NATIONAL HURRICANE CENTER FORECAST VERIFICATION REPORT

2022 HURRICANE SEASON

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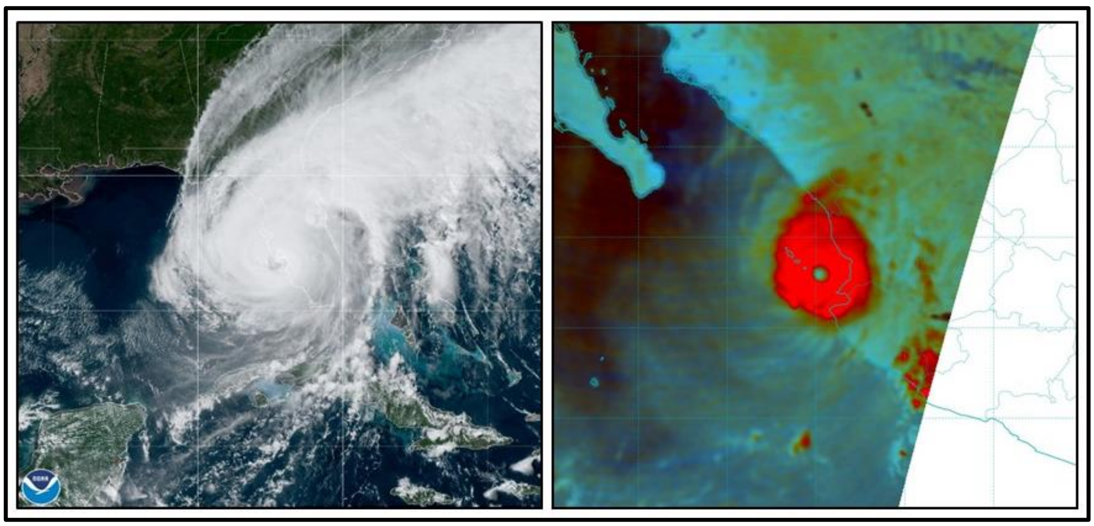

GOES-16 GEOCOLOR IMAGE AT 1920 UTC 28 SEPTEMBER OF HURRICANE IAN JUST BEFORE LANDFALL IN SOUTHWESTERN FLORIDA. CREDIT: NOAA/NESDIS/STAR (LEFT). 89-GHZ AMSR-2 MICROWAVE SATELLITE IMAGE OF HURRICANE ROSLYN AT 0910 UTC 23 OCTOBER, ABOUT TWO HOURS BEFORE IT MADE LANDFALL ALONG THE COAST OF NAYARIT, MEXICO. IMAGE COURTESY OF THE NAVAL RESEARCH LABORATORY (RIGHT).

ABSTRACT

There were 255 official forecasts issued during the 2022 Atlantic hurricane season, which is below the long-term average number of forecasts and the lowest level of tropical cyclone activity since 2015. The mean NHC official track forecast errors in the Atlantic basin were notably below their previous 5-yr means. Records for track accuracy were set at 24, 36, 48, 60, 96, and 120 h in 2022. Track forecast errors have decreased significantly over the long term, but there has been less improvement during the past several years. The official track forecasts were slightly outperformed by the consensus models at most time periods. There was no clear best-performing track model, but GFSI performed well at the short lead times, HMNI best at the middle lead times, and AEMI was superior at long range. EMXI was competitive with the best models while HWFI, CMCI, and NVGI

were less skillful. The Government Performance and Results Act of 1993 (GPRA) track goal was met.

Mean official intensity errors for the Atlantic basin in 2022 were lower than the previous 5-yr means from 12 to 72 h, but higher than the means at 96 and 120 h. Decay-SHIFOR errors in 2022 followed a similar pattern to the official forecasts. The official forecasts beat all of the models at 12 and 24 h, and records for intensity accuracy were set from 12-60 h. 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. Among the guidance, IVCN and HCCA were the best performers. HWFI was the best individual model and HMNI, DSHP, LGEM, and CTCI were also quite skillful. GFSI was competitive with the best models, but EMXI had considerably less skill. The GPRA intensity goal was also met.

There were 354 official forecasts issued in the eastern North Pacific basin in 2022, although only 66 of these verified at 120 h. This level of forecast activity was a little above average. The mean NHC official track forecast errors in the east Pacific basin were a little lower than the previous 5-yr means at the short forecast lead times, but above the means at 96 and 120 h. No records for track accuracy were set in 2022. The official track forecasts were very skillful, but they were outperformed by HCCA at most times. EMXI was an excellent model in this basin and competitive with HCCA. GFSI and AEMI were the next best individual track models in this basin. HWFI, HMNI, CMCI, and EGRI were fair performers, while NVGI lagged behind.

For intensity, the official forecast errors in the eastern North Pacific basin were lower than the previous 5-yr means at all times. Decay-SHIFOR errors were substantially lower than their 5-yr means at the longer lead times, indicating that predicting the intensity of the season's storms at the longer lead times was less challenging than average. No records for intensity accuracy were set in 2022. The official forecasts were close to the IVCN consensus model and were skillful through 96 h. HCCA and HMNI were the best models while DSHP performed poorly.

An evaluation of track performance during the 2020-22 period in the Atlantic basin indicates that HCCA and TVCA were the best models. The official track forecasts for the 3-yr sample had skill that was quite close to the best aids throughout the forecast period. GFSI, AEMI, and EMXI were competitive with one another, but had 5-10% less skill than the consensus models and official forecasts. For intensity in the Atlantic basin, the official forecasts performed quite well and had skill that was comparable to the best guidance, the consensus models. HWFI was generally the best individual model.

A three-year evaluation from 2020-22 in the eastern North Pacific basin indicates that the official track forecasts were very skillful, and had skill levels close to the consensus models. Regarding intensity, the official forecasts during the 3-yr sample performed as good as or better than the consensus aids. HMNI was the best individual model and was competitive with the consensus aids.

Quantitative probabilistic forecasts of tropical cyclogenesis are expressed in 48- and 120-h time frames in 10% increments and in terms of categories ("low", "medium", or "high"). In the Atlantic basin, results from 2022 indicate that the probabilistic forecasts were generally well calibrated at most probabilities, but a high bias was present for the 48-h forecasts. In the eastern

North Pacific basin, a slight low bias existed, especially for the medium and high probabilities, for both the 48- and 120-h forecasts. In 2023, the 120-h forecasts will be replaced with 168-h (7-day) forecasts.

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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]

Forecast intensity 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 and 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're probably less useful for interpreting forecast performance with smaller samples (e.g., for a single storm).

The trajectory-CLIPER (TCLP) model is an alternative to the CLIPER and SHIFOR models for providing baseline track and intensity forecasts (DeMaria, personal communication). The input to TCLP [Julian Day, initial latitude, longitude, maximum wind, and the time tendencies of position and intensity] is the same as for CLIPER/SHIFOR, but rather than using linear regression to predict the future latitude, longitude and maximum wind, a trajectory approach is used. For track,

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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.

a monthly climatology of observed storm motion vectors was developed from a 1982-2011 sample. The TCLP storm track is determined from a trajectory of the climatological motion vectors starting at the initial date and position of the storm. The climatological motion vector is modified by the current storm motion vector, where the influence of the current motion vector decreases with time during the forecast. A similar approach is taken for intensity, except that the intensity tendency is estimated from the logistic growth equation model (LGEM) with climatological input. Similar to track, the climatological intensity tendency is modified by the observed tendency, where the influence decreases with forecast time. The track used for the TCLP intensity forecast is the TCLP track forecast. When the storm track crosses land, the intensity is decreased at a climatological decay rate. A comparison of a 10-yr sample of TCLP errors with those from CLIPER5 and DSHIFOR5 shows that the average track and intensity errors of the two baselines are within 10% of each other at all forecast times out to five days for the Atlantic and eastern North Pacific. One advantage of TCLP over CLIPER5/DSHIFOR5 is that TCLP can be run to any desired forecast time.

NHC also issues forecasts of the size of tropical cyclones; these “wind radii” forecasts are estimates of the maximum extent of winds of various thresholds (34, 50, and 64 kt) expected in each of four quadrants surrounding the cyclone. Unfortunately, there is insufficient surface wind information 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. As a result, post-storm best track wind radii are likely to have errors so large as to render a verification of official radii forecasts unreliable and potentially misleading; consequently, no verifications of NHC wind radii are included in this report. In time, as our ability to measure the surface wind field in tropical cyclones improves, it may be possible to perform a meaningful verification of NHC wind radii forecasts (Cangialosi and Landsea 2016). In addition, there are currently some internal efforts at NHC to review wind radii climatology and verification for a subset of cases and these results will be included in a separate report later this year.

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.[9]

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 other 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 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[10] on 21 March 2023 for the Atlantic basin, and on 24 March 2023 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 2022 verification and previews anticipated changes for 2023.

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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".

9 The UKM and EMX models are only available through 120 h twice a day (at 0000 and 1200 UTC). Consequently, roughly half the interpolated forecasts from these models are 12 h old.

10 In ATCF lingo, these are known as the "a decks" and "b decks", respectively.

2. Atlantic Basin

a. 2022 season overview – Track

Figure 1 and Table 2 present the results of the NHC official track forecast verification for the 2022 season, along with results averaged for the previous 5-yr period, 2017-2021. In 2022, the NHC issued 255 Atlantic basin tropical cyclone forecasts[11], a number notably below the long term mean (325) and the lowest number of forecasts issued since 2015 (Fig. 2). Mean track errors ranged from 21 n mi at 12 h to 126 n mi at 120 h. The mean official track forecast errors in 2022 were below the 5-yr means at all times, and up to 27% smaller at 120 h. The CLIPER errors for 2022 were similar to their 5-yr means from 12 to 72 h, but lower than their long-term means at 96 and 120 h, indicating that the track of the season's storms were less challenging than normal to predict at long range. Records for track accuracy were set at 24, 36, 48, 60, 96, and 120 h, and records were only missed by a fraction of 1 n mi at 12 and 72 h. The official track forecast vector biases were small and northwestward at the short lead times, but more notably southwestward at 96 and 120 h (i.e., the official forecast tended to fall to the southwest of the verifying position). Track forecast skill ranged from 54% at 12 h to 76% at 60 h (Table 2). The track errors have decreased slightly at all forecast times over the past couple of years, and over the past few decades, the 24−72-h track forecast errors have been reduced drastically by about 75% (Fig. 3a). Track forecast error reductions of about 60% 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 gradual increase in skill over the long term (Fig. 3b). Although the long-term trends are quite well established, the improvements in track error and skill have slowed some during the past several years. Figure 4 indicates that on average the NHC track errors decrease as the initial intensity of a cyclone increases, and that relationship holds true through most of the 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.

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

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

Table 3a presents a homogeneous[12] verification for the official forecast along with a selection of early models for 2022. 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 5. The figure shows that the official forecasts were highly skillful, and near the best models throughout the forecast period. The best models were the consensus aids HCCA and TVCA, with HCCA having the highest skill at all times, except 120 h. Among the individual models, there was no clear best performer. GFSI was a good model at the early lead times and the best individual model at 12 and 24 h, but its skill trailed other models after that time. EMXI was a good performer overall, and the best model at 36 h. HMNI had superior skill to all of the individual models from 48 to 96 h, and AEMI was the best model at 120 h. HWFI was less skillful than the aforementioned models and CMCI and NVGI were not competitive in 2022. An evaluation over the three years 2020-22 (Fig. 6) indicates that HCCA and TVCA were also the best models for this sample, and the official forecasts had about the same skill levels as those models throughout the forecast period. GFSI, EMXI, and AEMI all had about the same levels of skill as each other and were the best performing individual models, but they had 5-10% lower skill than the consensus aids. EGRI and HWFI were a little less skillful.

