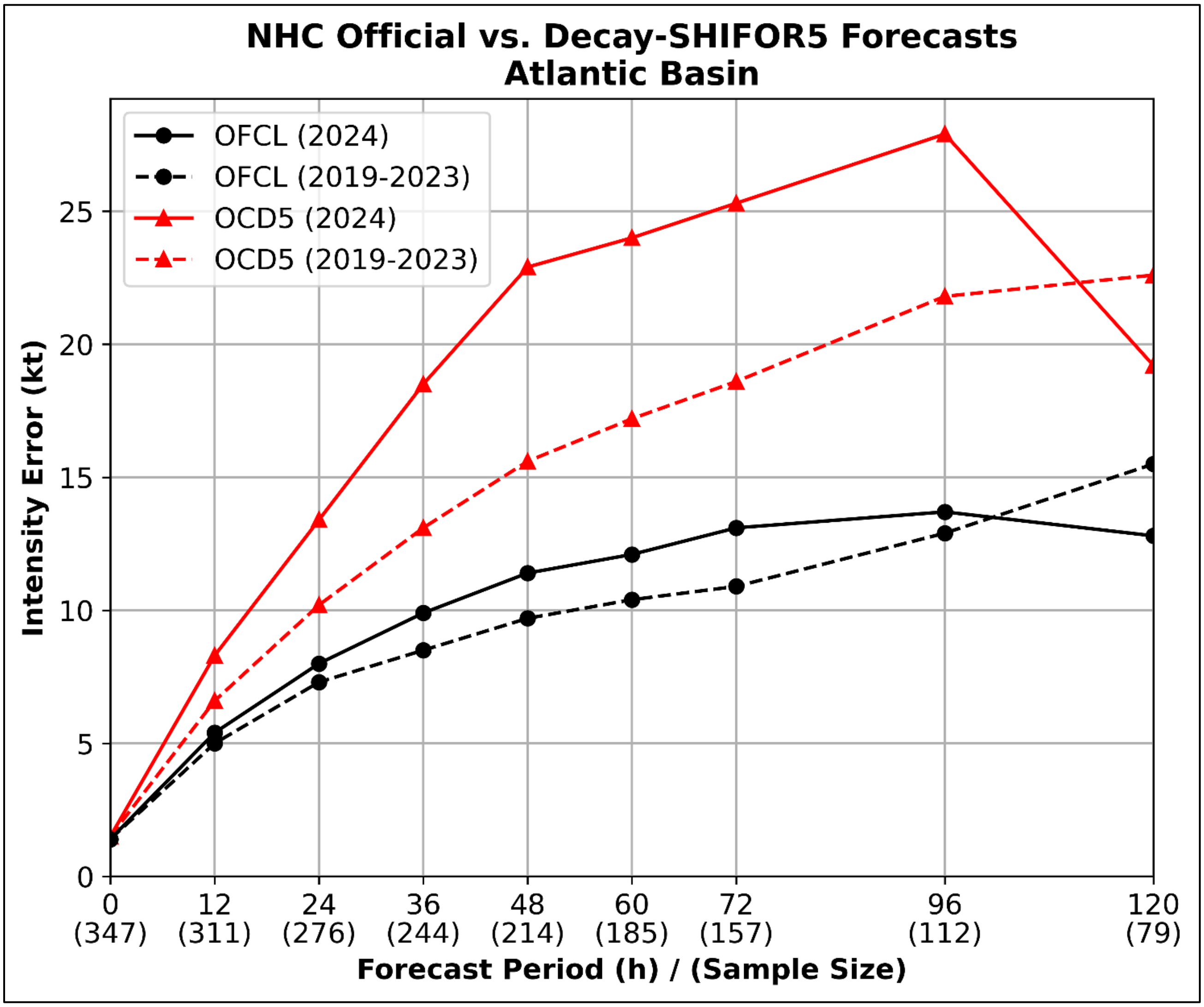
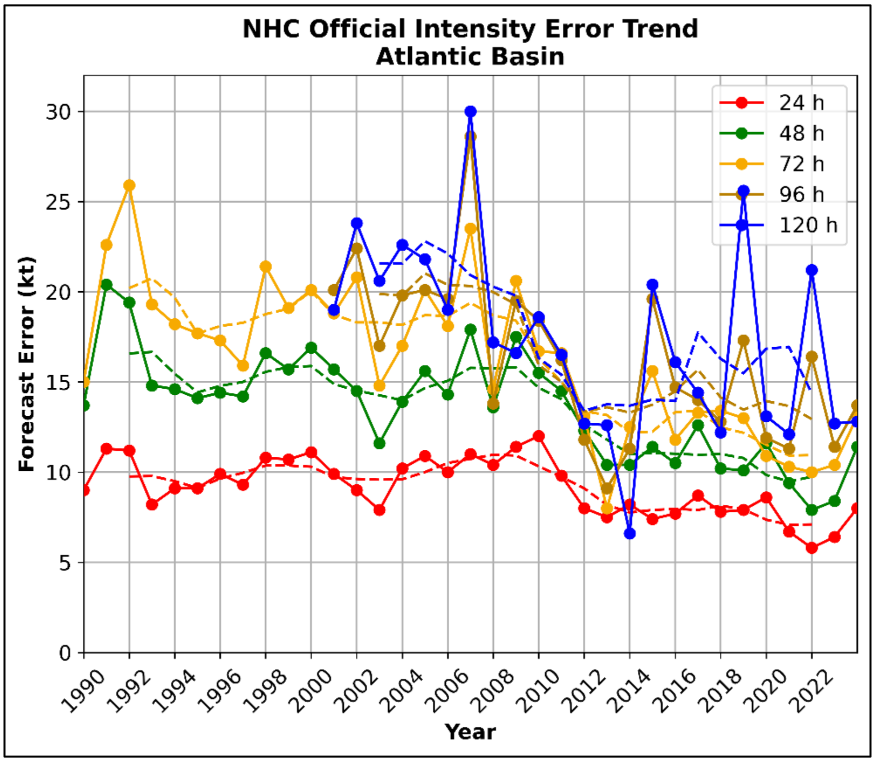


Figure 11. NHC official and Decay-SHIFOR5 (OCD5) Atlantic basin average intensity errors for 2024 (solid lines) and 2019–2023 (dashed lines).



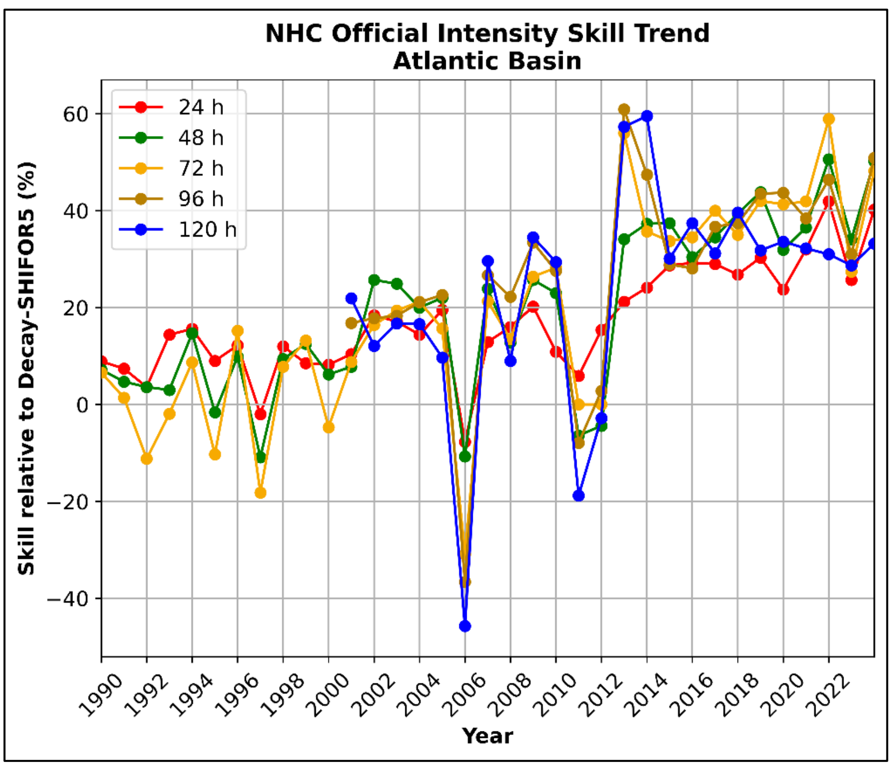


Figure 12. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the Atlantic basin. Dashed lines in error trend represent a 5-yr running mean.

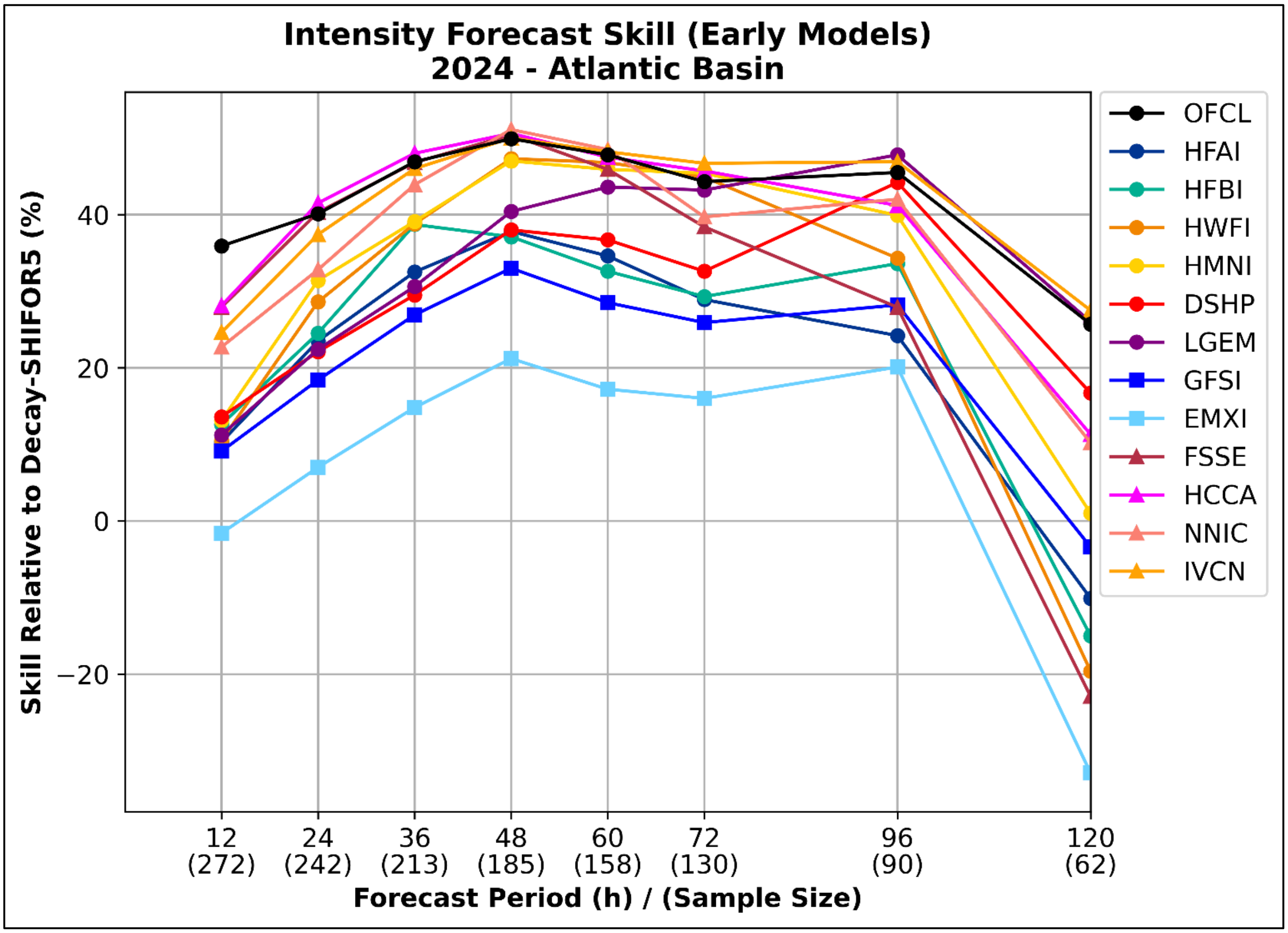


Figure 13. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2024.

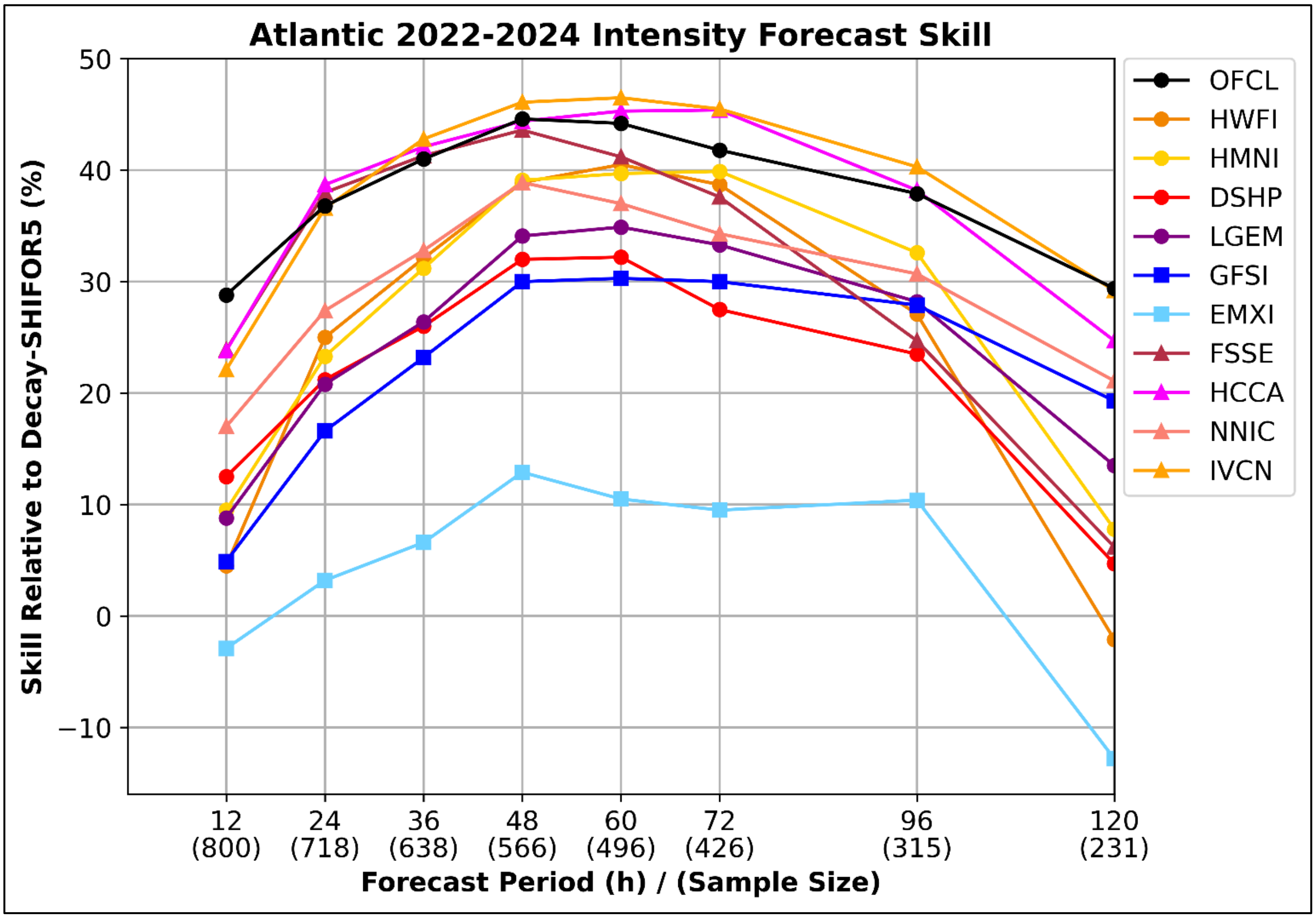


Figure 14. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2022–2024.

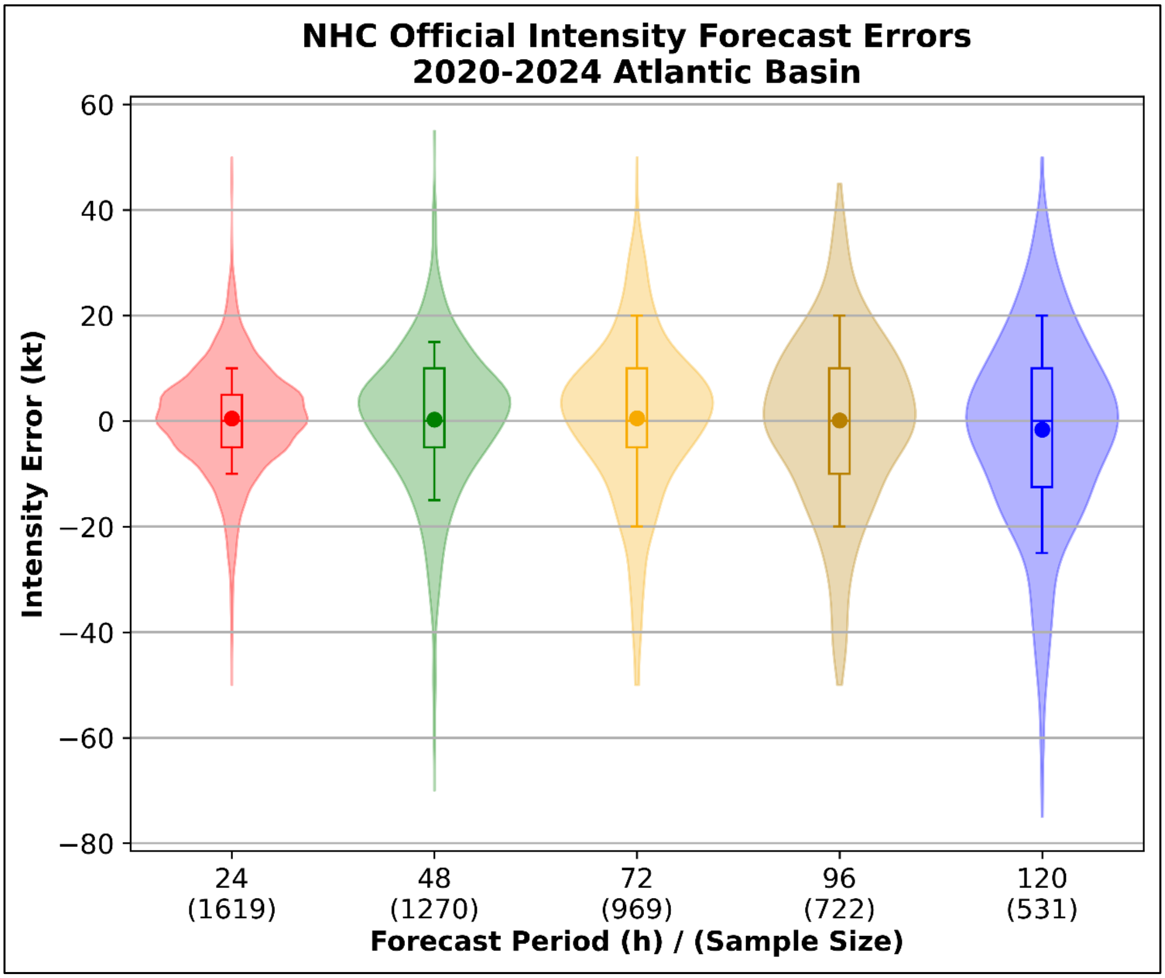


Figure 15. Violin diagram of NHC official intensity forecasts for the Atlantic basin for 2020–2024. The mean is shown by the colored dot, median by the horizontal line, 25-75th percentiles by the box edges, and 10-90th percentiles by whiskers.

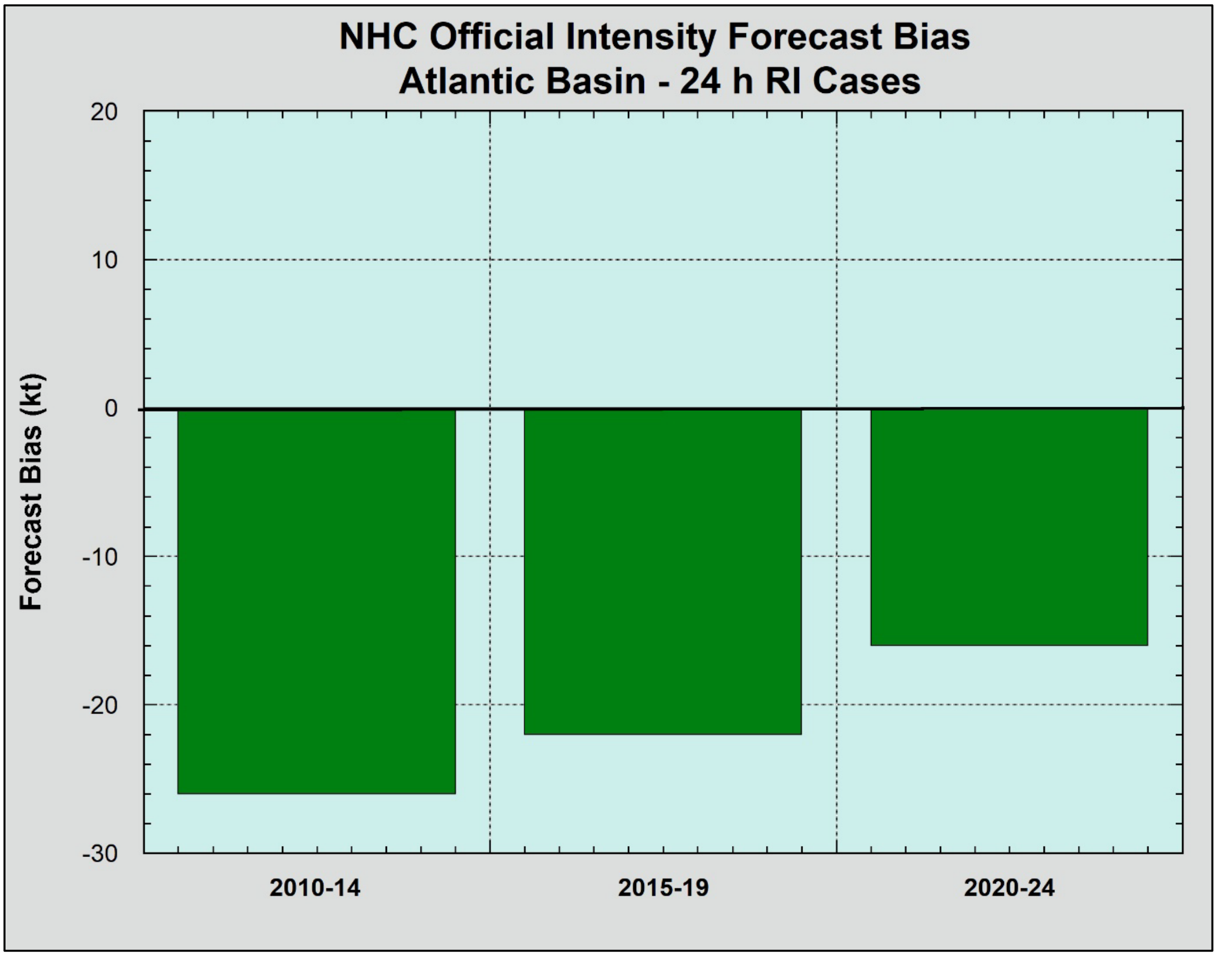


Figure 16. NHC's 24-hour intensity bias for rapid intensification events in the Atlantic basin binned in 5-year spans from 2010 to 2024.

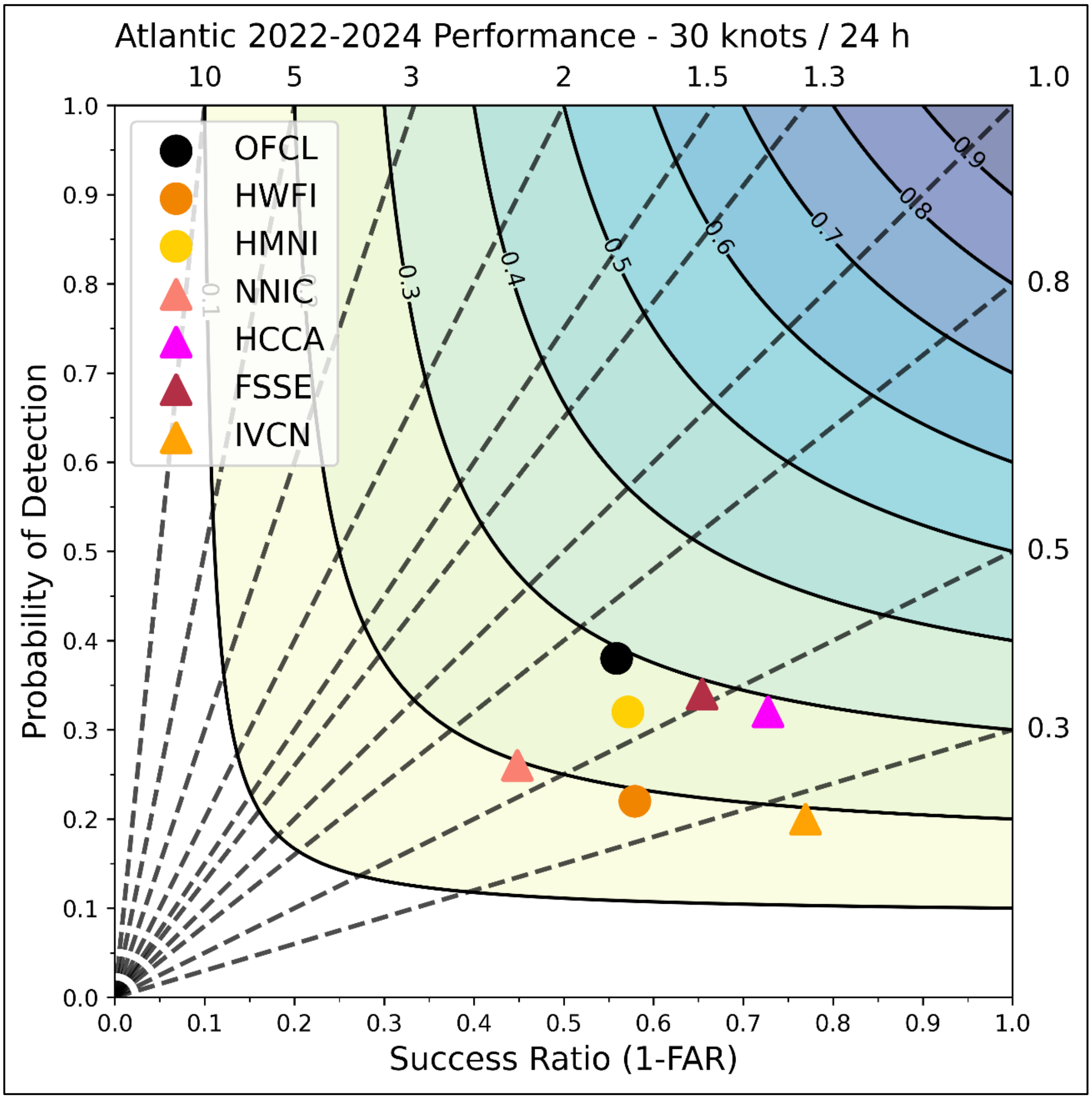
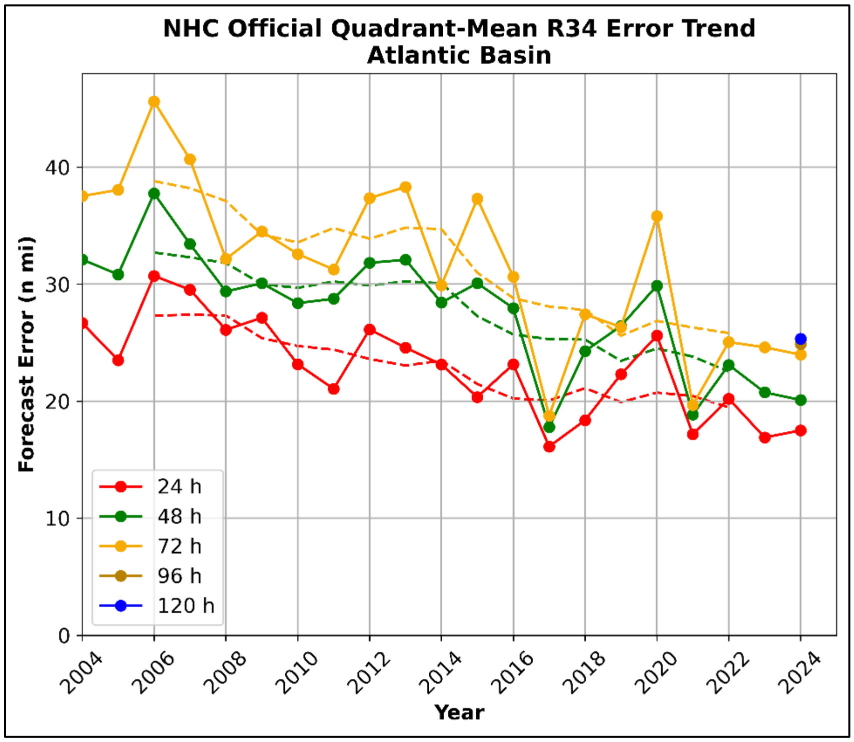


Figure 17. Roebber performance diagram of NHC official forecast and selected early intensity models of rapidly strengthening storms from 2022-24 in the Atlantic basin. Probability of detection is given by the ratio of hits to the total number of times the events occurred. False Alarm Ratio (FAR) is given by the ratio of false alarms to the total number of forecast events. Critical success index is shown in shading/solid contours, and the forecast bias is shown by the dashed lines.



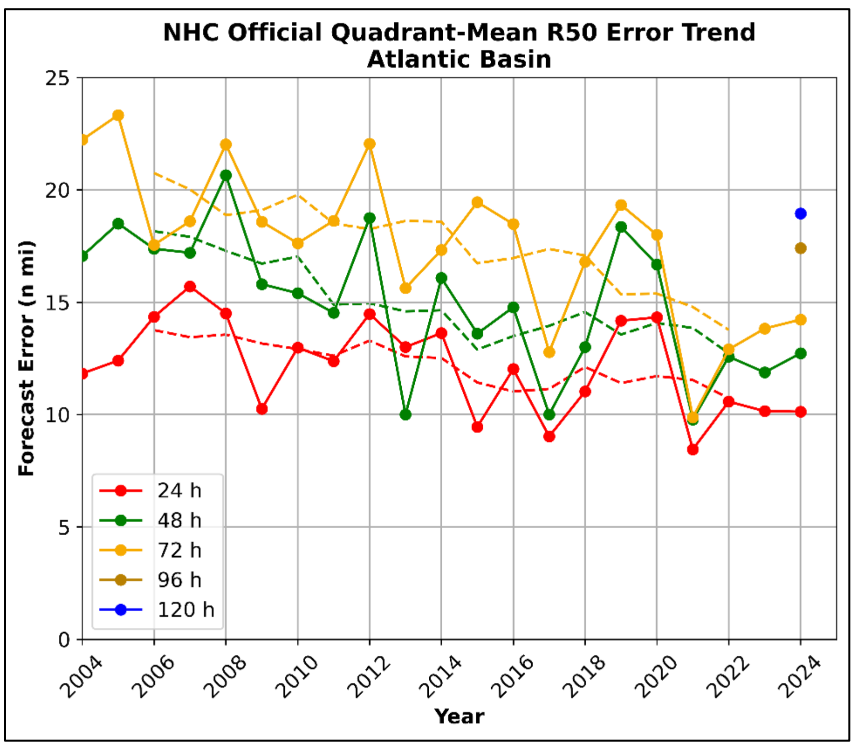


Figure 18. Recent trends in NHC 34- (top) and 50-kt (bottom) wind radii official forecast error for the Atlantic basin. The results represent a quadrant average. The dashed lines represent a 5-yr running mean.

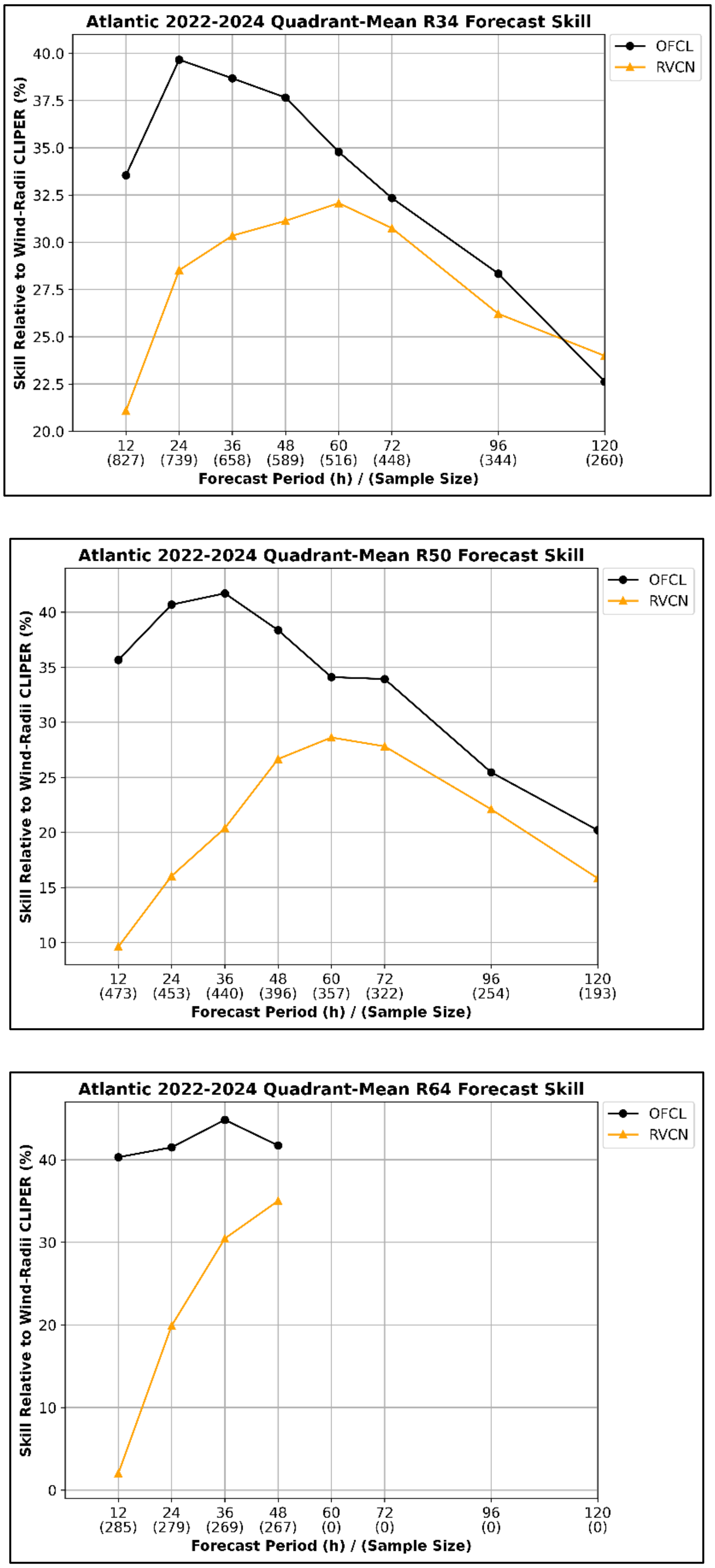


Figure 19. Quadrant-mean skill of NHC and RVCN for the 34-kt (top), 50-kt (middle), and 64-kt (bottom) wind radii forecasts for the Atlantic basin in 2024.