Vector biases of the guidance models for 2022 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 longer forecast times. EMXI had a more significant south-southwest bias at 96 and 120 h, while GFSI had a smaller east bias at those forecast times. Figure 7 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 forecast time period. It can be seen that for the 2020-22 sample the official forecasts had lower error and were more consistent than GFSI, EMXI, and EGRI.

A separate homogeneous verification of the primary consensus models for 2022 is shown in Figure 8. The figure shows that HCCA was the most skillful model overall, but TVCA, TVDG, TVCX, and GFEX had only slightly less skill. FSSE had similar skill levels to the best aids early, but trailed some after 48 h. AEMI was notably less skillful through 96 h, but its skill levels were not far off from the best aids at 120 h.

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 2022, the GPRA goal was 55 n mi, and the verification for this measure was met at 52.5 n mi.

b. 2022 season overview – Intensity

Figure 9 and Table 4 present the results of the NHC official intensity forecast verification for the 2022 season, along with results averaged for the preceding 5-yr period. Mean forecast errors in 2022 ranged from 5 kt at 12 h to 21 kt at 120 h. These errors were 11-24% lower than the previous 5-yr means from 12 to 72 h, but the errors were considerably higher than the 5-yr means at 96 and 120 h. Intensity forecast skill ranged from 28% at 12 h to 59% at 72 h. Records

[12] 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.

for accuracy were set for the 12-60 h forecast periods in 2022. The official forecasts had little bias from 12 to 60 h, but a low bias existed from 72 to 120 h. The Decay-SHIFOR5 errors exhibited a somewhat similar pattern to the official forecasts, with the errors being up to 16% lower than their 5-yr means for the short lead times, but considerably higher than their means at 96 and 120 h. Figure 10 indicates that the NHC official intensity errors decreased at the 24-, 48-, and 72-h forecast times during the couple of years, but there was a notable increase in error at 96 and 120 h. Over the long-term, despite year-to-year variability, there has been a considerable decrease in error that began around 2010. It appears that the intensity predictions are gradually improving as the forecasts are generally more skillful in the past 10 years or so than they were in the 1990s and the first decade of the 2000s (Cangialosi et. al 2020), and progress has also been made in predicting rapid intensification (DeMaria et. al 2021).

Table 5a presents a homogeneous verification for the official forecasts and the primary early intensity models for 2022. Intensity biases are given in Table 5b, and forecast skill is presented in Figure 11. The official forecasts were quite skillful, and they beat all of the models at 12 and 24 h. The consensus models IVCN and HCCA were the best aids overall and outperformed the official forecasts at the other time periods. Among the individual models, HWFI was the best model and it had equal or higher skill than the official forecasts and the consensus aids from 60-120 h. HMNI was generally the next best model, but its skill trailed at the longer lead times. DSHP, LGEM, and CTCI were fair performers and were somewhat competitive with the best aids. GFSI was also competitive with the standard intensity models, and there has been a substantial improvement in its performance for intensity during the past few years. Conversely, EMXI had little to no skill through the forecast period. An inspection of the intensity biases (Table 5b) indicates that most of the models had low biases, especially at the longer lead times. HWFI had the least bias overall, while GFSI and EMXI had large low biases.

An evaluation over the three years 2020-22 (Fig. 12) indicates that the official forecasts have been consistently performing quite well, and had skill values close to the best aids IVCN and HCCA. For this sample, HWFI was the best individual model at most forecast times. HMNI, DSHP, and LGEM were fair performers, but they were generally not as skillful as HWFI. GFSI had skill throughout the forecast period, and was somewhat competitive with the best models. EMXI was only skillful from 48 to 96 h and was not competitive with the remainder of the guidance.

The 48-h official intensity error, evaluated for all tropical cyclones, is another GPRA measure for NHC. In 2022, the GPRA goal was 10 kt and the verification for this measure was met at 7.9 kt.

c. Verifications for individual storms

Forecast verifications for individual storms are given in Table 6. Of note are the large track errors for Tropical Storm Gaston near the Azores and Tropical Storm Karl in the southwestern Gulf of Mexico, especially at the longer forecast lead times. In both cases, the steering flows were quite weak, resulting in those storms stalling or meandering for a period of time, which proved challenging to predict. Conversely, the official track forecast errors were quite low for Hurricanes Danielle and Fiona, and were well below NHC's 5-yr means. The track forecasts for Ian were near the 5-yr means. Figure 13 shows an illustration of the official track errors stratified by storm.

With regards to intensity, Hurricane Fiona was the most challenging cyclone to predict and NHC had particularly large intensity errors at 96 and 120 h for a sizeable number of forecasts. In fact, these errors had a significant influence on the 2022 seasonal verification given that Fiona was one of the longer-lived tropical cyclones of the year. Conversely, excellent intensity forecasts were issued for Hurricanes Julia and Lisa, which both made landfall in Central America. Figure 14 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=2022&basin=atl.

3. Eastern North Pacific Basin

a. 2022 season overview – Track

The NHC track forecast verification for the 2022 season in the eastern North Pacific, along with results averaged for the previous 5-yr period, is presented in Figure 15 and Table 7. There were 354 forecasts issued for the eastern Pacific basin in 2022, which is slightly above the long-term mean of about 330 forecasts (Fig. 16). Since most of the tropical cyclones in the basin were short-lived, only 66 of the forecasts verified at 120 h. Mean track errors ranged from 21 n mi at 12 h to 126 n mi at 120 h. These errors were a little lower than the 5-yr means from 12 to 60 h, but higher than the means at 96 and 120 h. The CLIPER errors were lower than their 5-yr means at all forecast times, indicating that the tracks of the season's storms were a little less challenging to predict than normal. No records for accuracy were set for track in this basin in 2022. The official track forecast vector biases were small through 48 h, but a more notable east-southeast bias existed from 60 to 120 h.

Figure 17 shows recent trends in track forecast accuracy and skill for the eastern North Pacific. Track errors were steady or slightly increased at all forecast times over the past couple of years, but over the long term, track errors have been dramatically reduced by about 70% for the 24 to 72 h forecasts since 1990. It should be noted, however, that like in the Atlantic basin there has been a slower rate of improvement during the past five years or so. At the 96- and 120-h forecast times, errors have dropped by about 60% since 2001, but the error trends have been flatter during the past few years. Forecast skill has been relatively steady for the past several years.

Table 8a presents a homogeneous verification for the official forecast and the early track models for 2022, with vector biases of the guidance models given in Table 8b. Skill comparisons of selected models are shown in Fig. 18. The official forecasts were very skillful and near the best models. HCCA was the best aid overall, and it beat the official forecasts at all times, except 36 h. EMXI was outstanding in this basin, with skill levels close to the official forecasts and HCCA, and EMXI was the best overall model at 120 h. TVCE was competitive, but not as good as HCCA and EMXI. AEMI was the next best model, but its skill was about 10-15% lower than the best aids. GFSI, CTCI, and CMCI were fair performers, while HWFI and NVGI trailed. An evaluation of the three years 2020-22 (Fig. 19) indicates that the official forecasts were very skillful, and they were near the performance of the consensus models. HCCA, TVCE, and FSSE slightly bested the official forecasts in the short term, but they had equal or slightly less skill than the official forecasts at the long lead times. Regarding the individual models, EMXI was the best performer at all forecast times, with AEMI not too far behind at the longer lead times. GFSI was next best, followed by HWFI, HMNI, CMCI, and EGRI. The official forecasts had similar biases to HCCA at most forecast times. HWFI and HMNI had very large southwest biases at 96 and 120 h, and GFSI and AEMI had notable east-southeast biases at the long-range forecast times. EMXI had the lowest biases among the models.

A separate verification of the primary consensus aids is given in Figure 21. The skill of the consensus models was tightly clustered, but HCCA was generally the best model. AEMI was less skillful (about 5-10% lower skill) than the highest performers, except at 120 h where its skill was comparable to the best aids.

b. 2022 season overview – Intensity

Figure 21 and Table 9 present the results of the NHC eastern North Pacific intensity forecast verification for the 2022 season, along with results averaged for the preceding 5-yr period. Mean forecast errors were 5 kt at 12 h and increased to 14 kt at 120 h. The errors were lower than the previous 5-yr means at all times, and up to 21% lower that the means at 60 and 120 h. The Decay-SHIFOR forecast errors were also lower than their 5-yr means and considerably so at 72-120 h. No records for accuracy were set in 2022. A review of error and skill trends (Fig. 22) indicates that although there is considerable year-to-year variability in intensity errors, there has been a decrease in error over the past couple of decades at all forecast times. Forecast skill has changed little during the last several years, however. High intensity forecast biases were noted for all forecast periods, with smaller biases at earlier forecast periods and the largest high bias at 120 h. Figure 23 and Table 10a present a homogeneous verification for the primary early intensity models for 2022. Forecast biases are given in Table 10b. The official forecasts were skillful through 96 h, but there was no skill at 120 h likely due to the low Decay-SHIFOR5 errors at that time. The consensus model IVCN had similar skill levels to the official forecasts, but HCCA performed better than the official forecasts and IVCN from 72 to 120 h. The best individual model was HMNI, which had more skill than the consensus aids and the official forecasts at 60 and 72 h. CTCI, HWFI, LGEM, and GFSI were fair performers, while DSHP performed quite poorly and had no skill beyond 48 h. A closer inspection of DSHP's forecasts indicates that there was a substantial high bias from 72-120 h, likely worsened by false alarms of rapid intensification. EMXI had little to no skill through the forecast period. An evaluation over the three years 2020-22 (Fig. 24) indicates that the official forecasts were skillful at all times, but skill slowly declined after 48 h. HMNI performed very well over the past few years and had about comparable skill to the consensus models HCCA, FSSE, and IVCN. HWFI was not too far behind. LGEM and GFSI were fair performers, but DSHP had generally less skill.

c. Verifications for individual storms

Forecast verifications for individual storms are given for reference 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=2022&basin=epac.

4. Genesis Forecasts

The NHC routinely issues Tropical Weather Outlooks (TWOs) 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 represented the forecaster's determination of the chance of tropical cyclone formation during the 48-h and 120-h periods following the nominal TWO issuance time. 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 2022 are given in Table 12 and illustrated in Figure 25. In the Atlantic basin, a total of 921 genesis forecasts were made. These 48-h forecasts had a slight high (over-forecast) bias for the 10-80% probabilities. Most of this bias is associated with tropical cyclones forming later than anticipated. In the eastern Pacific, a total of 732 genesis forecasts were made. The forecasts in this basin were well calibrated for the low probabilities, but a slight low (under-forecast) bias is apparent for the 50-90% probabilities. It should be noted that a 3-yr verification of the 48-h genesis forecasts from 2020-22 revealed that the biases in both the Atlantic and east North Pacific basins were muted for this larger sample (not shown).

Verification of the 120-h outlook for the Atlantic and eastern North Pacific basins for 2022 are given in Table 13 and illustrated in Figure 26. In the Atlantic basin, the 120-h forecasts were generally reliable and did not have any significant biases. In the eastern North Pacific, the genesis forecasts had a slight low bias at the medium and high 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. The TWO will be extended to 7 days in 2023, and this lead time will replace the 120-h period. Future verification will evaluate the 2- and 7-day results.

5. Looking Ahead to 2023

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 2023 for the Atlantic and eastern North Pacific basins (based on error distributions for 2018-22) are given in Table 14. In the Atlantic basin, the cone circles will be largely unchanged, slightly smaller at 60 and 72 h and slightly larger at 36, 96, and 120 h. In the eastern Pacific basin, the cone circles will be more consistently smaller from 36 h onward, and will be up to 8% smaller at the longer lead times. It should be noted that since the sample size has increased at 60 h, the cone circles will no longer be based on an interpolation of the 48- and 72-h cone sizes at that forecast time.

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 from 2022 is given in Table 15. The compositions for the 2023 consensus models are currently being evaluated and will be posted in a separate document at a later date.

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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
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
TABD	Beta and advection model (deep layer)	Single-layer trajectory	E	Trk
CLP5	CLIPER5 (Climatology and Persistence model)	Statistical (baseline)	E	Trk

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
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
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
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
TVCN	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
TVCA	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCE	Average of at least two of GFSI EGRI HWFI EMXI CTCI	Consensus	E	Trk
TVCX	EMXI and average of at least two of GFSI EGRI HWFI EMXI CTCI	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 HWFI	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, CTCI, HMNI and HWFI	Consensus	E	Int
IVDR	CTCI (double weight) HWFI (double weight) HMNI (double weight) GFSI DSHP LGEM	Consensus	E	Int
IVCN	Average of at least two of DSHP LGEM HWFI HMNI CTCI	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 2022 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
2022 mean OFCL error (n mi)	21.1	31.3	41.6	52.5	65.3	78.1	98.7	126.2
2022 mean CLIPER5 error (n mi)	45.8	97.6	153.6	212.5	269.1	317.2	378.2	414.3
2022 mean OFCL skill relative to CLIPER5 (%)	53.9	67.9	72.9	75.3	75.7	75.4	73.9	65.5
2022 mean OFCL bias vector (°/n mi)	329/003	311/005	329/005	307/004	236/004	181/006	209/026	216/058
2022 number of cases	227	200	173	151	132	114	80	56
2017-2021 mean OFCL error (n mi)	23.6	35.5	47.6	61.4	78.2	91.3	125.6	172.1
2017-2021 mean CLIPER5 error (n mi)	45.5	98.2	156.7	213.7	252.4	316.9	403.6	484.6
2017-2021 mean OFCL skill relative to CLIPER5 (%)	48.1	63.8	69.6	71.3	69.0	71.2	68.9	64.5
2017-2021 mean OFCL bias vector (°/n mi)	018/002	001/001	002/001	053/002	030/007	090/006	126/013	149/017
2017-2021 number of cases	1879	1677	1495	1331	697	1029	792	607
2022 OFCL error relative to 2017-2021 mean (%)	-10.6	-11.8	-12.6	-14.5	-16.5	-14.5	-21.4	-26.7
2022 CLIPER5 error relative to 2017-2021 mean (%)	0.7	-0.6	-2.0	-0.6	6.2	0.1	-6.7	-17.0

Table 3a. Homogenous comparison of Atlantic basin early track guidance model errors (n mi) for 2022. 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	21.4	31.3	41.6	52.2	61.4	72.3	92.8	120.4
OCD5	46.0	97.0	151.3	208.3	263.5	305.4	362.7	390.8
GFSI	22.7	33.8	45.9	60.9	72.9	91.6	137.1	188.8
HMNI	25.1	38.4	48.2	55.7	**60.8**	**70.6**	102.2	168.3
HWFI	24.5	40.4	55.9	70.4	76.4	89.9	125.9	160.0
EMXI	23.2	34.0	45.8	58.1	68.7	80.5	107.6	172.4
CMCI	25.7	42.6	60.5	79.0	94.1	114.2	155.4	206.7
NVGI	30.3	50.4	70.3	94.0	112.2	131.6	169.8	208.4
CTCI	24.5	36.8	49.0	60.2	69.5	81.8	105.9	146.2
AEMI	23.3	35.3	48.7	64.2	76.6	94.6	122.3	139.2
HCCA	**20.1**	**27.8**	**36.5**	**45.1**	**52.8**	**62.0**	**80.1**	120.4
TVCA	**20.8**	**29.7**	**40.2**	**50.4**	**57.6**	**67.7**	**87.9**	**117.7**
Forecasts	201	177	154	135	116	100	71	50

Table 3b. Homogenous comparison of Atlantic basin early track guidance model bias vectors (º/n mi) for 2022.

	Forecast Period (h)							
Model ID	12	24	36	48	60	72	96	120
OFCL	325/003	321/006	341/006	329/004	153/001	184/005	205/029	207/064
OCD5	007/001	013/020	032/034	033/058	045/060	044/029	250/071	245/191
GFSI	313/004	323/004	010/005	018/005	059/006	080/003	094/015	089/042
HMNI	293/005	300/007	323/009	339/010	358/009	327/008	231/031	219/079
HWFI	330/005	345/008	003/013	008/017	012/012	326/004	215/021	212/034
EMXI	314/005	306/008	295/007	240/009	203/016	204/029	212/069	219/124
CMCI	285/009	273/016	274/022	271/031	268/039	265/054	260/091	249/128
NVGI	347/005	010/010	024/015	020/016	017/013	320/007	311/011	072/044
CTCI	353/005	006/008	022/015	033/018	049/019	069/016	099/024	124/032
AEMI	276/005	272/006	279/007	263/009	248/009	242/017	237/031	217/039
HCCA	291/002	298/003	355/002	037/001	132/005	168/008	190/028	196/060
TVCA	325/004	330/006	351/007	002/006	100/002	192/009	200/029	203/052
Forecasts	201	177	154	135	116	100	71	50

Table 4. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the Atlantic basin for the 2022 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
2022 mean OFCL error (kt)	4.8	5.8	7.2	7.9	9.0	10.0	16.4	21.2
2022 mean Decay-SHIFOR5 error (kt)	6.7	9.9	12.5	15.9	19.8	24.2	30.7	30.8
2022 mean OFCL skill relative to Decay-SHIFOR5 (%)	28.4	41.4	42.4	50.3	54.5	58.7	46.6	31.1
2022 OFCL bias (kt)	0.3	0.2	0.1	0.6	-0.6	-3.3	-8.2	-12.9
2022 number of cases	227	200	173	151	132	114	80	56
2017-21 mean OFCL error (kt)	5.4	8.0	9.5	10.9	11.0	12.1	13.1	14.7
2017-21 mean Decay-SHIFOR5 error (kt)	7.0	11.1	14.5	17.1	18.0	20.2	21.9	22.1
2017-21 mean OFCL skill relative to Decay-SHIFOR5 (%)	22.9	27.9	34.5	36.3	38.9	40.1	40.2	33.5
2017-21 OFCL bias (kt)	0.3	0.2	-0.1	-0.5	0.2	-0.6	-1.8	-4.8
2017-21 number of cases	1879	1677	1495	1331	697	1029	792	607
2022 OFCL error relative to 2017-21 mean (%)	-11.1	-27.5	-24.2	-27.5	-18.2	-17.4	25.2	44.2
2022 Decay-SHIFOR5 error relative to 2017-21 mean (%)	-4.5	-12.1	-16.0	-7.5	9.1	16.5	28.7	28.2

Table 5a. Homogenous comparison of selected Atlantic basin early intensity guidance model errors (kt) for 2022. 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	4.6	5.7	7.3	8.2	9.3	10.2	16.6	22.0
OCD5	6.7	10.0	12.6	15.8	19.8	23.5	32.6	31.7
HWFI	6.4	7.4	8.3	9.3	9.5	**9.4**	**12.8**	**18.8**
HMNI	5.7	7.7	7.9	9.1	9.8	10.7	17.2	23.8
CTCI	6.2	7.7	8.7	10.4	11.6	11.5	17.4	**21.5**
DSHP	5.6	7.4	9.0	10.5	11.6	13.0	19.2	25.5
LGEM	6.0	7.9	9.6	10.3	11.1	12.3	**16.3**	22.9
IVCN	5.1	6.1	**6.9**	**8.0**	**8.6**	**9.2**	**14.9**	**19.9**
HCCA	4.9	6.0	7.3	8.5	**8.9**	**8.8**	**13.4**	**17.5**
GFSI	5.9	7.7	9.0	9.6	10.2	10.5	**15.7**	**20.8**
EMXI	6.8	10.5	13.1	14.4	16.6	18.8	27.6	37.9
NNIC	5.4	6.8	8.1	9.4	9.5	10.6	**11.2**	**18.6**
Forecasts	213	187	161	140	121	103	70	50

Table 5b. Homogenous comparison of selected Atlantic basin early intensity guidance model biases (kt) for 2022. Biases smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)							
Model ID	12	24	36	48	60	72	96	120
OFCL	0.3	0.5	0.2	0.7	-0.7	-3.1	-9.6	-13.4
OCD5	-2.2	-4.0	-5.5	-7.3	-9.9	-13.9	-28.4	-31.3
HWFI	-2.7	-2.3	-1.1	**0.0**	**0.2**	**1.2**	**2.5**	**-0.1**
HMNI	-1.6	-2.4	-3.3	-3.5	-4.4	-5.6	-13.7	-17.5
CTCI	-1.5	-2.1	-1.4	-0.8	-1.9	-3.2	**-7.5**	**-10.2**
DSHP	-0.6	**-0.3**	0.4	1.1	0.7	**0.0**	**-5.7**	**-10.5**
LGEM	-1.2	-1.6	-1.1	**-0.6**	-1.7	-3.1	-10.0	-17.4
IVCN	-1.2	-1.4	-1.0	**-0.4**	-1.2	**-1.8**	**-7.6**	**-11.2**
HCCA	-0.3	0.5	1.5	2.3	1.9	**1.1**	**-4.8**	**-7.1**
GFSI	-1.7	-2.7	-3.3	-4.2	-5.4	-5.6	-11.2	-16.3
EMXI	-3.0	-5.0	-7.1	-9.4	-12.5	-16.0	-27.3	-37.7
NNIC	**0.1**	1.4	2.6	2.6	1.7	**0.4**	**4.0**	**7.1**
Forecasts	213	187	161	140	121	103	70	50

Table 6. Official Atlantic track and intensity forecast verifications (OFCL) for 2022 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: AL012022 ALEX

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	7.7	7.7	6	1.7	1.7
012	4	50.3	56.8	4	5.0	7.0
024	2	119.7	186.3	2	10.0	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: AL022022 BONNIE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	5.3	5.3	5	1.0	1.0
012	5	15.7	24.5	5	3.0	5.2
024	5	33.7	42.9	5	6.0	5.8
036	5	62.9	70.7	5	8.0	11.2
048	5	84.2	96.3	5	9.0	16.0
060	5	99.4	146.1	5	14.0	22.6
072	5	105.6	160.2	5	20.0	32.8
096	5	98.9	199.6	5	23.0	43.2
120	5	91.5	251.2	5	10.0	27.2

Verification statistics for: AL032022 COLIN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	3	4.3	4.3	3	1.7	1.7
012	1	16.1	30.4	1	5.0	1.0
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: AL052022 DANIELLE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	29	7.9	7.9	29	0.7	0.9
012	27	13.0	37.0	27	3.5	4.8
024	25	23.0	85.0	25	6.4	8.2
036	23	26.8	123.6	23	7.0	9.5
048	21	25.4	158.5	21	6.4	8.0
060	19	30.1	188.3	19	6.1	6.3
072	17	41.4	238.3	17	5.0	5.1
096	13	49.8	267.2	13	5.8	3.3
120	9	58.4	217.9	9	6.1	9.8

Verification statistics for: AL062022 EARL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	31	3.9	3.9	31	3.1	3.1
012	29	20.7	41.3	29	6.7	7.3
024	27	27.7	87.1	27	8.0	7.8
036	25	32.8	136.6	25	11.2	8.7
048	23	40.9	185.1	23	12.6	10.9
060	21	49.8	221.2	21	12.4	15.8
072	19	57.2	250.3	19	12.1	17.1
096	15	106.1	332.9	15	14.7	23.5
120	11	253.4	478.5	11	17.7	18.9