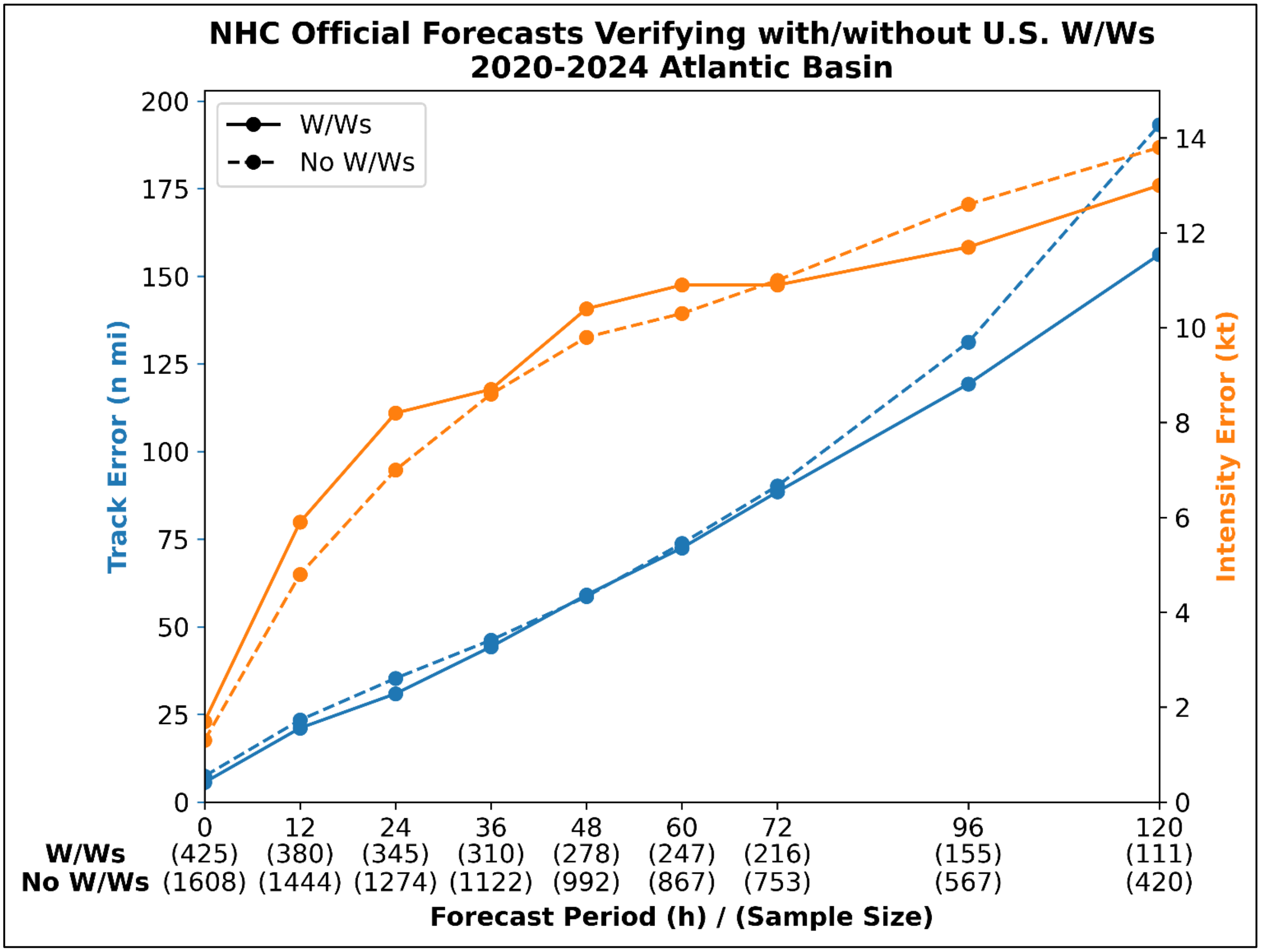


Figure 20. A comparison of NHC official track (blue) and intensity (orange) errors when U.S. watches and warnings were in effect and when they weren't in the Atlantic basin from 2020–2024.

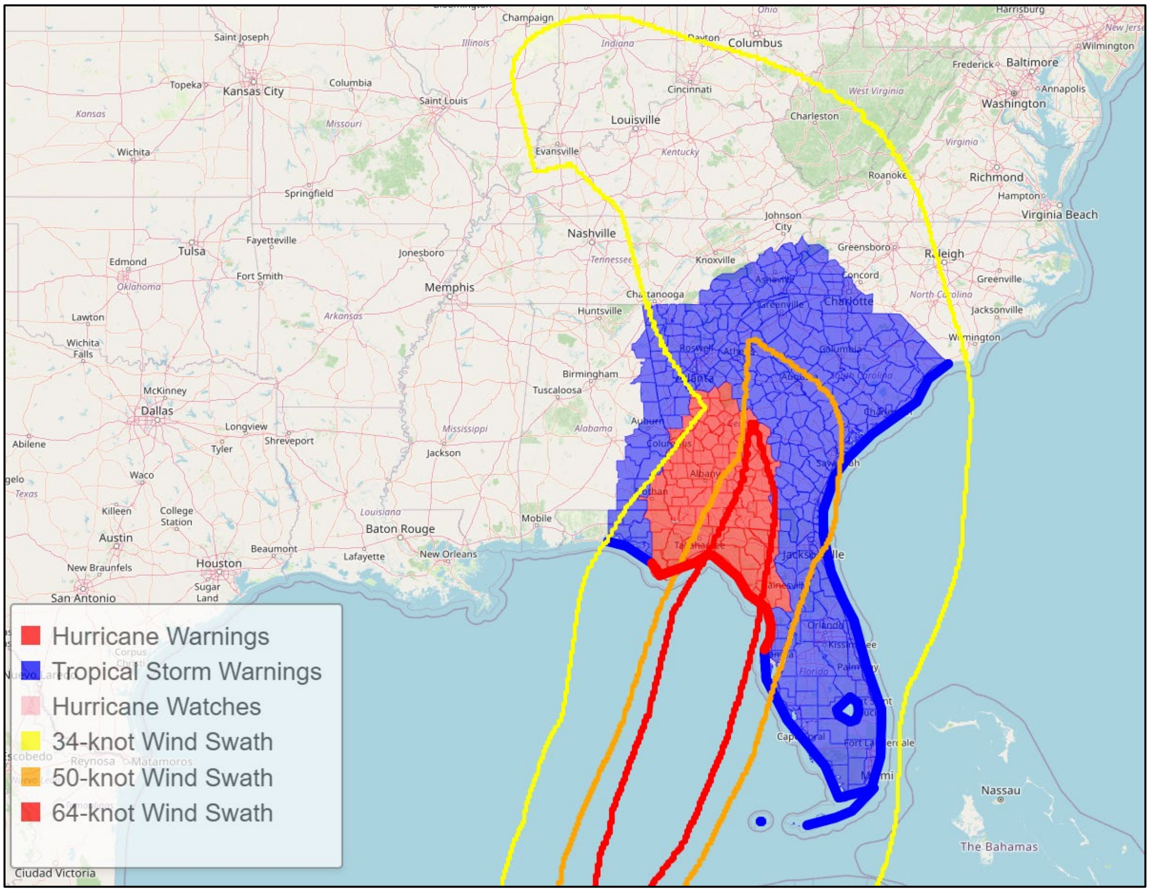


Figure 21. NHC's best track wind radii (34-, 50-, and 64-kt) of Hurricane Helene overlaid with Hurricane and Tropical Storm Warnings issued during the event.

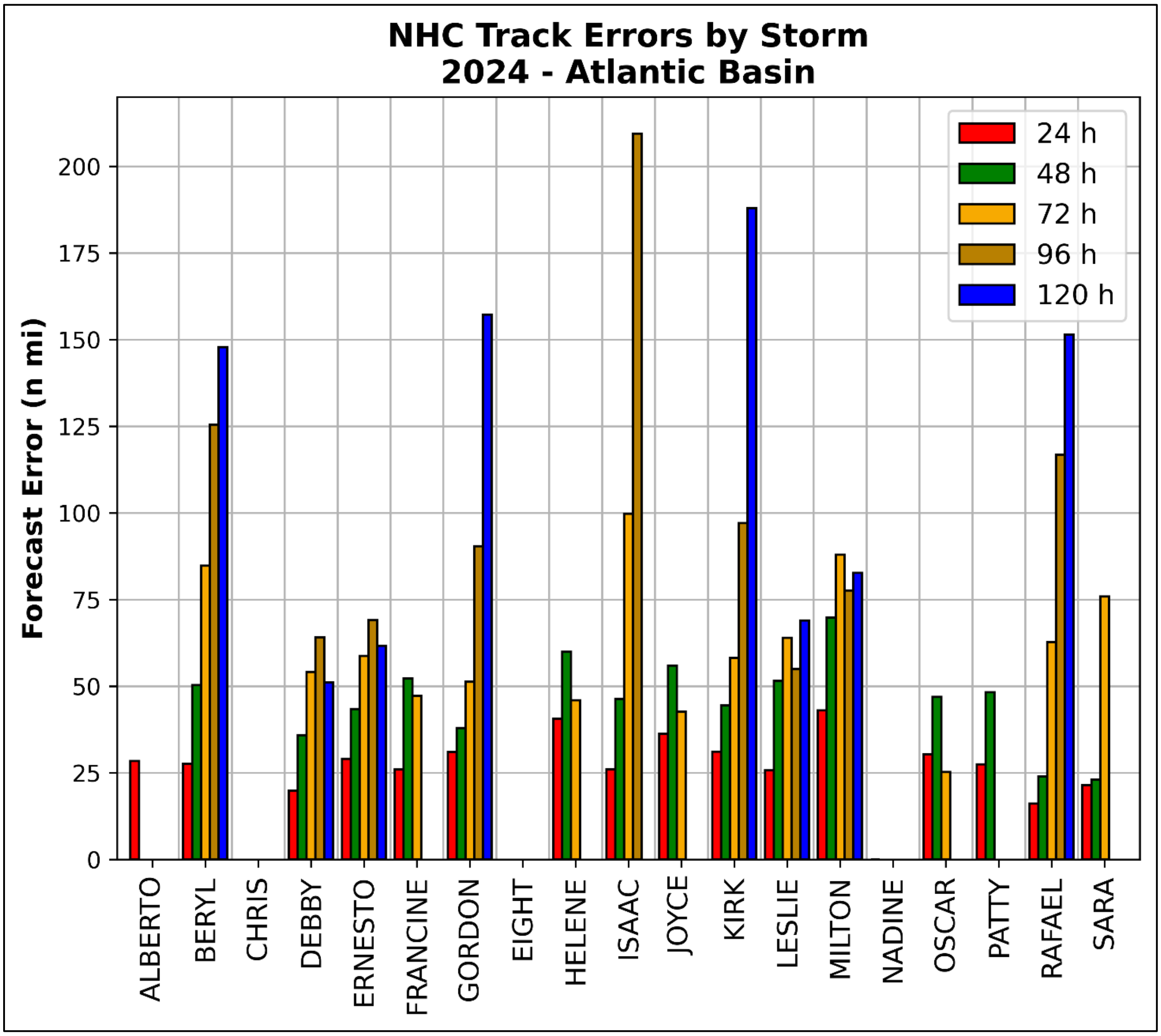


Figure 22. 2024 NHC official track errors by tropical cyclone at 24, 48, 72, 96 and 120 h.

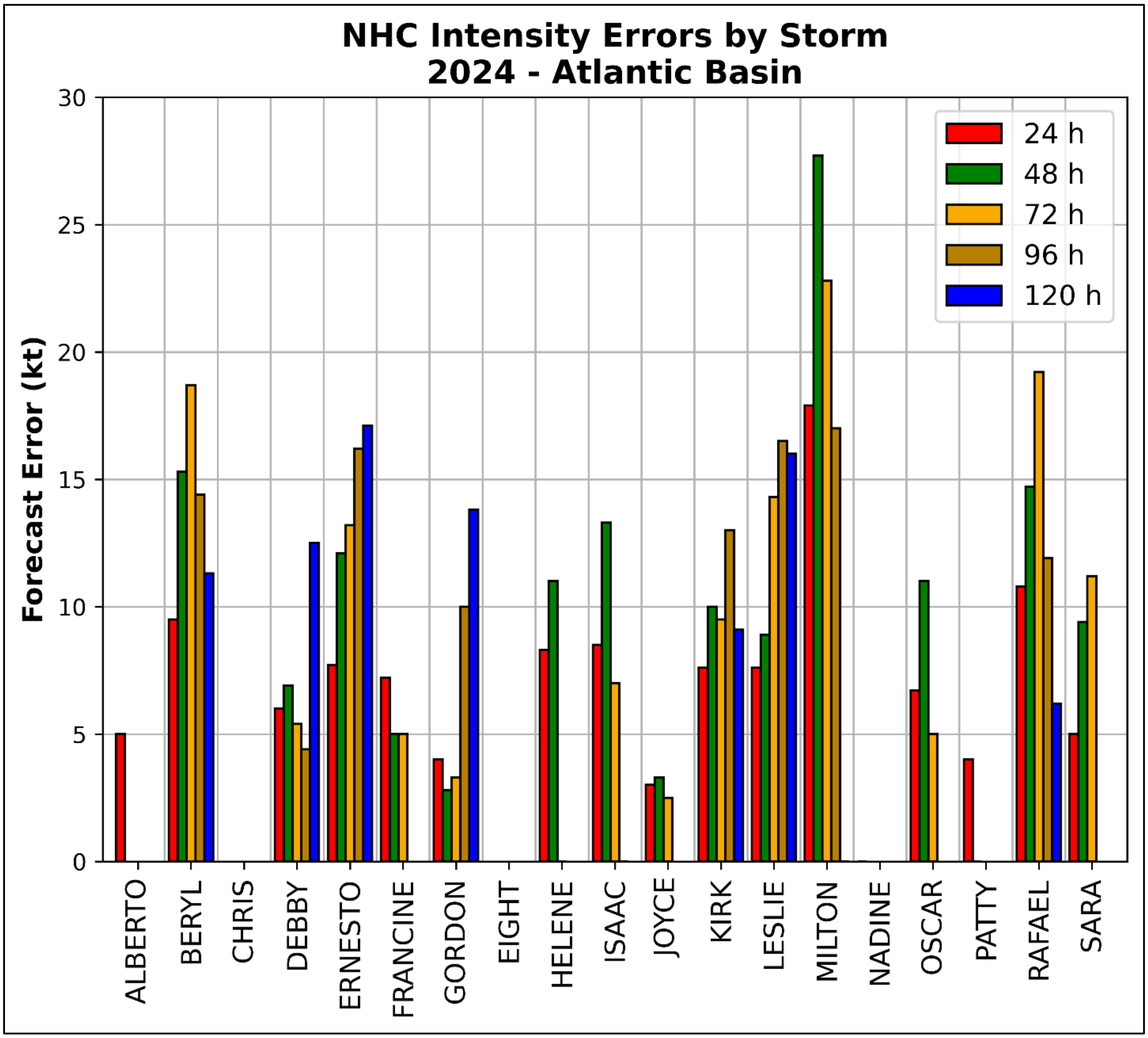


Figure 23. 2024 NHC official intensity errors by tropical cyclone at 24, 48, 72, 96 and 120 h.

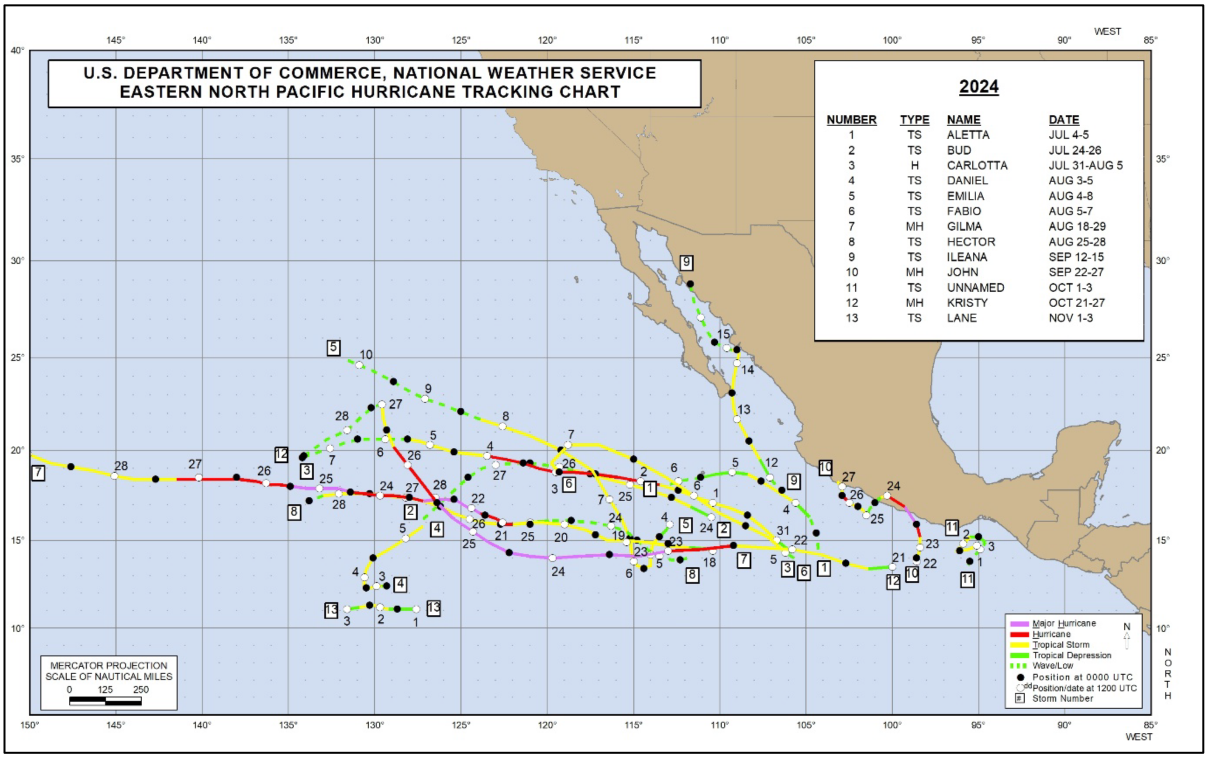


Figure 24. Map of the 2024 eastern North Pacific basin tropical storms and hurricanes.

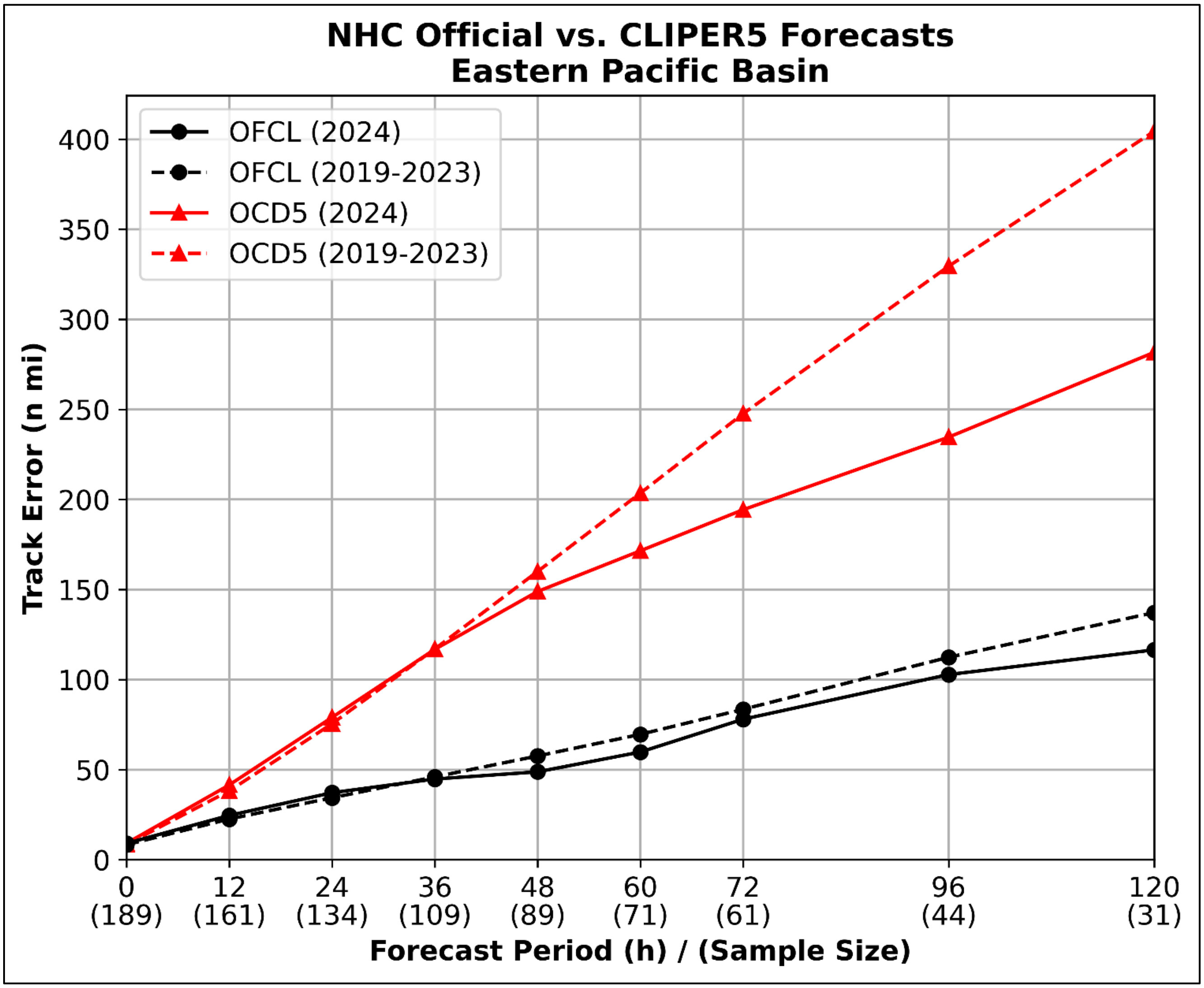


Figure 25. NHC official and CLIPER5 (OCD5) eastern North Pacific basin average track errors for 2024 (solid lines) and 2019–2023 (dashed lines).

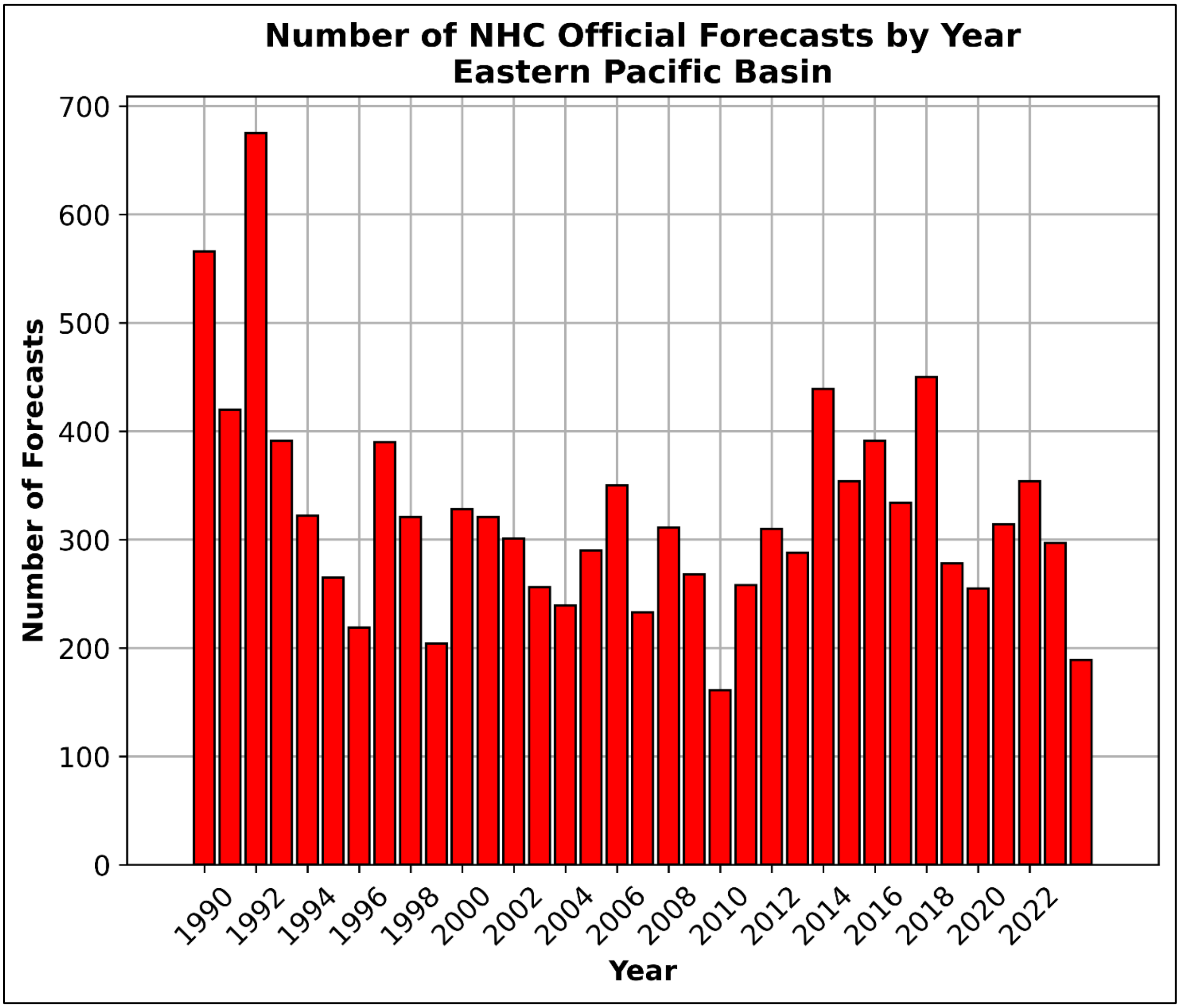
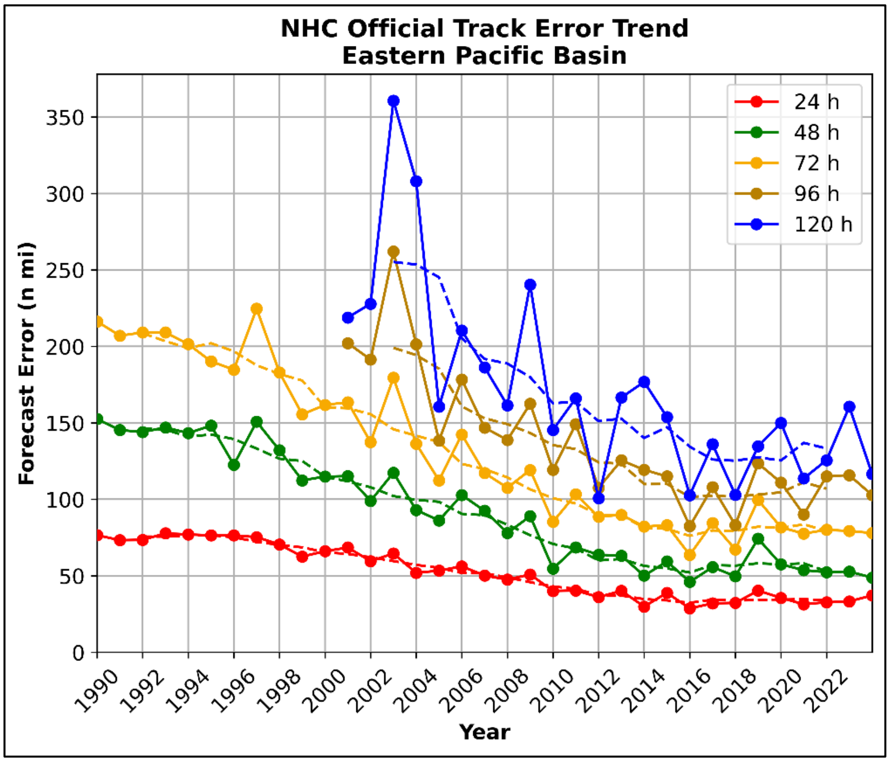


Figure 26. Number of NHC official forecasts for the eastern North Pacific basin stratified by year from 1990–2024.



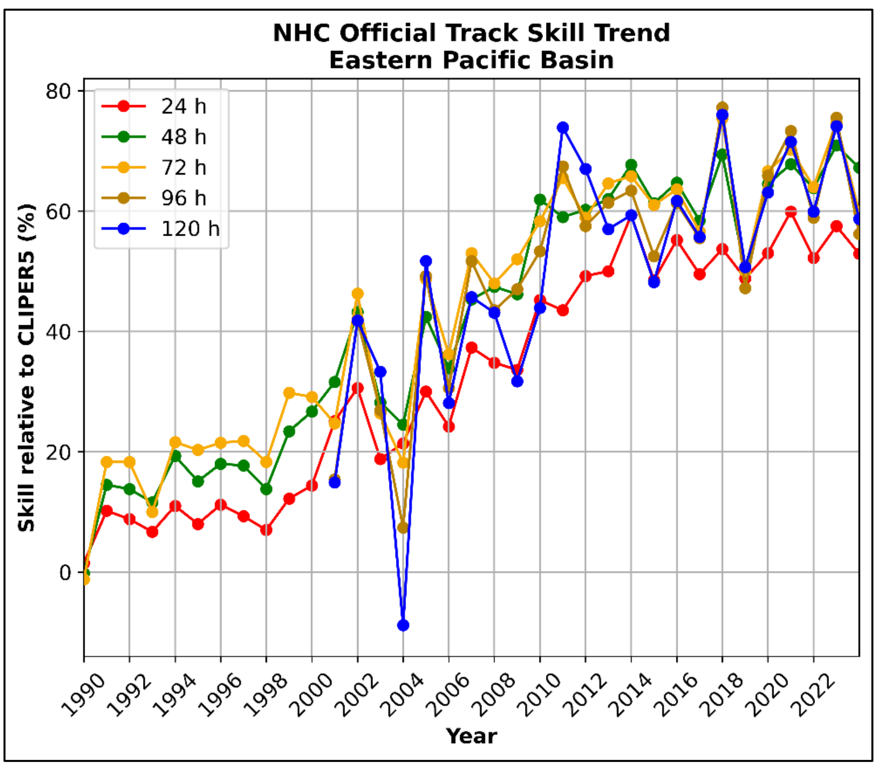


Figure 27. Recent trends in NHC official track forecast error (top) and skill (bottom) for the eastern North Pacific basin. Dashed lines in error trend represent a 5-yr running mean.

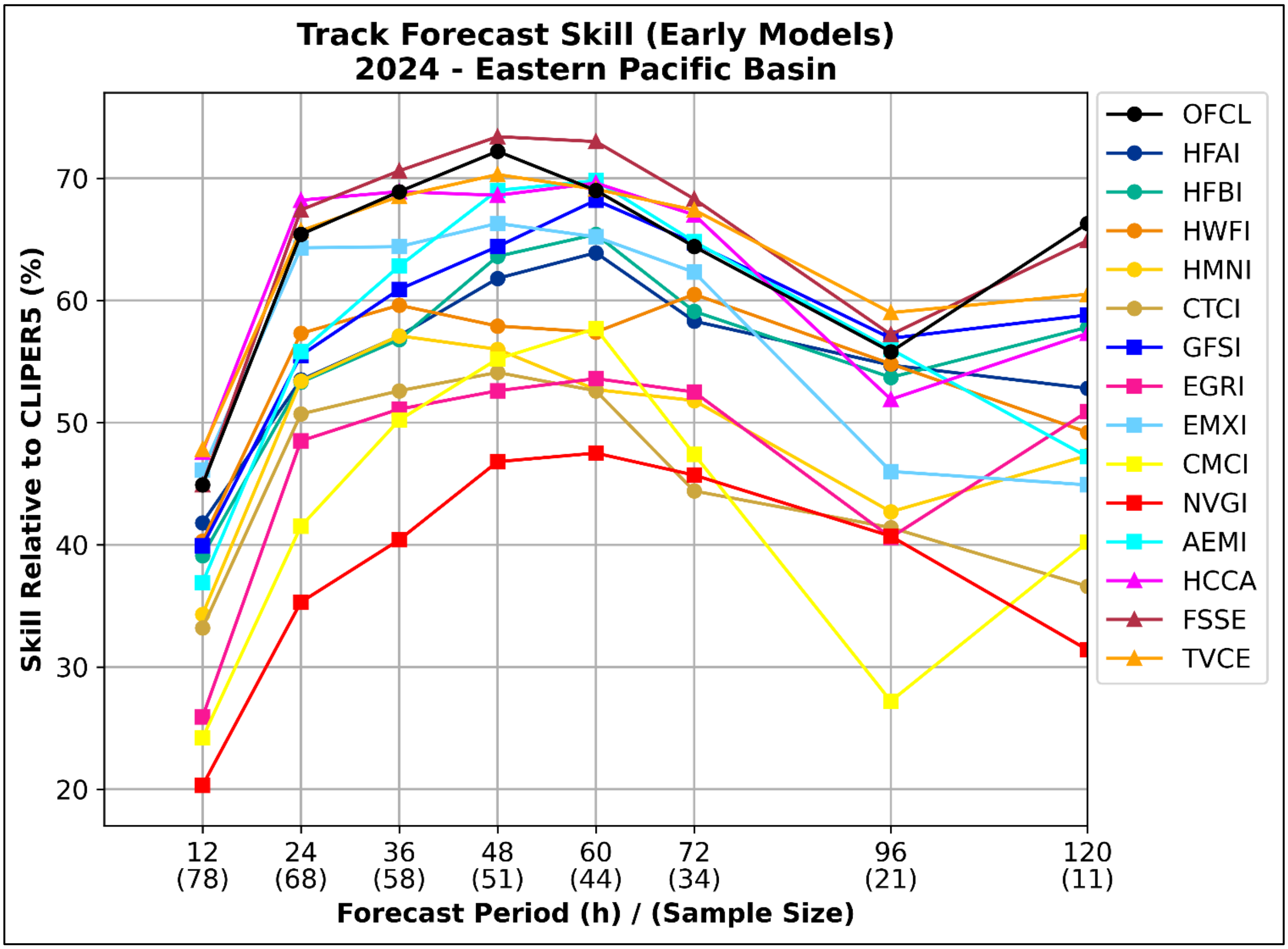


Figure 28. Homogenous comparison for selected eastern North Pacific early track models for 2024. This verification includes only those models that were available at least 2/3 of the time (see text).