Verification statistics for: AL072022 FIONA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	38	4.4	4.7	38	0.5	0.8
012	36	23.9	38.5	36	4.7	8.1
024	34	30.2	68.8	34	4.3	12.3
036	32	40.8	109.9	32	6.6	17.5
048	30	43.9	146.5	30	7.2	25.1
060	28	51.9	186.4	28	10.2	29.5
072	26	54.1	220.5	26	13.8	35.2
096	22	59.1	313.0	22	25.9	45.3
120	18	69.7	393.5	18	36.4	44.8

Verification statistics for: AL082022 GASTON

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	22	8.0	8.4	22	0.9	0.9
012	20	21.9	76.6	20	3.8	5.1
024	18	33.0	189.4	18	5.3	6.6
036	16	46.4	323.8	16	4.7	6.1
048	14	67.5	482.4	14	4.6	7.7
060	12	89.1	607.1	12	3.8	11.6
072	10	124.6	660.1	10	2.5	16.8
096	6	174.8	678.1	6	2.5	21.0
120	2	243.0	576.0	2	2.5	16.0

Verification statistics for: AL092022 IAN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	31	3.6	3.5	31	1.8	1.8
012	29	18.3	39.3	29	7.6	11.4
024	27	32.0	90.6	27	9.3	16.7
036	25	50.9	147.7	25	11.0	21.1
048	23	67.8	195.8	23	12.4	25.3
060	21	87.6	248.7	21	15.2	31.8
072	19	110.5	303.1	19	12.9	40.7
096	15	140.3	442.4	15	18.7	43.4
120	11	141.8	589.7	11	20.9	41.2

Verification statistics for: AL102022 HERMINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	10.9	10.9	6	1.7	1.7
012	4	22.4	40.7	4	5.0	5.0
024	2	36.4	95.7	2	5.0	11.0
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: AL112022 ELEVEN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	5	11.1	11.1	5	4.0	4.0
012	3	29.2	54.7	3	8.3	8.0
024	1	0.0	101.8	1	10.0	16.0
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: AL122022 TWELVE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	9	13.6	13.6	9	0.6	0.6
012	7	51.1	58.7	7	0.7	2.9
024	5	67.6	63.9	5	2.0	7.0
036	3	59.0	66.3	3	3.3	10.3
048	1	109.3	90.7	1	0.0	16.0
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: AL132022 JULIA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	11	6.4	6.2	11	1.4	1.4
012	11	11.5	33.7	11	4.1	5.9
024	11	28.5	73.2	11	4.1	9.5
036	9	52.9	113.4	9	2.8	9.9
048	7	76.5	186.3	7	2.9	10.0
060	5	104.2	271.1	5	6.0	11.8
072	3	127.1	331.0	3	3.3	15.7
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: AL142022 KARL

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	13	7.1	7.1	13	0.4	0.4
012	11	25.7	52.7	11	4.5	7.3
024	9	53.2	123.5	9	5.6	11.9
036	7	86.4	216.3	7	5.0	20.3
048	5	135.9	278.2	5	3.0	25.4
060	3	209.4	294.9	3	0.0	23.7
072	1	250.4	226.2	1	10.0	28.0
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: AL152022 LISA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	2.5	2.5	20	1.8	1.8
012	18	15.4	30.6	18	3.6	4.1
024	16	20.4	58.9	16	2.5	4.2
036	14	29.4	81.6	14	5.4	6.6
048	12	43.1	106.3	12	6.2	10.0
060	10	68.5	174.4	10	3.5	14.6
072	8	96.5	279.7	8	5.0	20.0
096	2	170.9	324.2	2	2.5	7.5
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: AL162022 MARTIN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	6.2	6.2	8	1.2	0.6
012	6	31.7	97.3	6	5.8	8.2
024	4	50.3	178.2	4	2.5	19.2
036	2	43.1	185.9	2	5.0	19.0
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: AL172022 NICOLE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	18	5.4	5.4	18	1.1	1.1
012	16	18.9	58.9	16	3.1	5.1
024	14	22.6	148.1	14	4.6	7.3
036	12	31.4	277.3	12	3.8	8.4
048	10	37.2	431.0	10	4.5	13.4
060	8	38.3	608.0	8	3.8	17.6
072	6	71.4	833.1	6	5.0	16.2
096	2	184.2	1277.3	2	17.5	27.0
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 2022 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
2022 mean OFCL error (n mi)	21.3	32.7	42.9	52.4	64.4	80.1	115.1	125.6
2022 mean CLIPER5 error (n mi)	34.6	68.3	106.5	144.6	184.0	222.7	280.1	313.2
2022 mean OFCL skill relative to CLIPER5 (%)	38.4	52.1	59.7	63.8	65.0	64.0	58.9	59.9
2022 mean OFCL bias vector (°/n mi)	256/002	212/004	182/006	143/010	129/018	116/028	096/046	114/049
2022 number of cases	318	283	249	217	189	160	109	66
2017-2021 mean OFCL error (n mi)	21.9	33.9	45.7	57.0	75.1	80.0	99.5	121.3
2017-2021 mean CLIPER5 error (n mi)	35.8	72.3	112.5	154.7	198.0	238.8	309.2	372.2
2017-2021 mean OFCL skill relative to CLIPER5 (%)	38.8	53.1	59.3	63.2	62.1	66.5	67.8	67.5
2017-2021 mean OFCL bias vector (°/n mi)	343/001	095/001	120/002	130/001	191/011	166/000	004/002	343/012
2017-2021 number of cases	1588	1410	1226	1064	919	352	695	511
2022 OFCL error relative to 2017-2021 mean (%)	-2.7	-3.5	-6.1	-8.0	-14.2	0.1	15.7	3.5
2022 CLIPER5 error relative to 2017-2021 mean (%)	-3.5	-5.9	-5.6	-7.0	-7.6	-7.2	-10.4	-19.2

Table 8a. Homogenous comparison of eastern North Pacific basin early track guidance model errors (n mi) for 2022. 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	21.8	33.9	45.5	57.9	68.0	77.4	87.6	103.4
OCD5	35.1	69.8	110.5	153.7	193.5	230.6	265.6	265.6
GFSI	24.6	40.8	59.3	81.3	94.0	110.4	131.2	127.1
HWFI	25.6	45.3	66.9	87.6	104.7	116.2	155.3	234.9
HMNI	25.3	41.8	58.9	73.5	89.7	104.2	136.6	184.4
CTCI	25.8	40.0	56.4	76.1	88.9	104.2	122.3	145.9
EMXI	22.9	35.1	47.2	**57.7**	69.7	78.8	91.9	**87.3**
CMCI	26.0	41.9	59.9	83.4	100.2	115.0	128.5	145.8
NVGI	31.7	55.6	77.2	93.8	101.8	116.0	134.4	167.6
AEMI	24.3	39.2	56.3	74.1	85.9	100.6	119.2	128.9
TVCE	**21.6**	34.4	47.6	59.7	70.2	78.4	97.7	128.2
HCCA	**21.5**	**33.6**	46.9	**55.7**	**64.5**	**71.6**	**81.2**	**102.6**
Forecasts	251	218	189	154	130	108	70	42

Table 8b. Homogenous comparison of eastern North Pacific basin early track guidance model bias vectors (º/n mi) for 2022.

	Forecast Period (h)							
Model ID	12	24	36	48	60	72	96	120
OFCL	268/003	236/005	198/007	148/011	153/015	154/020	170/027	180/037
OCD5	248/003	236/008	241/020	244/035	236/053	219/068	194/077	141/083
GFSI	190/001	133/007	117/018	104/037	104/047	104/060	101/081	110/081
HWFI	250/006	217/014	206/023	193/028	201/037	202/045	219/065	236/137
HMNI	265/005	224/007	190/011	176/017	197/025	206/033	225/044	245/108
CTCI	074/003	090/011	086/020	081/035	071/039	065/040	056/022	253/025
EMXI	278/007	266/012	248/015	221/016	216/023	217/031	219/048	211/033
CMCI	112/002	112/012	104/025	093/042	087/055	084/072	089/070	102/074
NVGI	360/003	018/008	006/013	006/018	357/020	355/016	264/018	219/028
AEMI	108/001	125/007	122/014	114/025	121/031	126/041	130/059	145/077
TVCE	270/004	234/007	210/010	175/012	191/017	196/023	211/037	227/062
HCCA	236/004	215/008	203/012	163/015	174/020	174/027	188/036	194/042
Forecasts	251	218	189	154	130	108	70	42

Table 9. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the eastern North Pacific basin for the 2022 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
2022 mean OFCL error (kt)	5.0	8.3	10.2	11.4	12.1	13.2	13.3	13.5
2022 mean Decay-SHIFOR5 error (kt)	6.6	11.4	15.0	15.9	16.3	15.7	14.6	12.4
2022 mean OFCL skill relative to Decay-SHIFOR5 (%)	24.2	27.2	32.0	28.3	25.8	15.9	8.9	-8.9
2022 OFCL bias (kt)	1.0	1.6	1.7	1.6	1.7	2.3	4.6	7.1
2022 number of cases	318	283	249	217	189	160	109	66
2017-21 mean OFCL error (kt)	5.5	9.1	11.2	12.9	15.4	15.6	16.4	17.0
2017-21 mean Decay-SHIFOR5 error (kt)	7.0	12.2	15.8	18.6	20.4	21.2	22.3	21.8
2017-21 mean OFCL skill relative to Decay-SHIFOR5 (%)	21.4	25.4	29.1	30.6	24.5	26.4	26.5	22.0
2017-21 OFCL bias (kt)	0.3	0.6	0.8	0.9	2.8	0.7	-0.7	-4.0
2017-21 number of cases	1588	1410	1226	1064	919	352	695	511
2022 OFCL error relative to 2017-21 mean (%)	-9.1	-8.8	-8.9	-11.6	-21.4	-15.4	-18.9	-20.6
2022 Decay-SHIFOR5 error relative to 2017-21 mean (%)	-6.1	-7.0	-5.3	-17.0	-25.2	-35.0	-52.7	-75.8

Table 10a. Homogenous comparison of eastern North Pacific basin early intensity guidance model errors (kt) for 2022. 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	4.7	8.0	10.3	11.9	13.0	14.6	14.1	13.6
OCD5	6.1	10.6	15.0	16.4	17.7	17.3	15.6	**13.1**
HWFI	6.1	8.6	10.7	**11.5**	**12.9**	14.9	15.7	20.2
HMNI	6.1	9.2	11.0	**11.4**	**10.9**	**11.5**	**12.8**	**11.7**
CTCI	5.8	8.5	10.5	12.7	15.3	16.7	17.6	13.8
DSHP	5.5	9.4	13.3	15.9	18.5	20.7	23.2	23.5
LGEM	5.4	8.7	12.0	14.3	16.1	16.5	**13.9**	**10.9**
IVCN	4.9	**7.5**	**9.8**	**11.2**	**12.7**	**13.8**	14.8	14.8
HCCA	5.2	8.0	10.9	12.5	13.2	**12.9**	**11.5**	**9.4**
GFSI	5.9	9.6	12.0	13.7	15.3	16.2	14.8	**11.4**
EMXI	6.5	10.6	14.1	15.6	16.9	17.7	16.3	**13.4**
NNIC	5.1	**7.5**	**10.2**	**11.1**	13.0	**14.1**	16.8	18.3
Forecasts	254	222	193	164	136	109	74	44