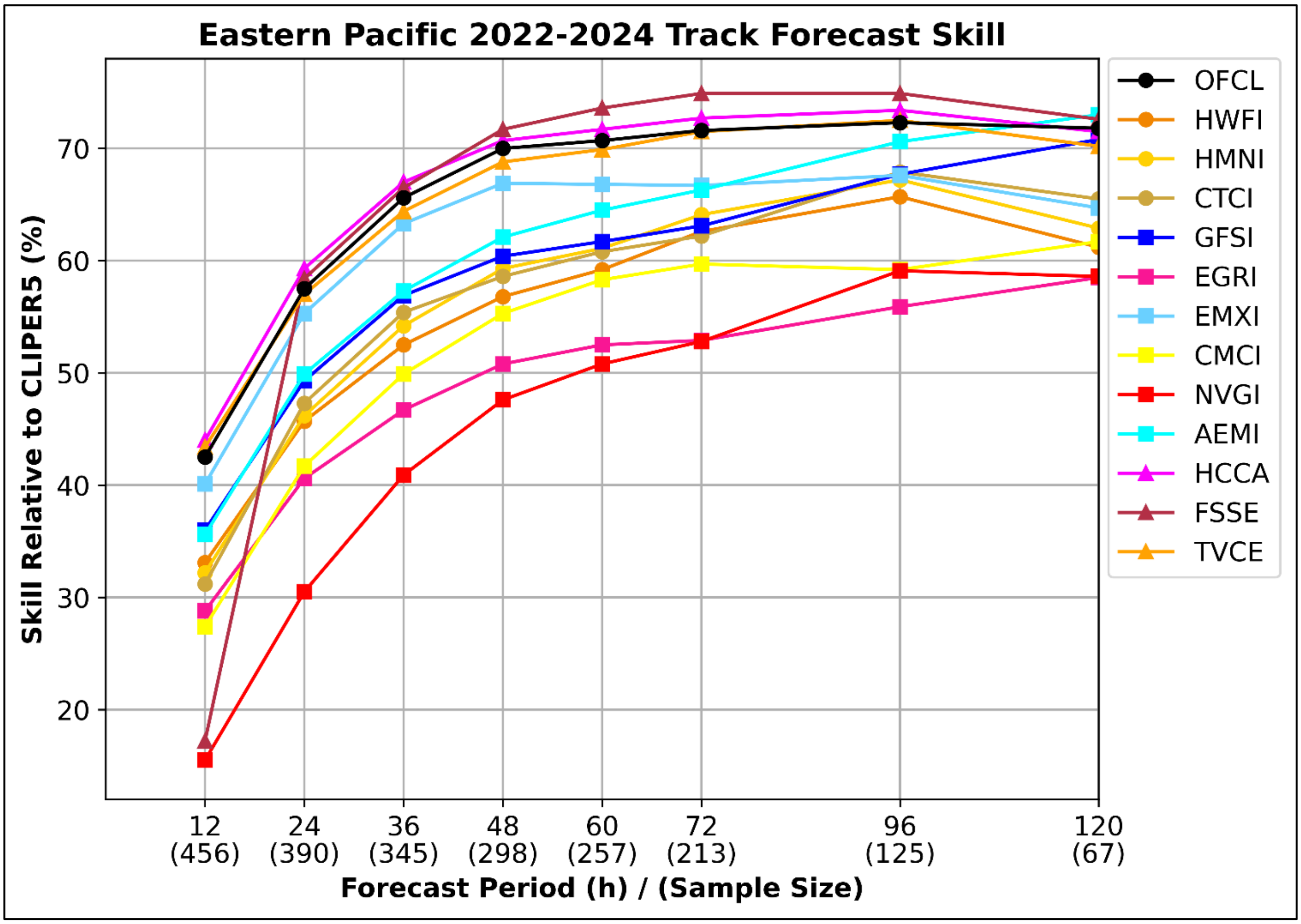


Figure 29. Homogenous comparison of track forecast skill for selected eastern North Pacific basin early models for 2022–2024.

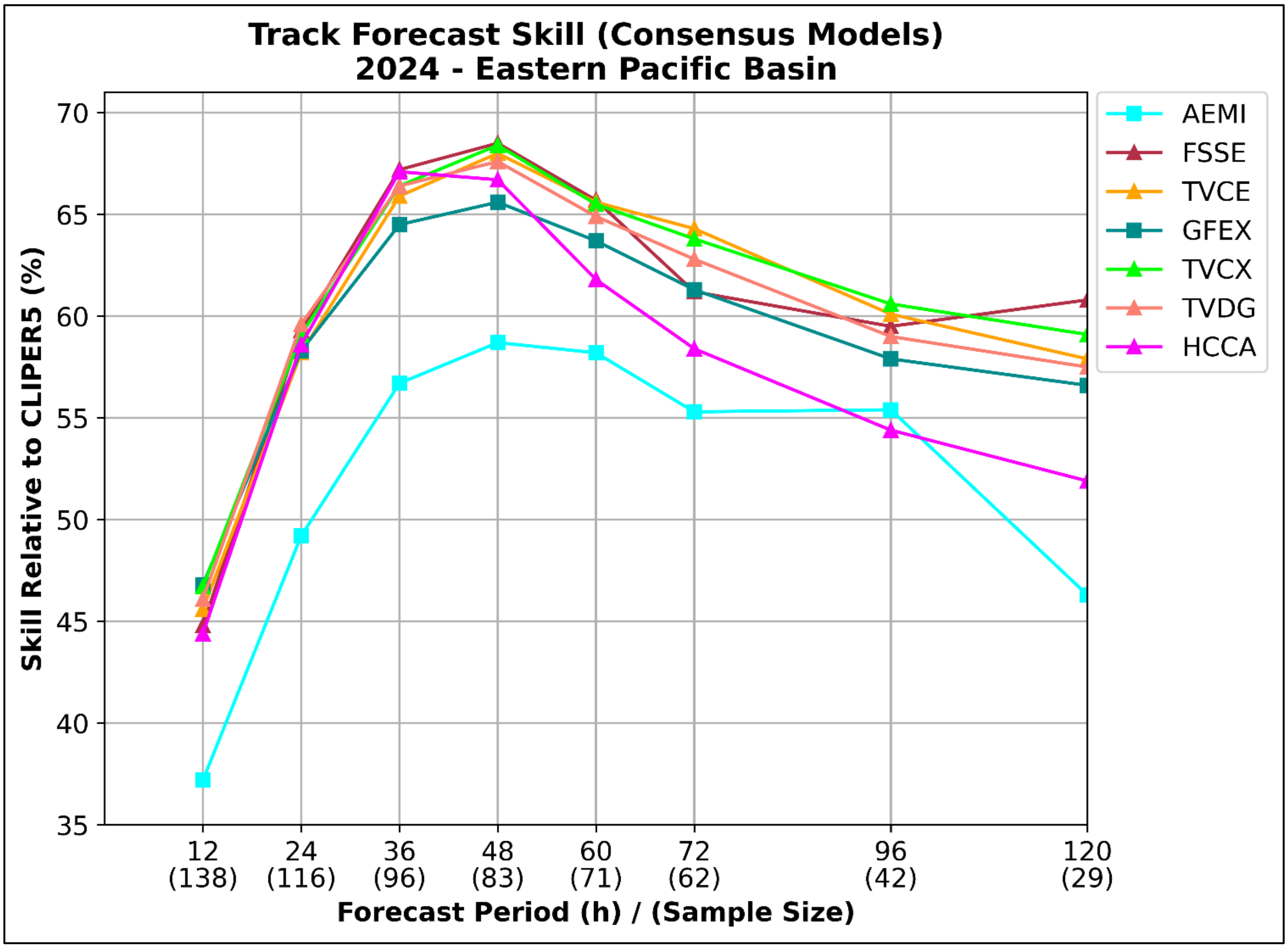
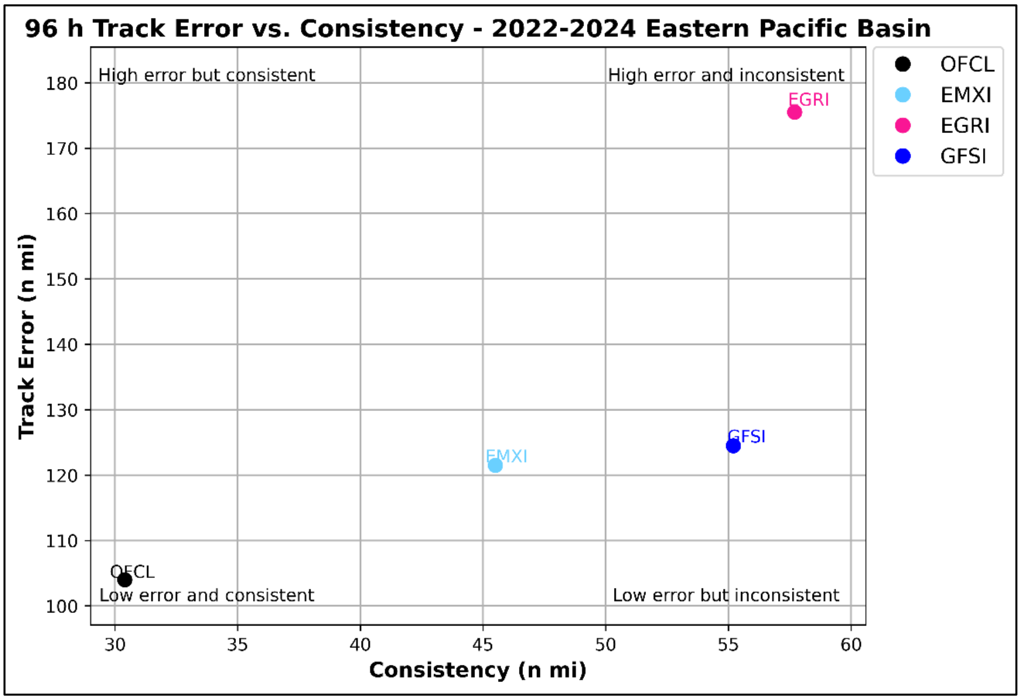


Figure 30. Homogenous comparison of the primary eastern North Pacific basin track consensus models for 2024.



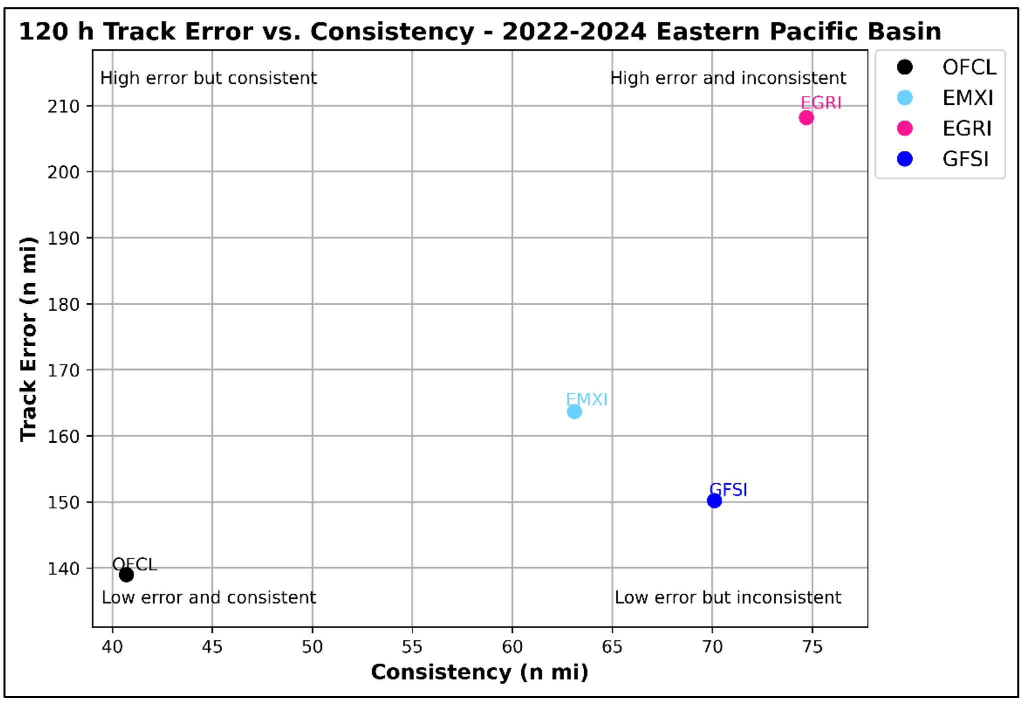


Figure 31. Track error vs. consistency around the 96-h (top) and 120-h (bottom) forecast periods in the East Pacific basin of GFSI, EMXI, EGRI, and OFCL (NHC) from 2022–24.

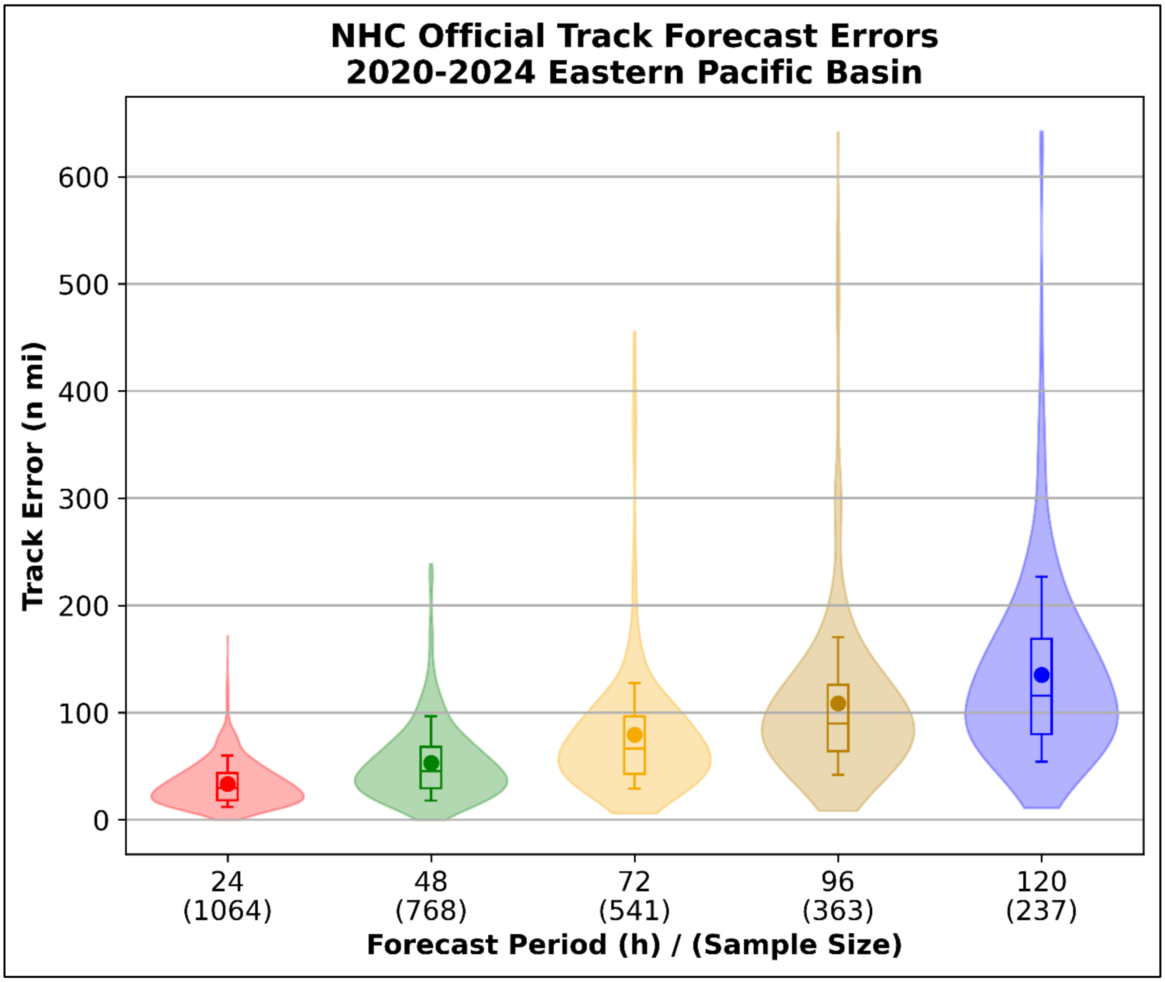


Figure 32. Violin diagram of NHC official track forecasts for the eastern North Pacific basin for 2020–2024. The mean is shown by the colored dot, median by the horizontal line, 25-75th percentiles by the box edges, and 10-90th percentiles by whiskers.