Table 10b. Homogenous comparison of eastern North Pacific basin early intensity guidance model biases (kt) for 2022. 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	1.2	2.0	2.2	2.4	2.6	2.7	2.8	5.5
OCD5	**0.4**	**0.7**	**0.8**	**0.5**	**0.0**	**0.0**	3.2	**4.4**
HWFI	-3.1	-3.5	-4.2	-3.3	**-1.0**	**1.7**	5.9	14.5
HMNI	-1.7	-3.1	-4.5	-5.5	-4.5	-3.5	-4.7	**2.1**
CTCI	**-0.7**	**-0.3**	**0.6**	**1.3**	**1.2**	**1.8**	**-1.4**	**-2.1**
DSHP	**0.6**	**1.9**	3.1	4.3	6.0	8.2	11.2	14.2
LGEM	**-0.5**	-2.1	-3.6	-4.2	-4.3	-4.4	-4.9	**-3.9**
IVCN	**-0.8**	**-1.1**	**-1.4**	**-1.2**	**-0.2**	**1.1**	**1.4**	**4.9**
HCCA	**0.6**	**1.6**	**1.9**	**2.0**	**1.9**	**1.6**	**-1.5**	**-0.1**
GFSI	-1.4	-2.2	-2.9	-3.7	-4.4	-3.1	**-1.3**	**0.8**
EMXI	-3.0	-6.1	-9.7	-12.3	-13.3	-14.1	-14.4	-13.0
NNIC	**0.5**	**0.9**	**0.9**	**0.6**	**0.7**	**1.4**	4.1	10.8
Forecasts	254	222	193	164	136	109	74	44

Table 11. Official eastern North Pacific track and intensity forecast verifications (OFCL) for 2022 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: EP012022 AGATHA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	15	6.1	6.1	15	2.7	2.7
012	13	22.2	42.0	13	8.5	12.1
024	11	28.5	98.2	11	14.1	21.4
036	9	22.4	193.5	9	15.0	32.6
048	7	17.6	291.9	7	11.4	26.9
060	5	24.6	394.2	5	4.0	25.6
072	3	28.8	549.5	3	10.0	16.7
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: EP022022 BLAS

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	22	13.3	13.3	22	1.6	1.6
012	20	25.2	38.0	20	5.0	6.3
024	18	38.0	65.7	18	6.9	11.8
036	16	55.5	100.1	16	6.9	14.1
048	14	59.1	108.1	14	4.3	14.4
060	12	61.0	109.8	12	6.2	18.1
072	10	59.6	119.4	10	9.5	19.2
096	6	68.4	169.8	6	3.3	8.0
120	2	99.6	108.1	2	0.0	8.0

Verification statistics for: EP032022 CELIA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	48	8.7	8.9	48	1.5	1.5
012	46	22.8	41.3	46	3.6	4.7
024	44	31.2	72.3	44	5.9	9.8
036	42	37.0	103.1	42	8.1	12.4
048	40	43.1	136.4	40	10.2	13.7
060	38	45.1	175.1	38	12.1	9.8
072	36	48.5	209.2	36	12.6	9.9
096	32	62.8	260.6	32	13.6	11.8
120	28	70.3	314.3	28	14.3	12.0

Verification statistics for: EP042022 BONNIE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	29	6.4	6.4	29	1.6	1.6
012	27	19.5	35.7	27	4.4	6.2
024	25	23.4	65.8	25	7.2	8.8
036	23	27.4	102.3	23	6.7	9.7
048	21	29.5	131.1	21	7.4	8.3
060	19	33.6	151.6	19	8.4	10.1
072	17	41.4	169.7	17	9.4	10.1
096	13	84.2	230.5	13	12.7	10.8
120	9	132.3	338.2	9	13.9	10.3

Verification statistics for: EP052022 DARBY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	19	1.2	1.2	19	1.1	1.6
012	19	17.8	19.7	19	10.0	12.4
024	19	33.2	40.7	19	18.4	23.1
036	19	49.9	63.3	19	20.5	30.2
048	19	66.9	89.6	19	19.5	27.7
060	19	83.1	117.7	19	18.4	21.8
072	18	102.0	136.2	18	20.8	18.2
096	14	136.2	176.4	14	23.2	23.1
120	10	187.7	298.6	10	18.0	16.3

Verification statistics for: EP062022 ESTELLE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	23	6.3	6.3	23	0.2	0.2
012	21	21.5	33.7	21	5.7	4.6
024	19	32.2	62.1	19	12.9	6.6
036	17	40.2	85.7	17	17.9	8.9
048	15	52.3	111.5	15	22.7	11.1
060	13	68.3	159.5	13	23.1	12.5
072	11	76.0	208.9	11	23.2	14.9
096	7	82.1	289.0	7	27.1	11.1
120	3	98.6	422.9	3	21.7	9.0

Verification statistics for: EP072022 FRANK

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	30	6.5	6.5	30	0.7	0.7
012	28	15.8	22.8	28	4.1	5.5
024	26	23.2	45.7	26	5.4	8.4
036	24	29.7	76.4	24	7.3	11.7
048	22	34.7	106.5	22	7.7	13.0
060	20	40.0	133.9	20	8.5	12.4
072	18	50.1	161.7	18	8.6	13.1
096	14	69.4	208.0	14	5.0	13.4
120	10	88.4	235.3	10	7.5	11.0

Verification statistics for: EP082022 GEORGETTE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	29	8.4	8.4	29	0.2	0.2
012	27	22.3	34.4	27	1.7	3.7
024	25	43.6	82.6	25	2.4	5.4
036	23	71.7	145.0	23	3.0	8.0
048	21	108.8	213.4	21	5.7	10.6
060	19	166.6	296.9	19	5.8	16.2
072	17	232.5	375.0	17	6.5	17.9
096	12	378.5	491.1	12	5.8	24.4
120	3	563.8	459.8	3	8.3	17.3

Verification statistics for: EP092022 HOWARD

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	18	2.0	2.3	18	1.4	1.4
012	16	14.7	22.1	16	5.0	6.1
024	14	21.8	40.7	14	10.4	13.1
036	12	26.8	70.3	12	12.1	16.8
048	10	32.5	108.0	10	15.0	19.9
060	8	36.7	140.5	8	18.8	17.0
072	6	50.8	173.9	6	15.0	10.7
096	2	68.5	221.8	2	2.5	2.5
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP102022 IVETTE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	12	6.5	7.5	12	1.2	1.2
012	10	21.8	34.5	10	2.5	4.4
024	8	42.2	83.5	8	3.8	3.9
036	6	58.6	150.4	6	6.7	5.8
048	4	73.1	249.6	4	11.2	6.8
060	2	70.3	326.4	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: EP112022 JAVIER

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	10.5	10.5	8	0.0	0.0
012	6	20.0	40.8	6	0.8	2.3
024	4	40.0	98.5	4	1.2	5.5
036	2	55.6	124.5	2	0.0	10.5
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: EP122022 KAY

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	21	3.7	3.7	21	2.6	3.1
012	19	23.8	50.3	19	7.4	6.4
024	17	34.2	98.1	17	11.5	9.2
036	15	41.9	143.0	15	14.3	9.0
048	13	58.7	210.6	13	15.4	9.8
060	11	71.4	277.5	11	13.6	12.6
072	9	87.0	358.6	9	12.8	14.9
096	5	112.2	471.6	5	16.0	7.2
120	1	182.6	628.6	1	20.0	21.0

Verification statistics for: EP132022 LESTER

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	8	27.8	27.8	8	1.2	1.2
012	6	45.2	46.7	6	4.2	7.2
024	4	62.5	81.6	4	8.8	21.2
036	2	109.9	111.1	2	12.5	34.5
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: EP142022 MADELINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	11	7.5	7.5	11	0.5	0.5
012	9	20.3	43.9	9	4.4	7.1
024	7	27.0	91.3	7	5.7	9.4
036	5	26.8	158.7	5	4.0	6.0
048	3	32.0	189.4	3	0.0	8.3
060	1	39.7	190.2	1	10.0	26.0
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: EP152022 NEWTON

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	8.6	6.8	16	0.3	0.3
012	14	22.8	25.8	14	3.6	5.3
024	12	38.5	50.0	12	5.0	8.9
036	10	54.9	68.1	10	5.5	14.5
048	8	63.2	79.3	8	4.4	17.5
060	6	60.5	102.0	6	2.5	23.7
072	3	67.7	115.7	3	3.3	24.7
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: EP162022 ORLENE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	20	6.8	7.0	20	2.2	2.2
012	18	23.2	29.1	18	8.9	10.8
024	16	42.3	66.1	16	13.1	17.9
036	14	55.3	116.3	14	15.4	22.4
048	12	60.9	182.7	12	14.2	25.2
060	10	58.1	254.4	10	14.5	28.5
072	8	58.7	344.4	8	21.9	33.5
096	4	85.0	520.3	4	23.8	25.0
120	0	-999.0	-999.0	0	-999.0	-999.0

Verification statistics for: EP172022 PAINE

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	6	9.6	9.6	6	0.8	0.8
012	4	18.5	19.3	4	3.8	4.5
024	2	31.1	39.6	2	0.0	8.5
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: EP182022 JULIA

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	3	6.4	8.8	3	1.7	1.7
012	1	21.4	30.0	1	0.0	2.0
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: EP192022 ROSLYN

VT (h)	NT	OFCL	OCD5	NI	OFCL	OCD5
000	16	7.1	6.7	16	0.6	0.6
012	14	19.5	43.4	14	6.1	11.4
024	12	27.4	85.1	12	9.6	22.5
036	10	33.6	119.4	10	15.0	34.2
048	8	32.1	150.1	8	21.9	40.6
060	6	53.9	192.6	6	25.8	47.5
072	4	97.8	240.9	4	21.2	44.0
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 2022.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	2	478
10	4	158
20	7	76
30	28	36
40	10	39
50	41	29
60	55	29
70	43	44
80	62	18
90	94	13
100	100	1

Table 12b. Verification of 48-h probabilistic genesis forecasts for the eastern North Pacific basin in 2022.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	1	420
10	13	88
20	8	50
30	42	33
40	44	39
50	71	21
60	70	20
70	85	33
80	100	13
90	100	14
100	100	1

Table 13a. Verification of 120-h probabilistic genesis forecasts for the Atlantic basin in 2022.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	3	118
10	10	250
20	12	184
30	26	107
40	25	65
50	54	28
60	37	35
70	73	56
80	94	34
90	100	43
100	100	1

Table 13b. Verification of 120-h probabilistic genesis forecasts for the eastern North Pacific basin in 2022.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	15	116
10	14	167
20	29	121
30	27	77
40	49	39
50	71	31
60	79	29
70	89	47
80	100	51
90	100	53
100	100	1

Table 14. NHC forecast cone circle radii (n mi) for 2023. Change from 2022 values expressed in n mi and percent are given in parentheses.

2023 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%)	25 (0: 0%)
24	39 (0: 0%)	38 (0: 0%)
36	53 (1: 2%)	51 (-1: -2%)
48	67 (0: 0%)	63 (-2: -3%)
60	81 (-3: -4%)	78 (-1: -1%)
72	99 (-1: -1%)	86 (-7: -8%)
96	145 (3: 2%)	110 (-10: -8%)
120	205 (5: 3%)	137 (-9: -6%)

Table 15. Composition of NHC consensus models from 2022. The compositions for 2023 are currently being evaluated.

NHC Consensus Model Definitions For 2022			
Model ID	**Parameter**	**Type**	**Members**
GFEX	Track	Fixed	GFSI EMXI
ICON	Intensity	Fixed	DSHP LGEM HWFI CTCI HMNI
TVCA**	Track	Variable	GFSI EGRI HWFI EMXI CTCI
TVCE	Track	Variable	GFSI EGRI HWFI EMXI CTCI HMNI EMNI
TVDG	Track	Variable	GFSI (double weight) EMXI (double weight) EGRI (double weight) CTCI HWFI
TVCX	Track	Variable	EMXI (double weight) GFSI EGRI HWFI
IVCN	Intensity	Variable	DSHP LGEM HWFI CTCI HMNI
IVDR	Intensity	Variable	CTCI (double weight) HWFI (double weight) HMNI (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.

LIST OF FIGURES

21. NHC official and Decay-SHIFOR5 (OCD5) eastern North Pacific basin average intensity errors for 2022 (solid lines) and 2017-2021 (dashed lines).

22. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the eastern North Pacific basin.

23. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2022. This verification includes only those models that were available at least 2/3 of the time (see text).

24. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2020-22.

25. Reliability diagram for Atlantic (top) and eastern North Pacific (bottom) probabilistic tropical cyclogenesis 48-h forecasts for 2022. The solid lines indicate the relationship between the forecasts and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the forecasts were distributed among the possible forecast values.

26. As described for Fig. 25, but for 120-h forecasts.

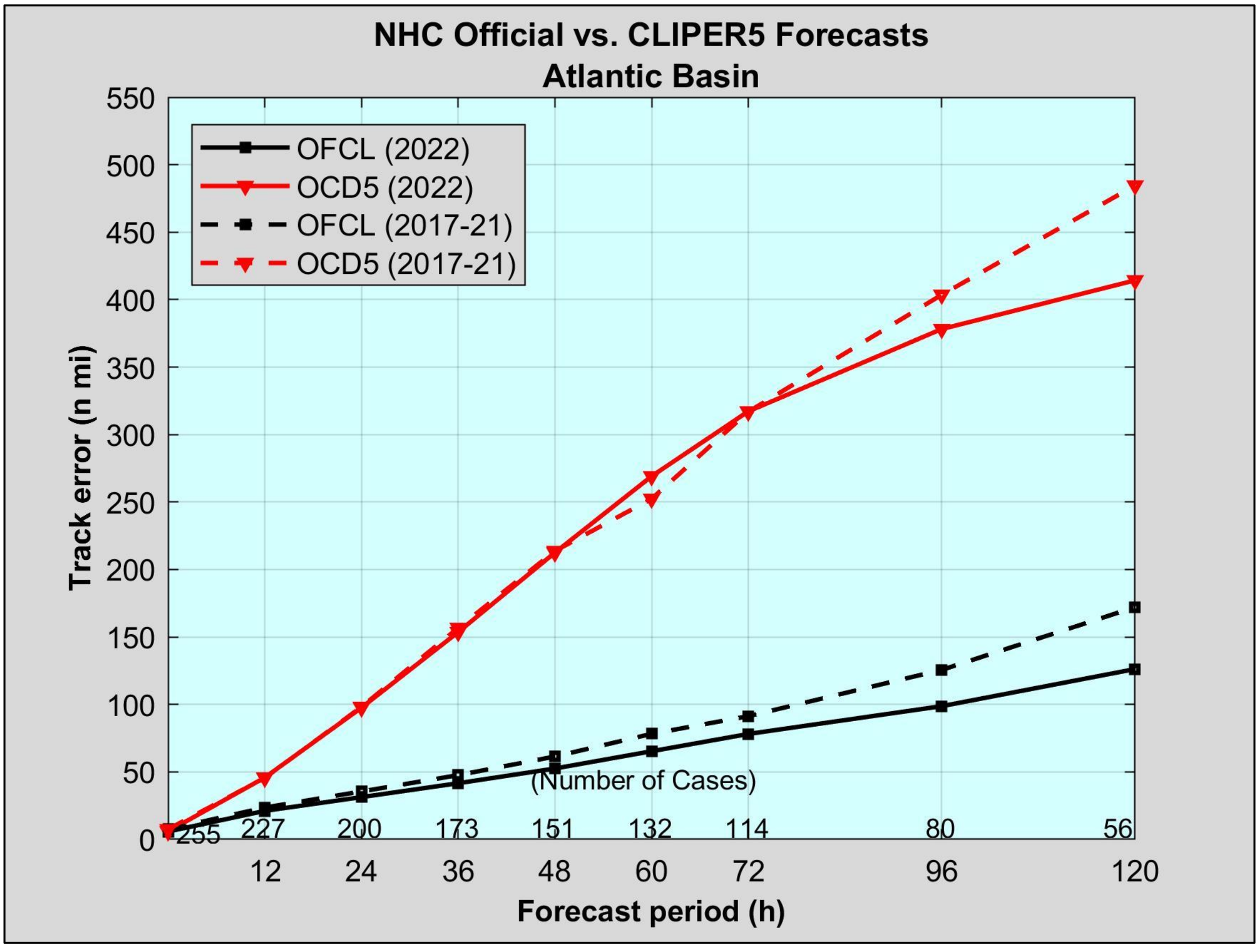

Figure 1. NHC official and CLIPER5 (OCD5) Atlantic basin average track errors for 2022 (solid lines) and 2017-2021 (dashed lines).

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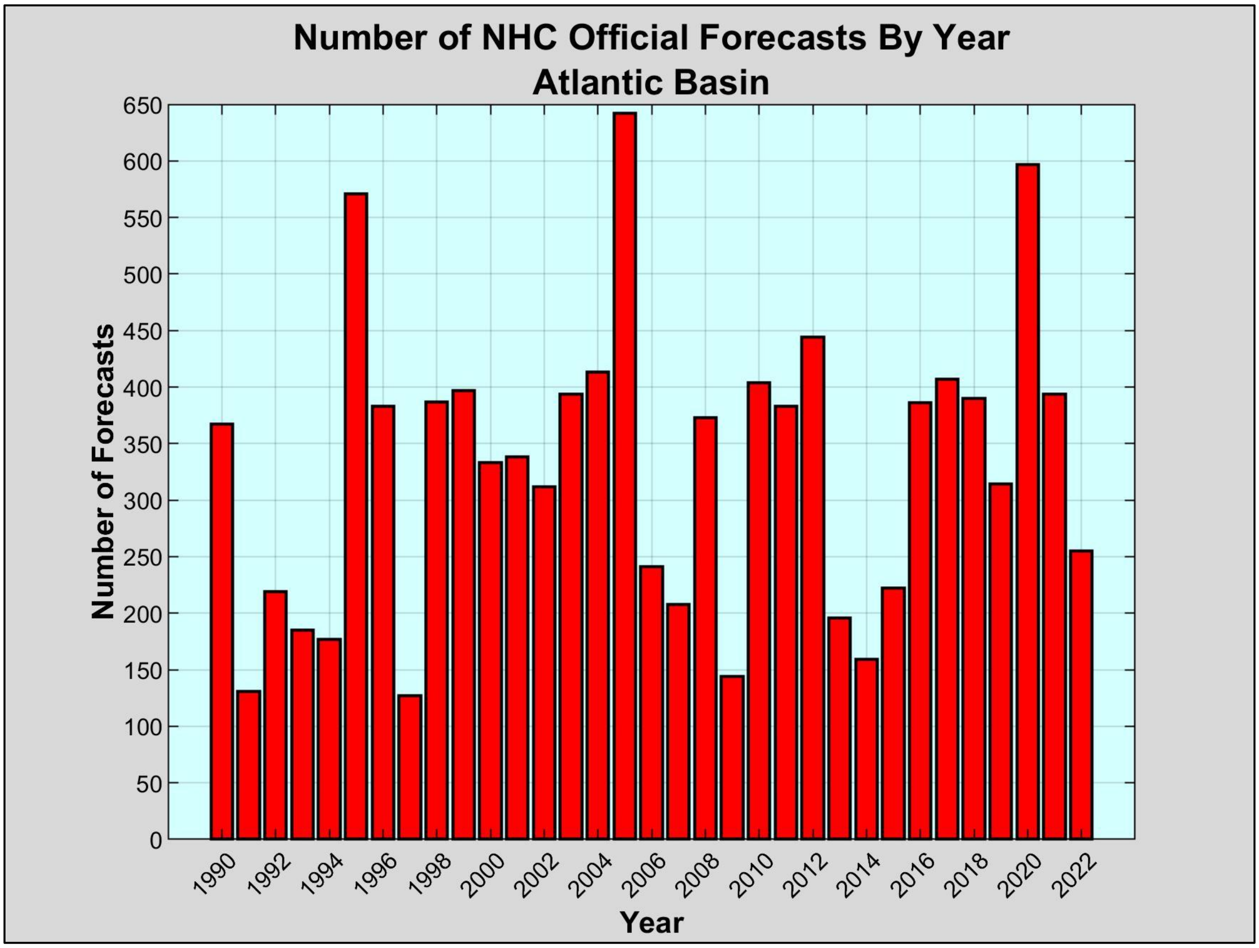


Figure 2. Number of NHC official forecasts for the Atlantic basin stratified by year.

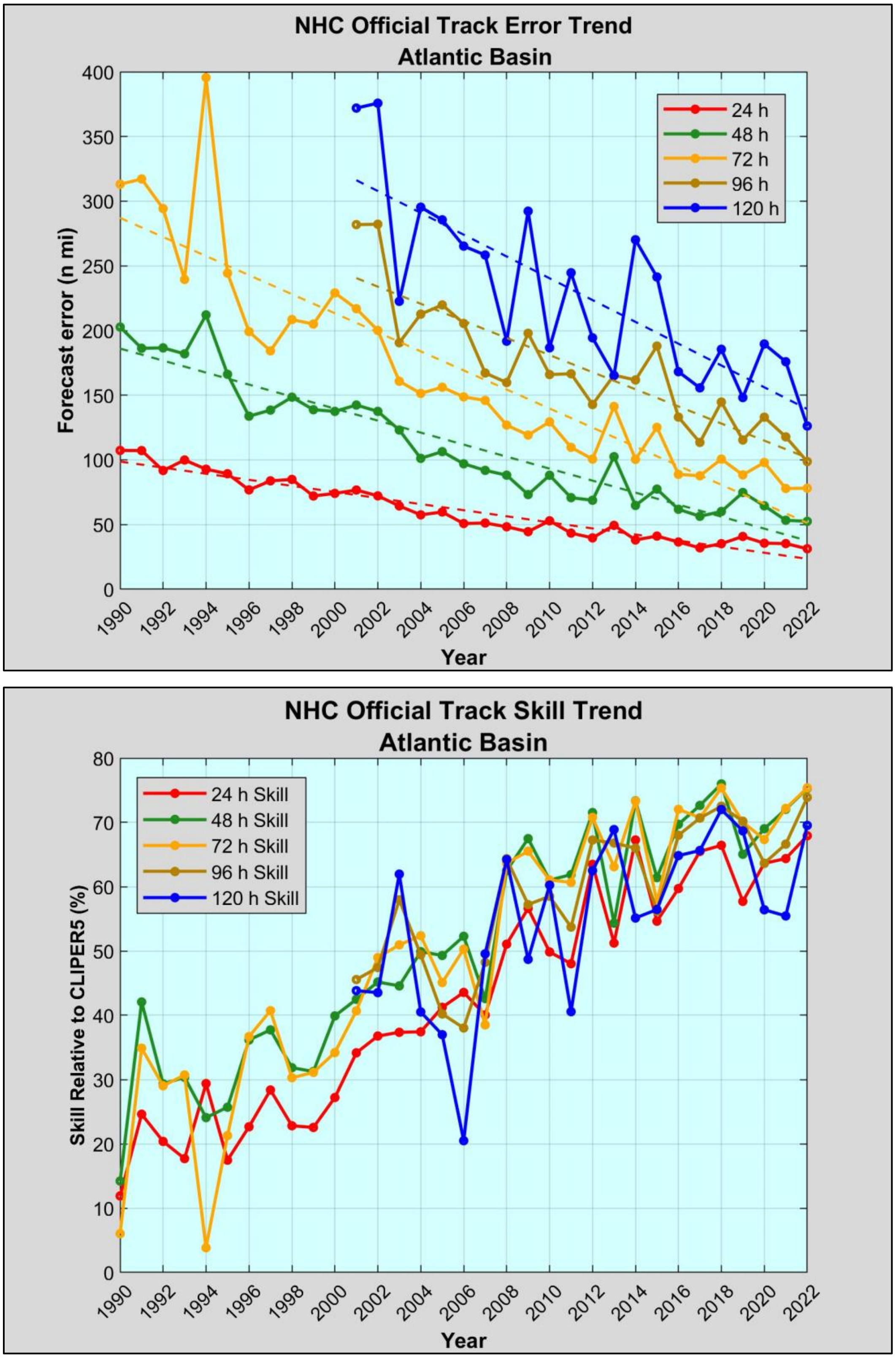


Figure 3. Recent trends in NHC official track forecast error (top) and skill (bottom) for the Atlantic basin.