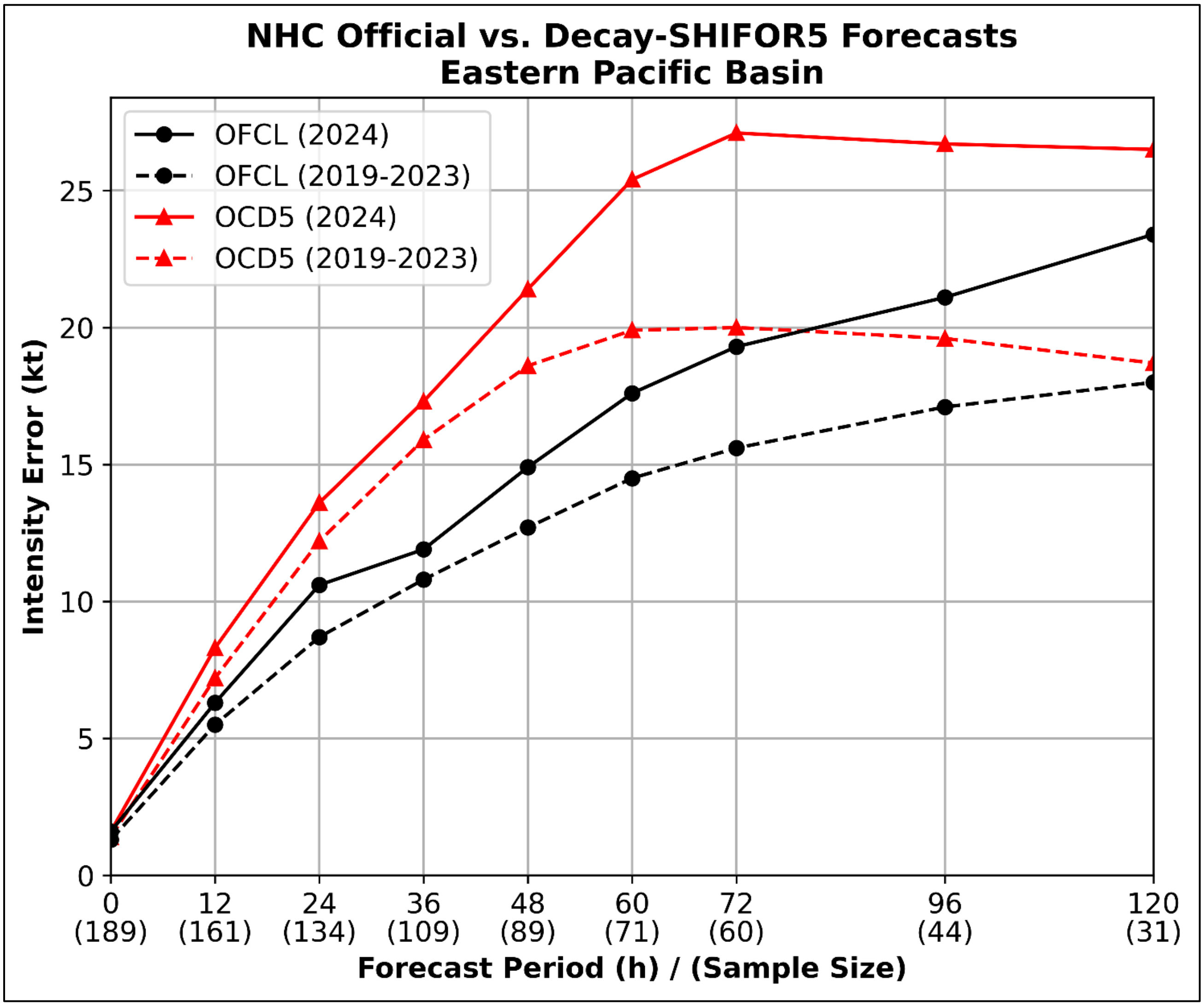
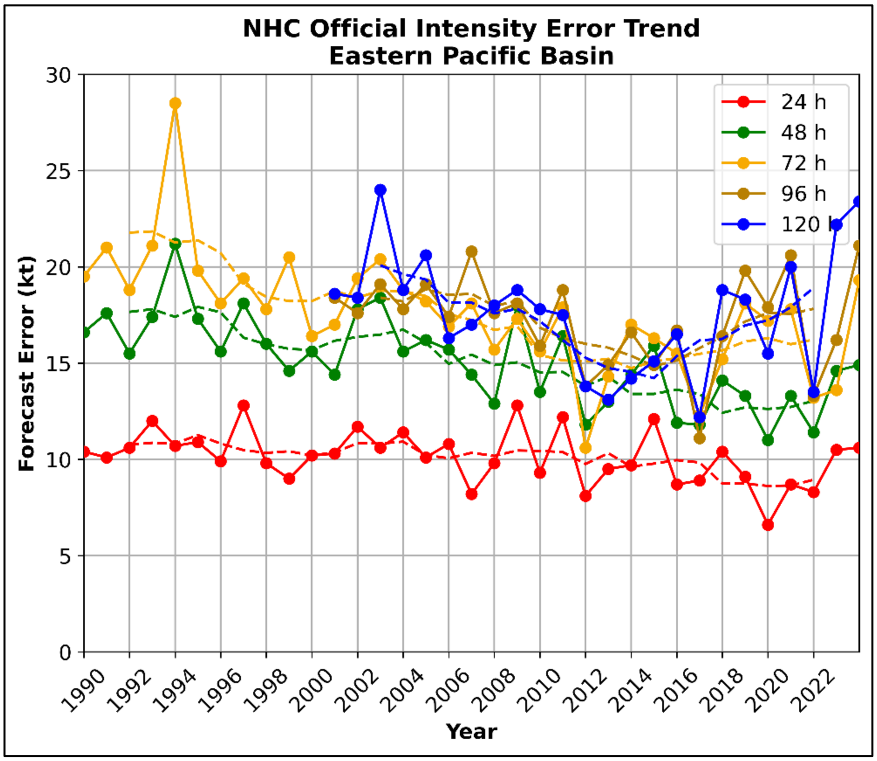


Figure 33. NHC official and Decay-SHIFOR5 (OCD5) eastern North Pacific basin average intensity errors for 2024 (solid lines) and 2019–2023 (dashed lines).



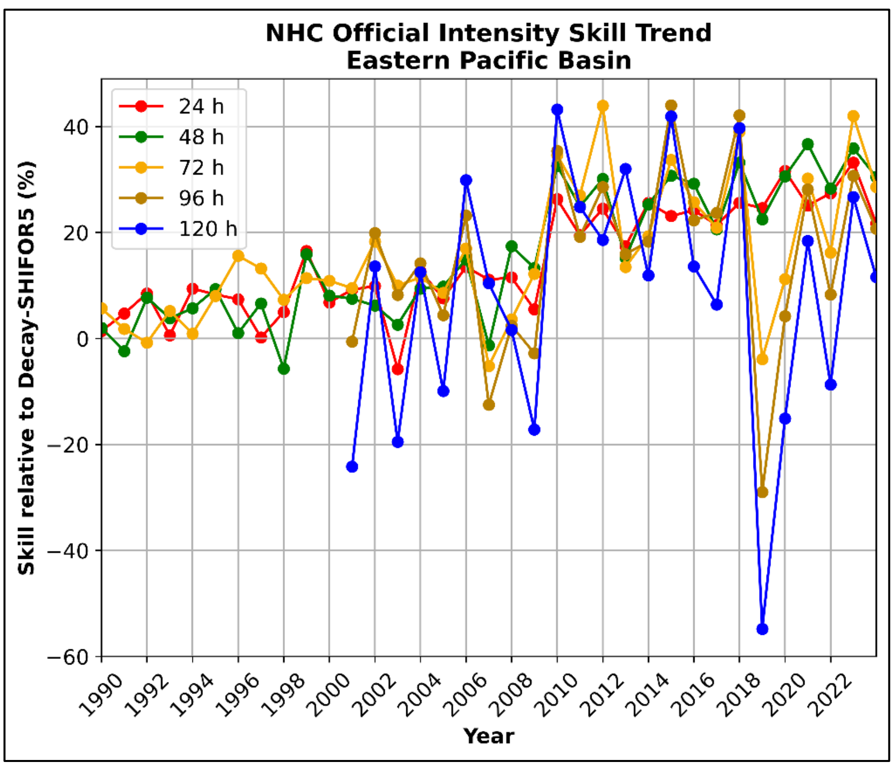


Figure 34. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the eastern North Pacific basin. Dashed lines in error trend represent a 5-yr running mean.

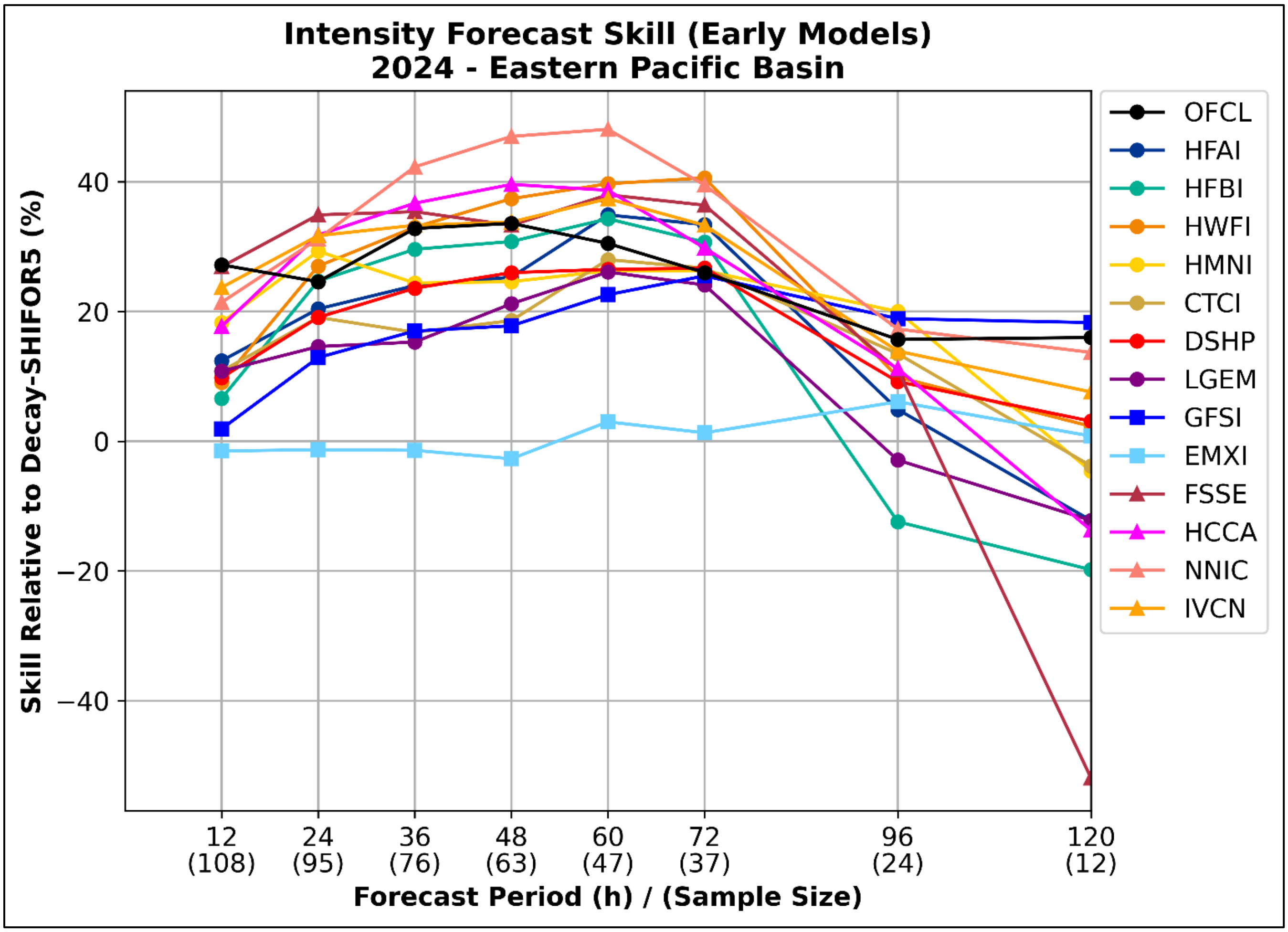


Figure 35. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2024.

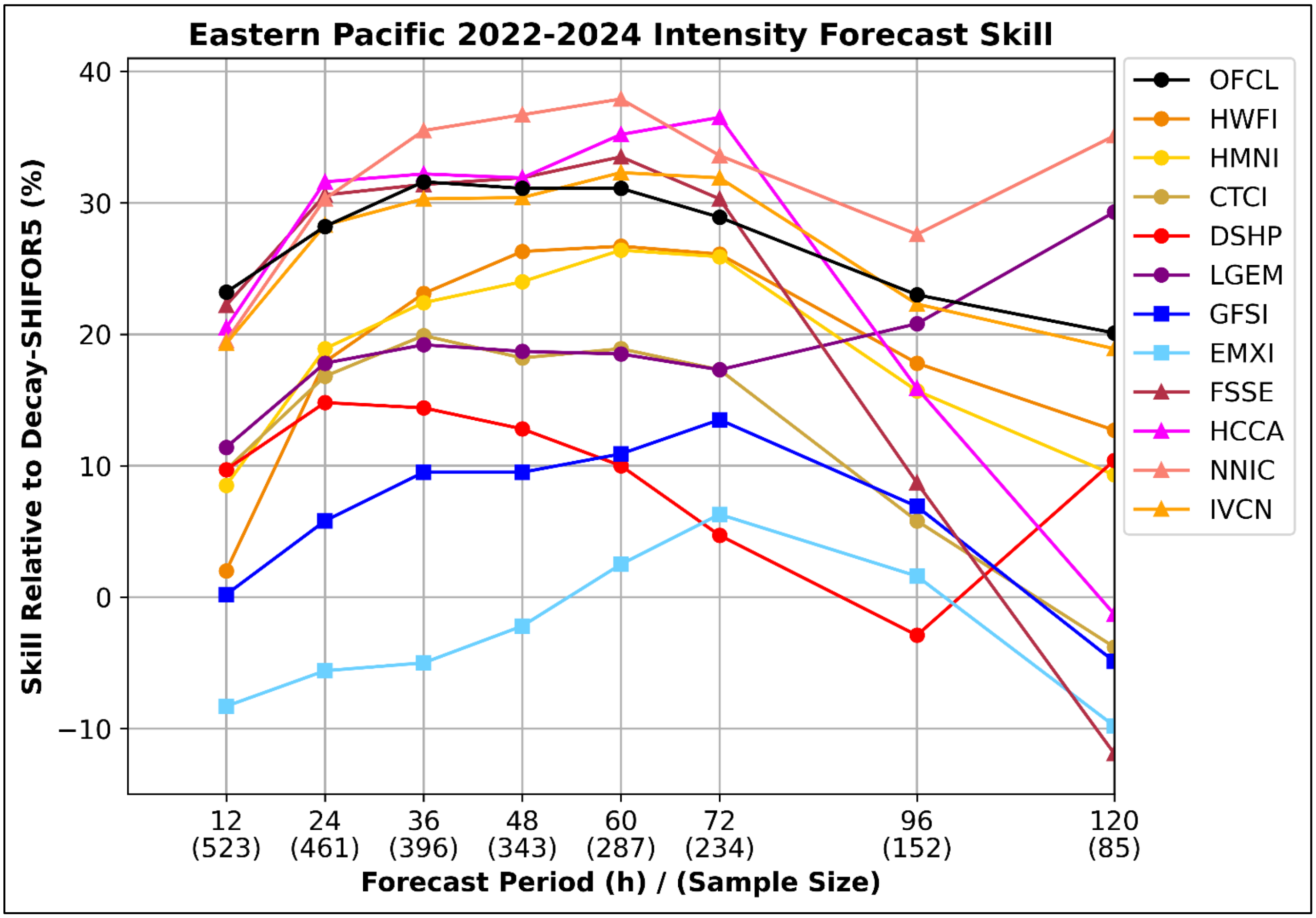


Figure 36. Homogenous comparison of forecast intensity skill for selected eastern North Pacific basin early guidance models for 2022–2024.

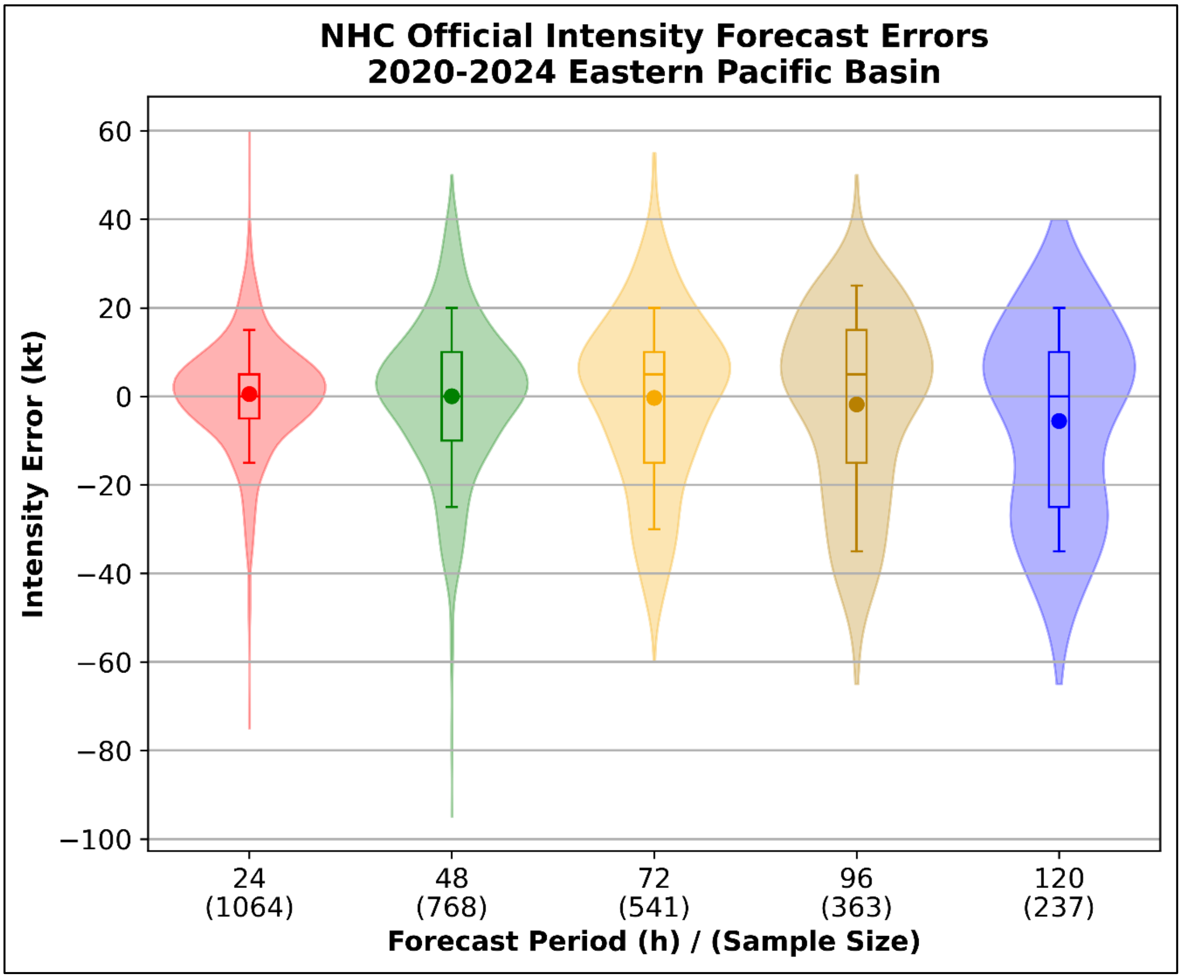


Figure 37. Violin diagram of NHC official intensity forecasts for the eastern North Pacific basin for 2020–2024. The mean is shown by the colored dot, median by the horizontal line, 25-75th percentiles by the box edges, and 10-90th percentiles by whiskers.