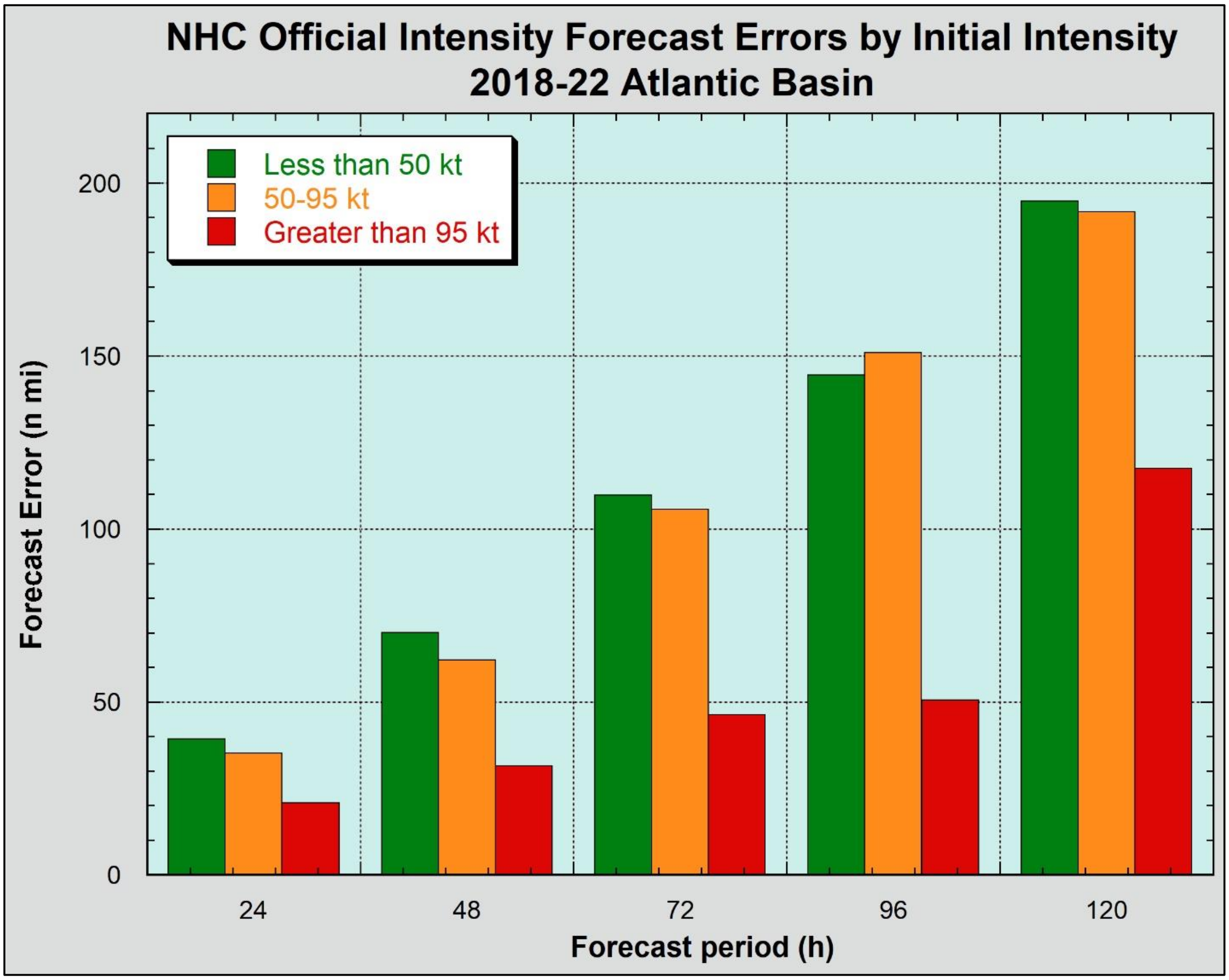


Figure 4. 2018-22 NHC official track forecast error binned by initial intensity for the Atlantic basin.

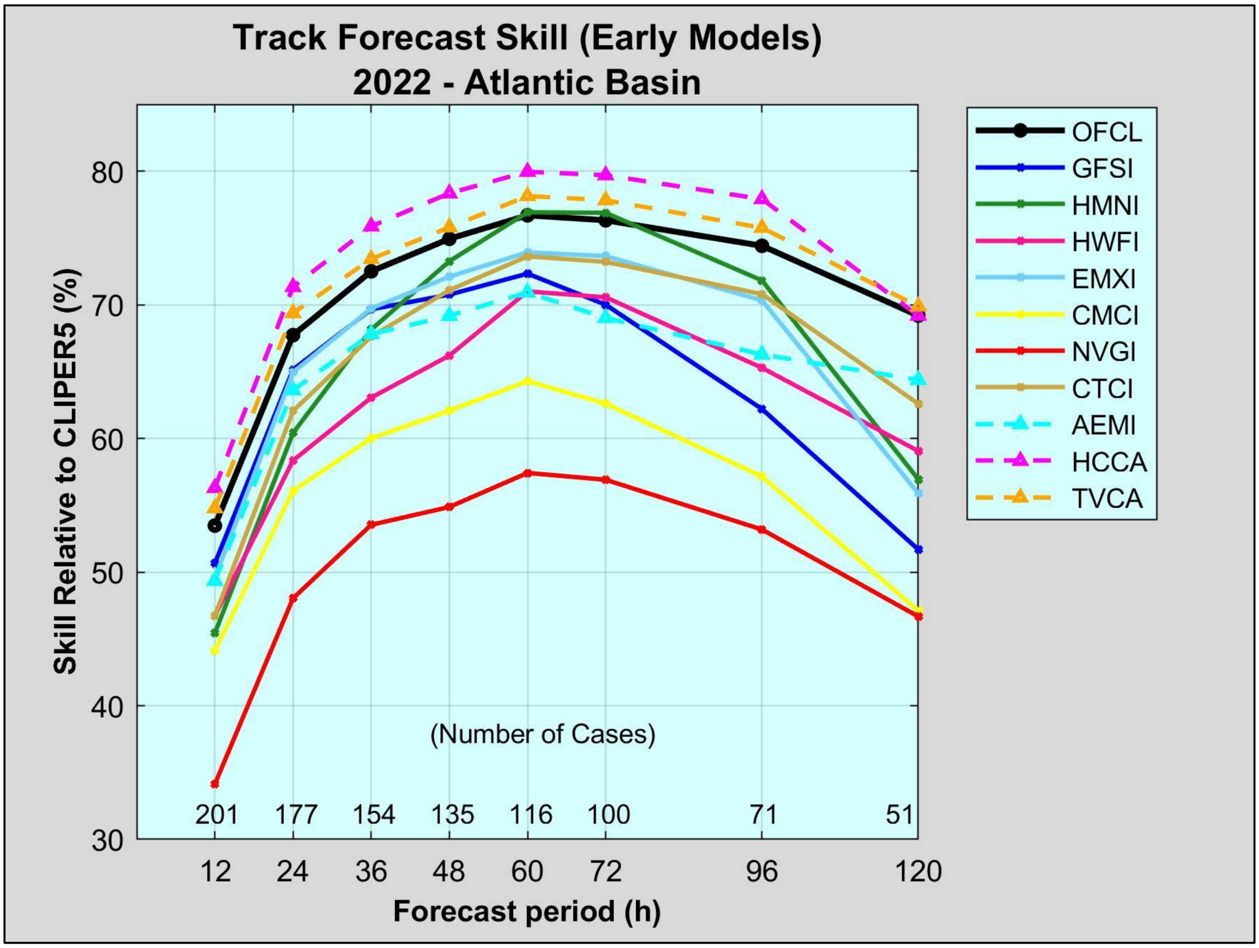


Figure 5. Homogenous comparison for selected Atlantic basin early track models for 2022. This verification includes only those models that were available at least 2/3 of the time (see text).

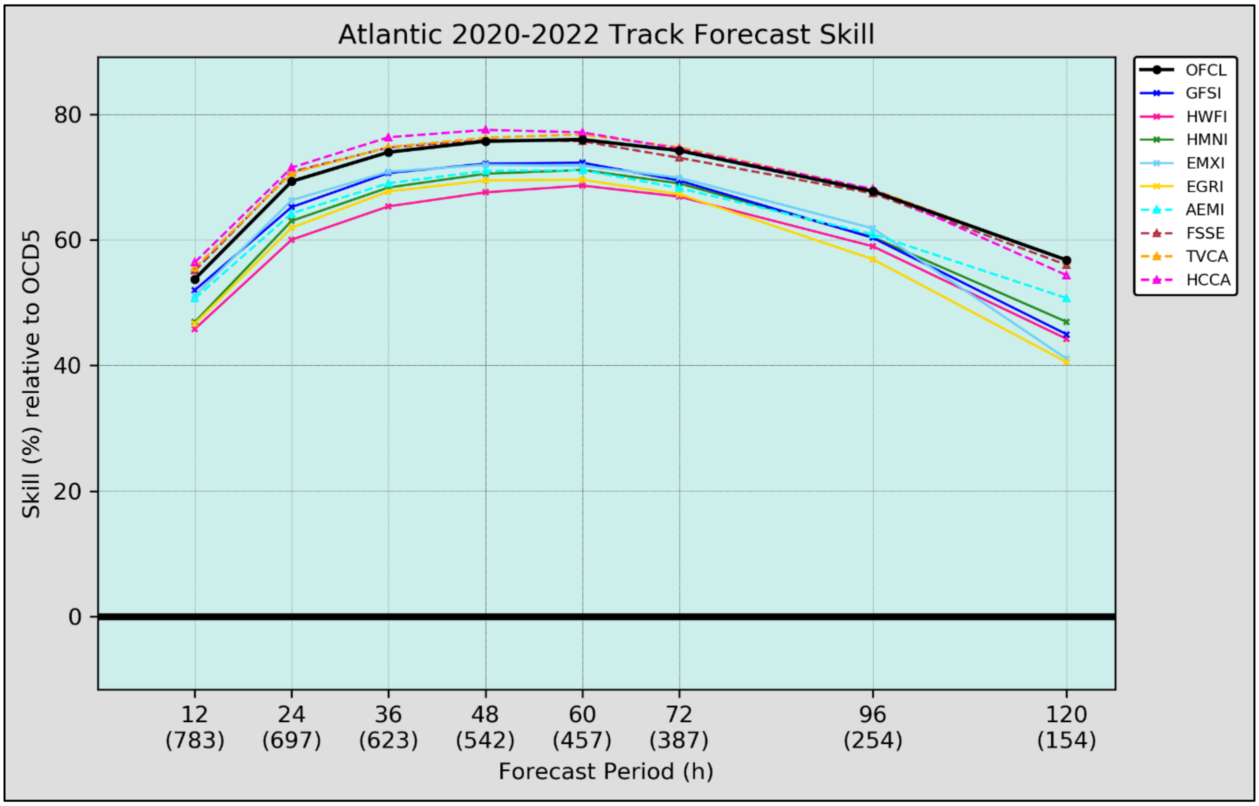


Figure 6. Homogenous comparison for selected Atlantic basin early track models for 2020-2022.