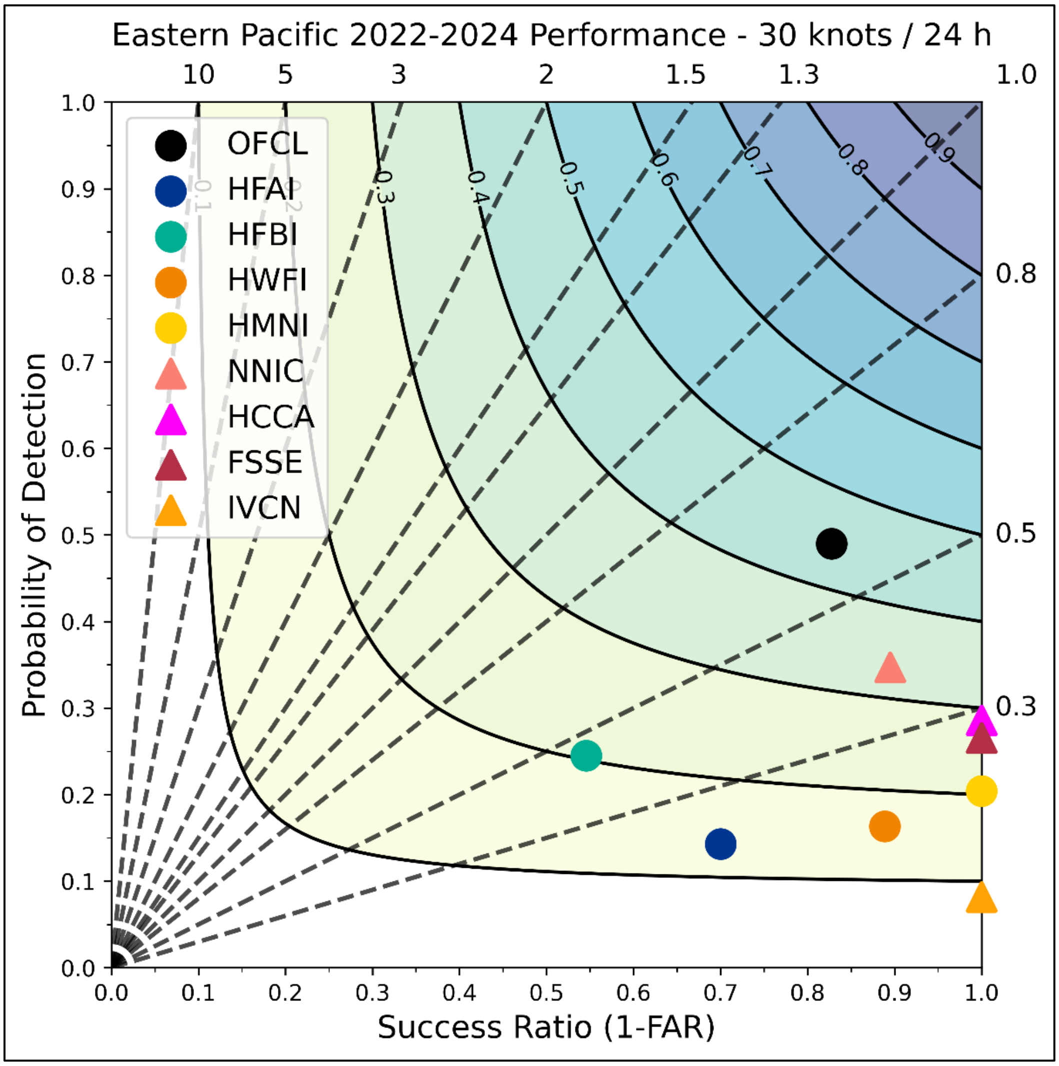
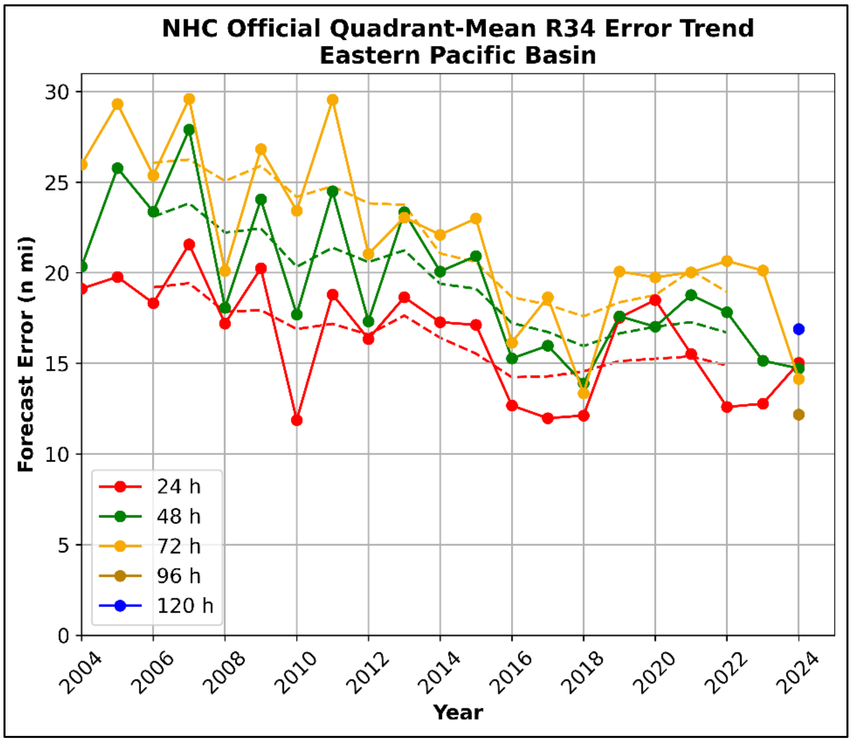


Figure 38. Roebber performance diagram of NHC official forecast and selected early intensity models of rapidly strengthening storms in 2022-24 in the eastern Pacific basin. Probability of detection is given by the ratio of hits to the total number of times the events occurred. False Alarm Ratio (FAR) is given by the ratio of false alarms to the total number of forecast events. Critical success index is shown in shading/solid contours, and the forecast bias is shown by the dashed lines.



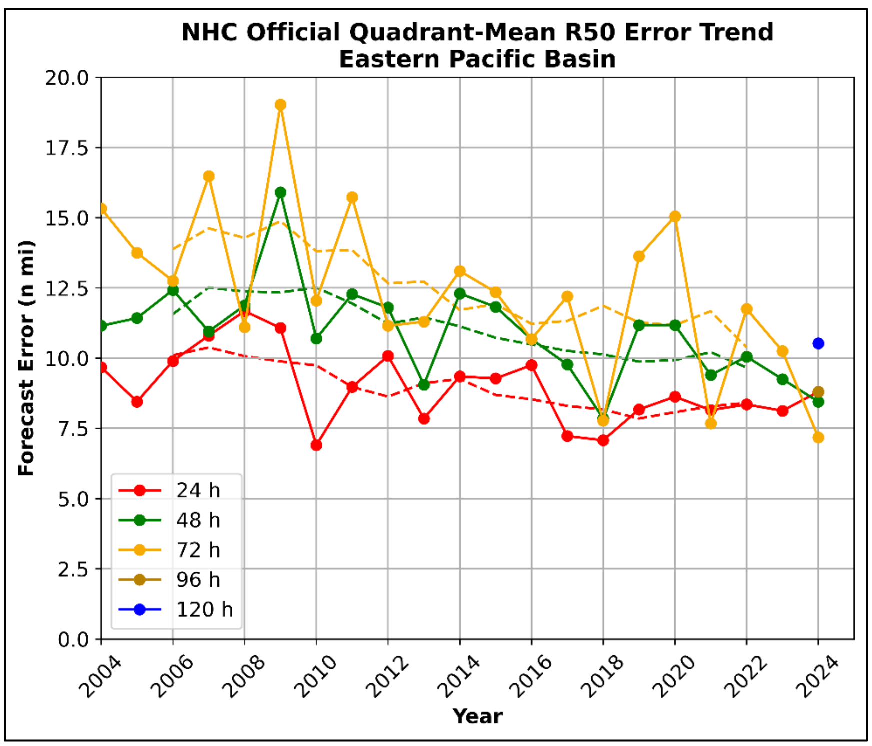


Figure 39. Recent trends in NHC 34- (top) and 50-kt (bottom) wind radii official forecast error for the eastern North Pacific basin. The results represent a quadrant average. Dashed lines represent 5-yr running means.

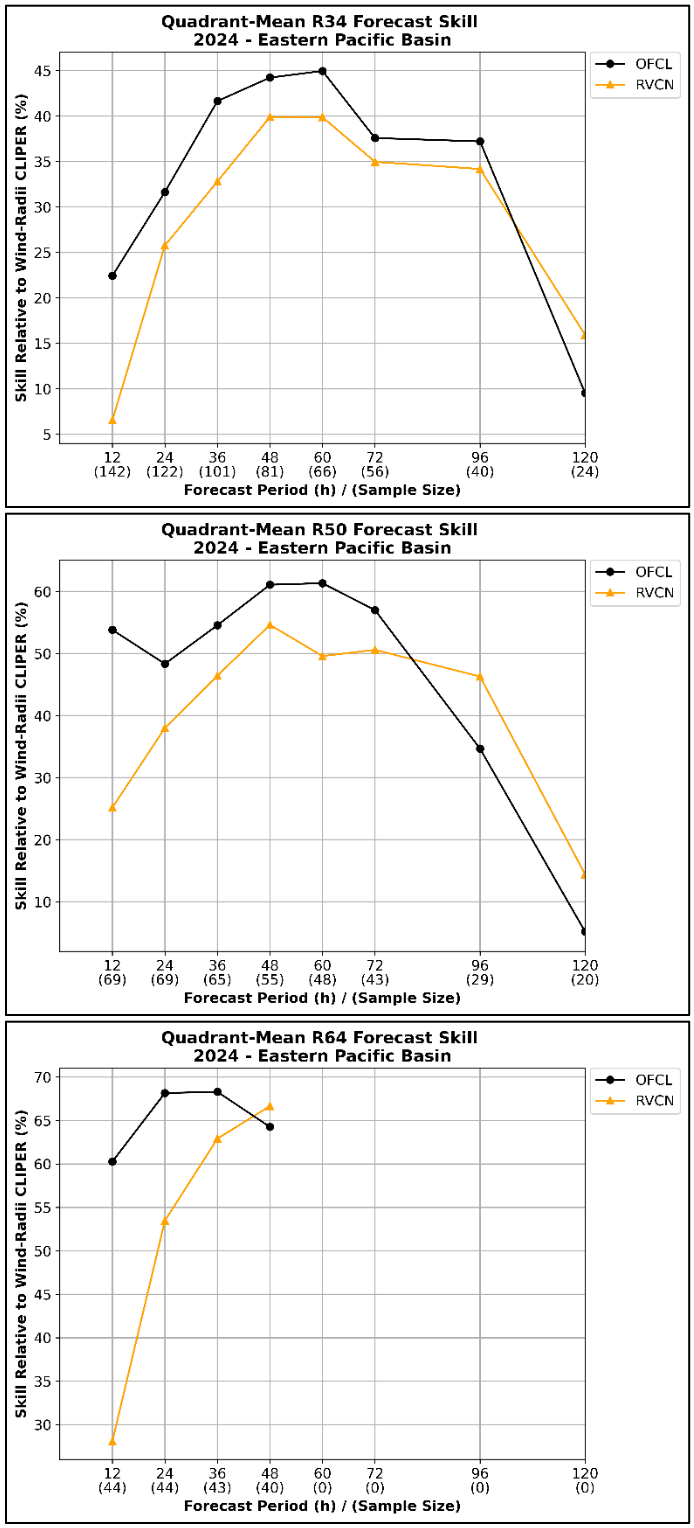


Figure 40. Quadrant-mean skill of NHC and RVCN for the 34-kt (top), 50-kt (middle), and 64-kt (bottom) wind radii forecasts for the eastern North Pacific basin in 2024.

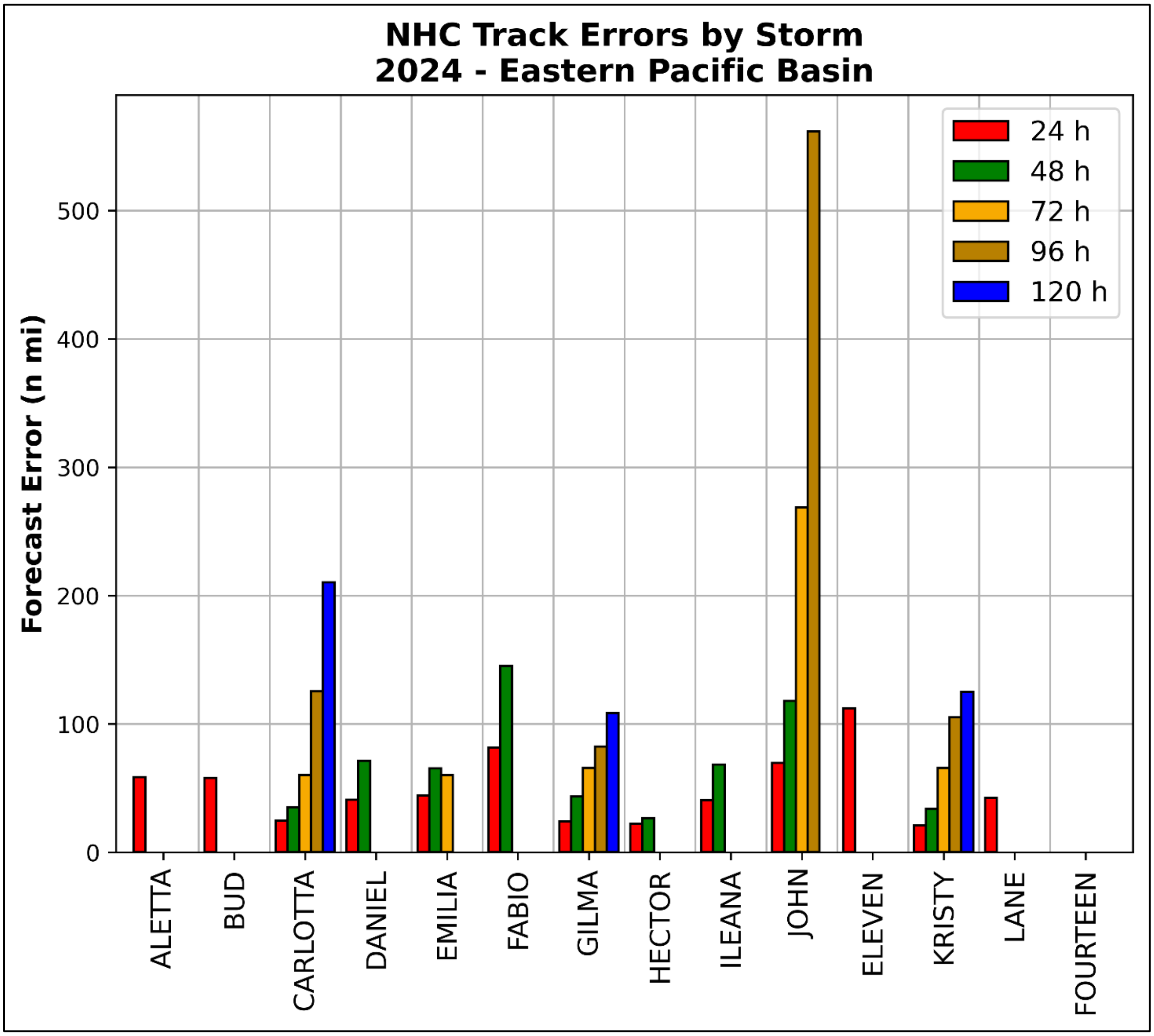


Figure 41. 2024 NHC eastern North Pacific official track errors by tropical cyclone at 24, 48, 72, 96, and 120 h.

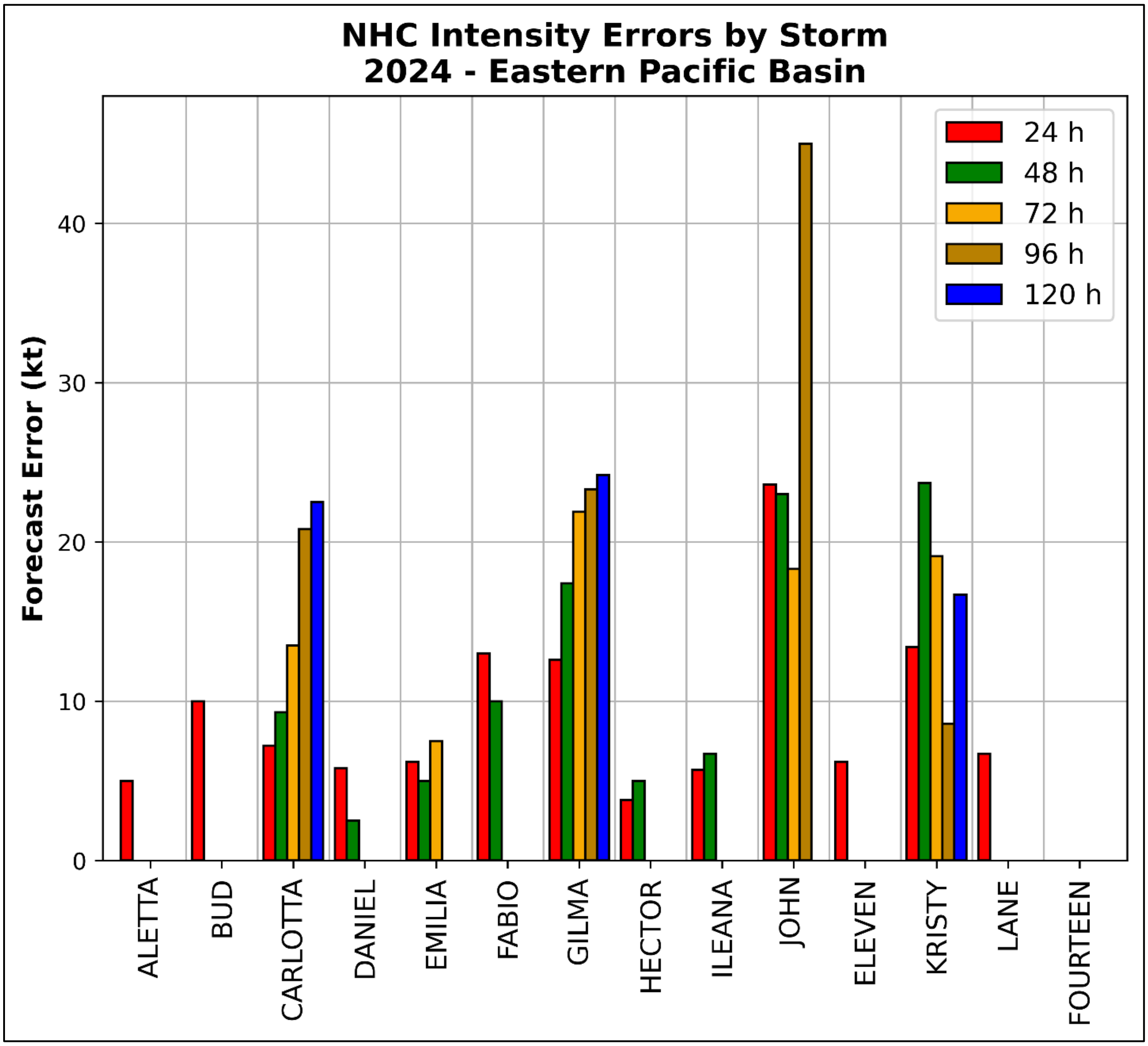
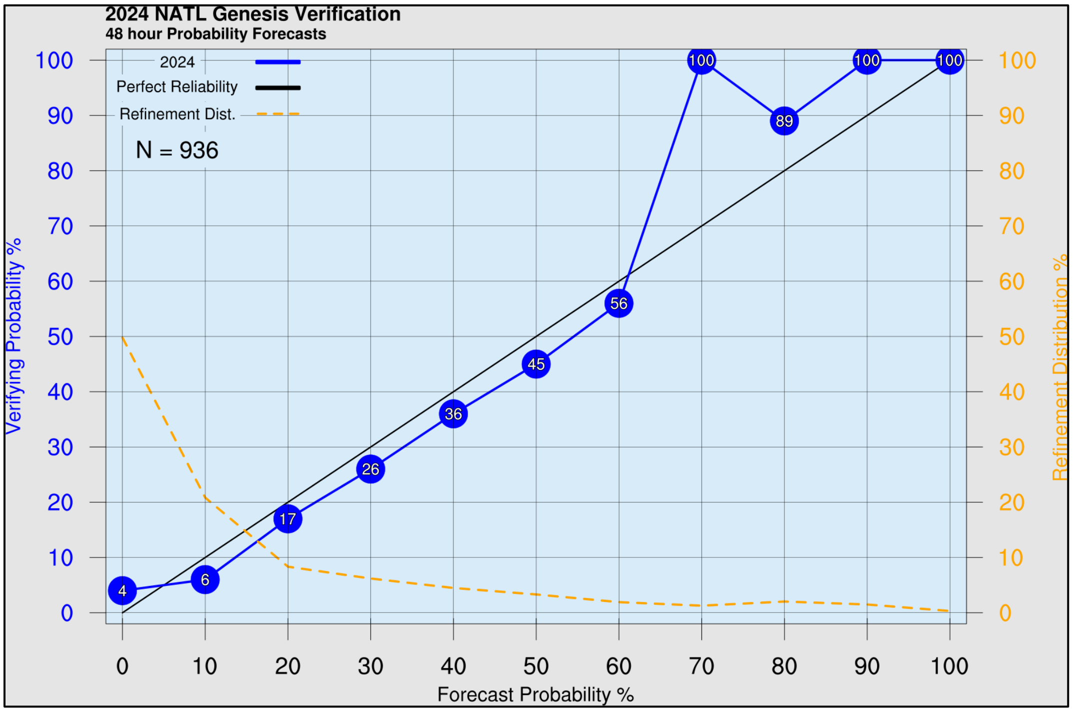


Figure 42. 2024 NHC eastern North Pacific official intensity errors by tropical cyclone at 24, 48, 72, 96, and 120 h.



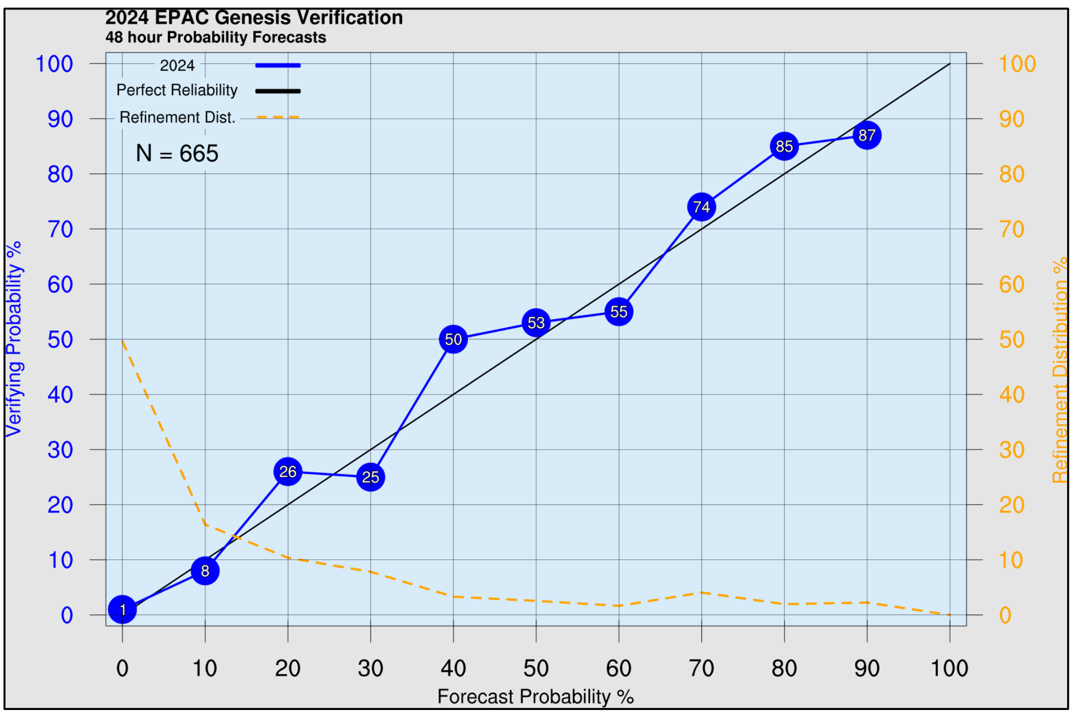
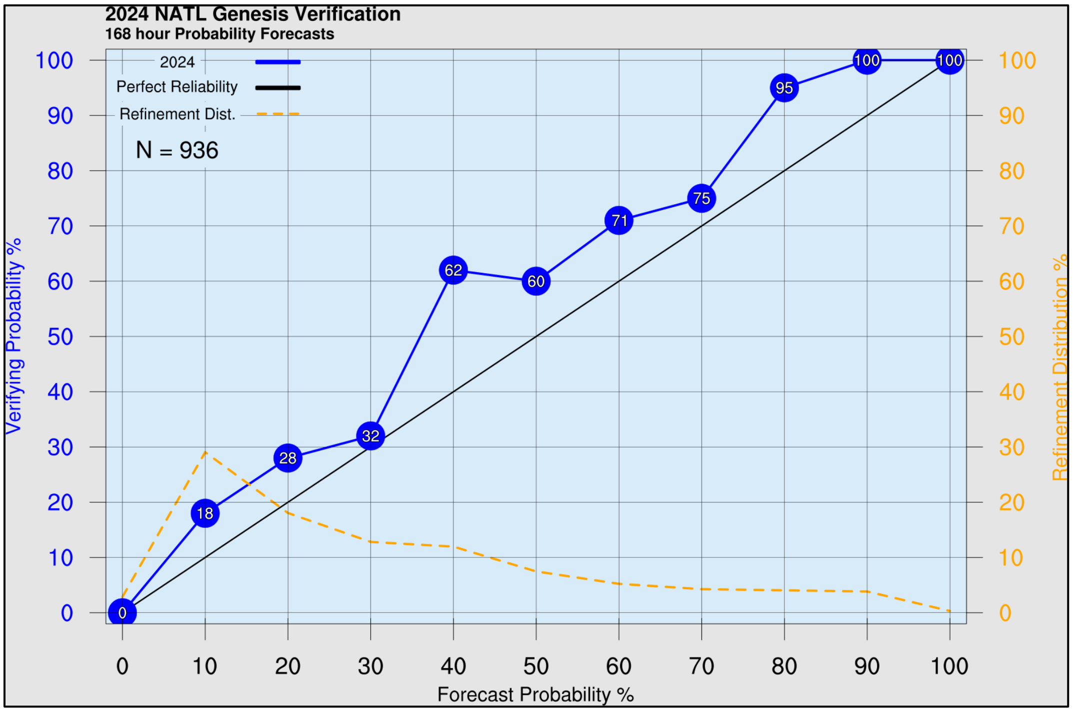


Figure 43. Reliability diagram for Atlantic (top) and eastern North Pacific (bottom) probabilistic tropical cyclogenesis 48-h forecasts for 2024. The lines indicate the relationship between the forecasts and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed line represents how the forecasts were distributed among the possible forecast values.



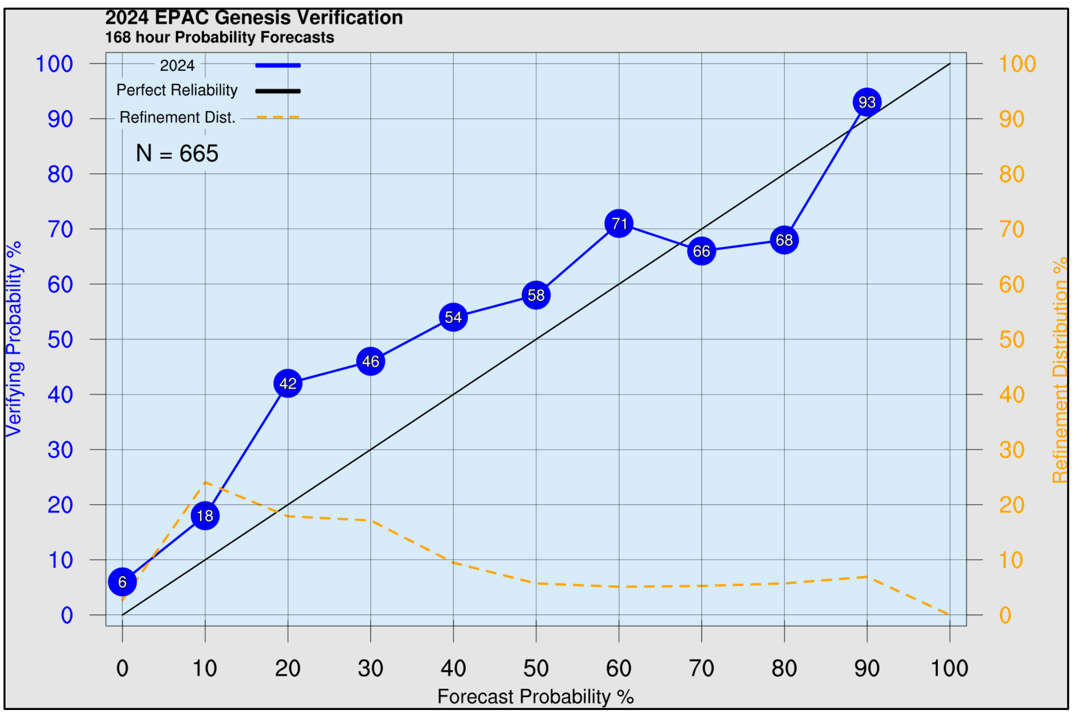
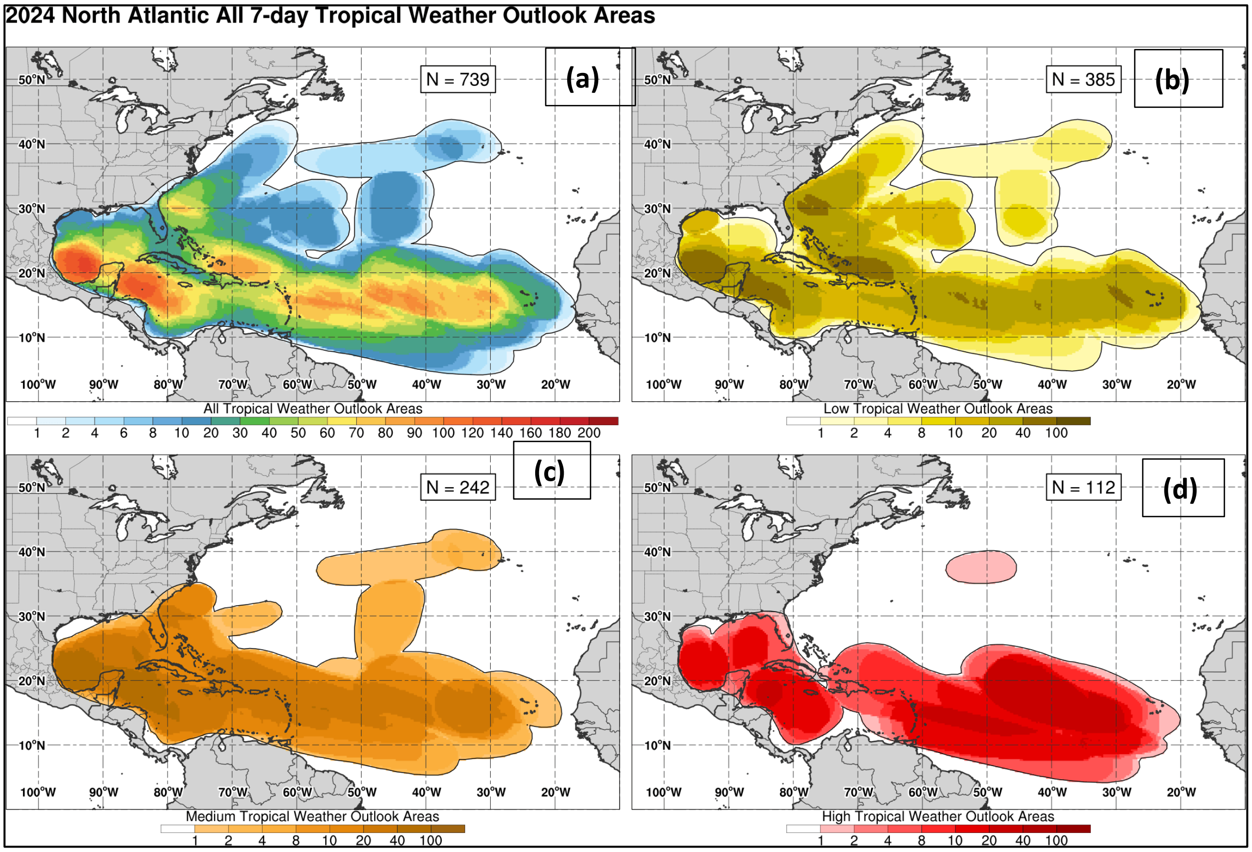


Figure 44. As described for Fig. 43, except for 168-h forecasts.



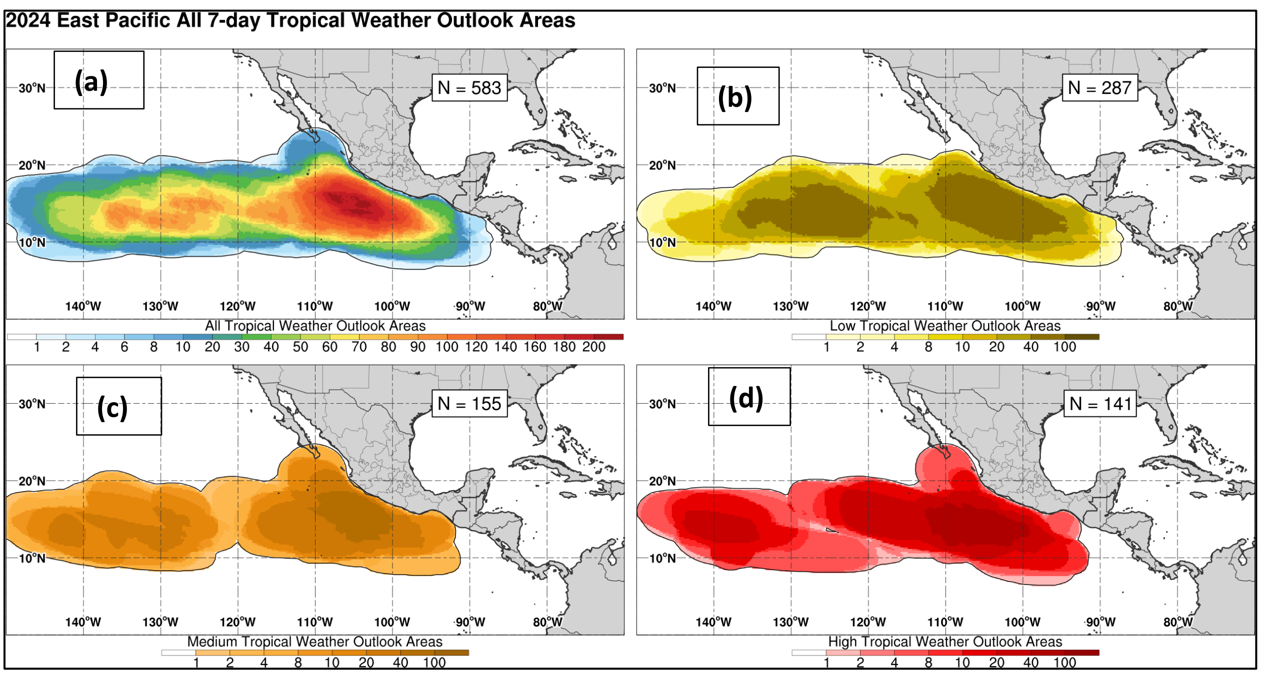


Figure 45. Composites of 7-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks for the Atlantic and East Pacific basins during the 2024 season for (a) all probabilistic genesis categories, (b) low (<40% category), (c) medium (40–60%) category, and (d) high (> 60% category).