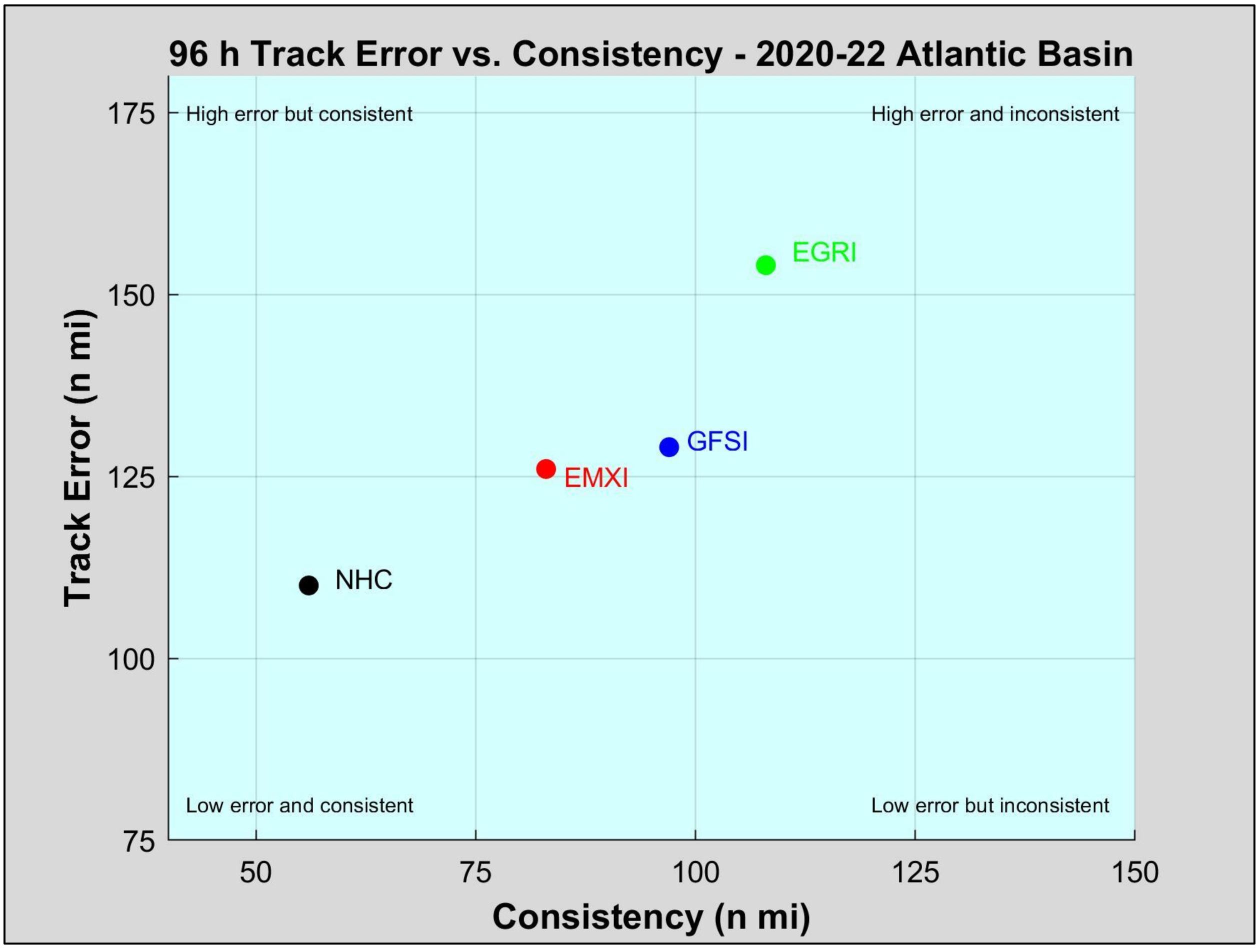


Figure 7. Track error vs. consistency around the 96-h forecast period in the Atlantic basin of GFSI, EMXI, EGRI, and OFCL (NHC) from 2020-22.

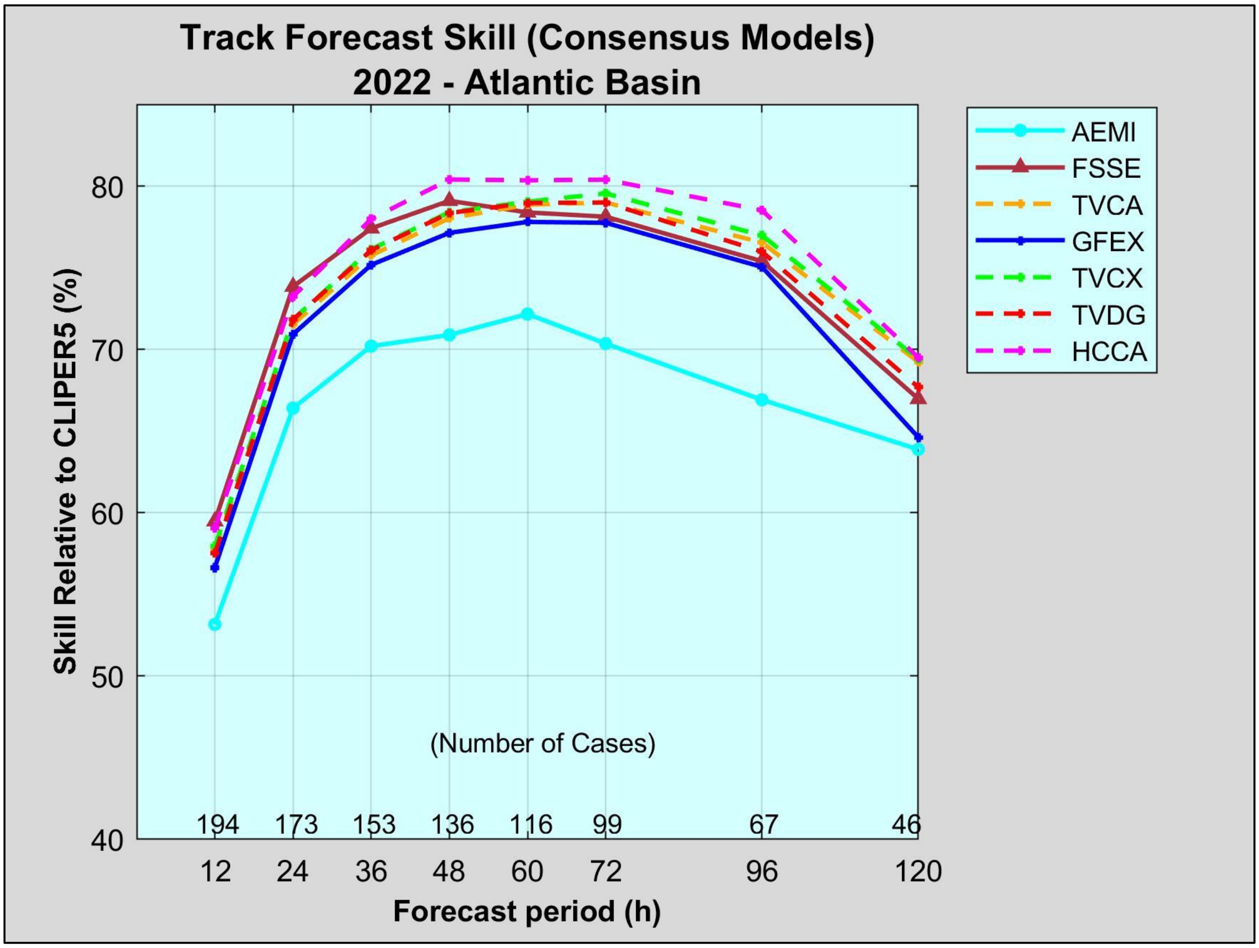


Figure 8. Homogenous comparison of the primary Atlantic basin track consensus models for 2022.

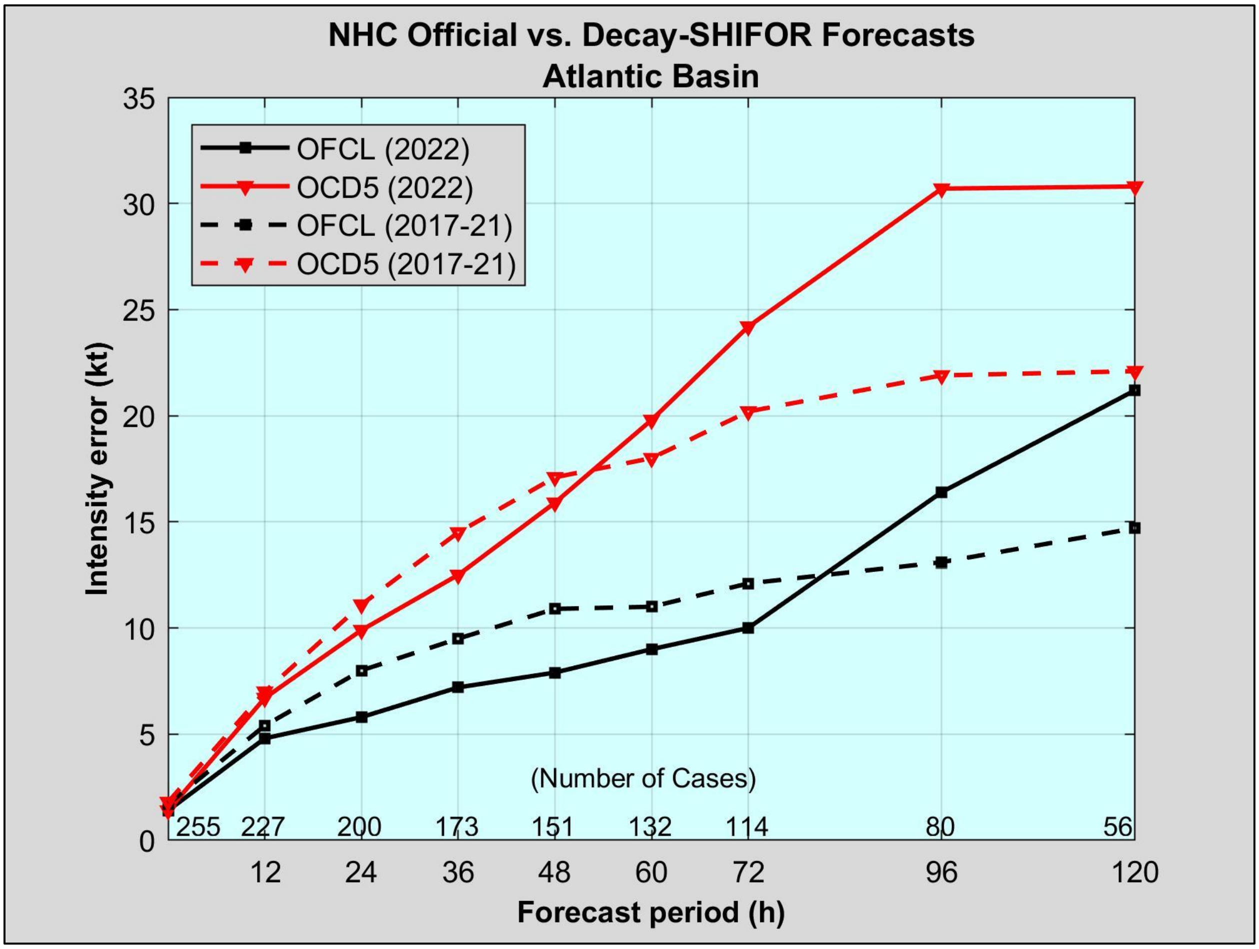
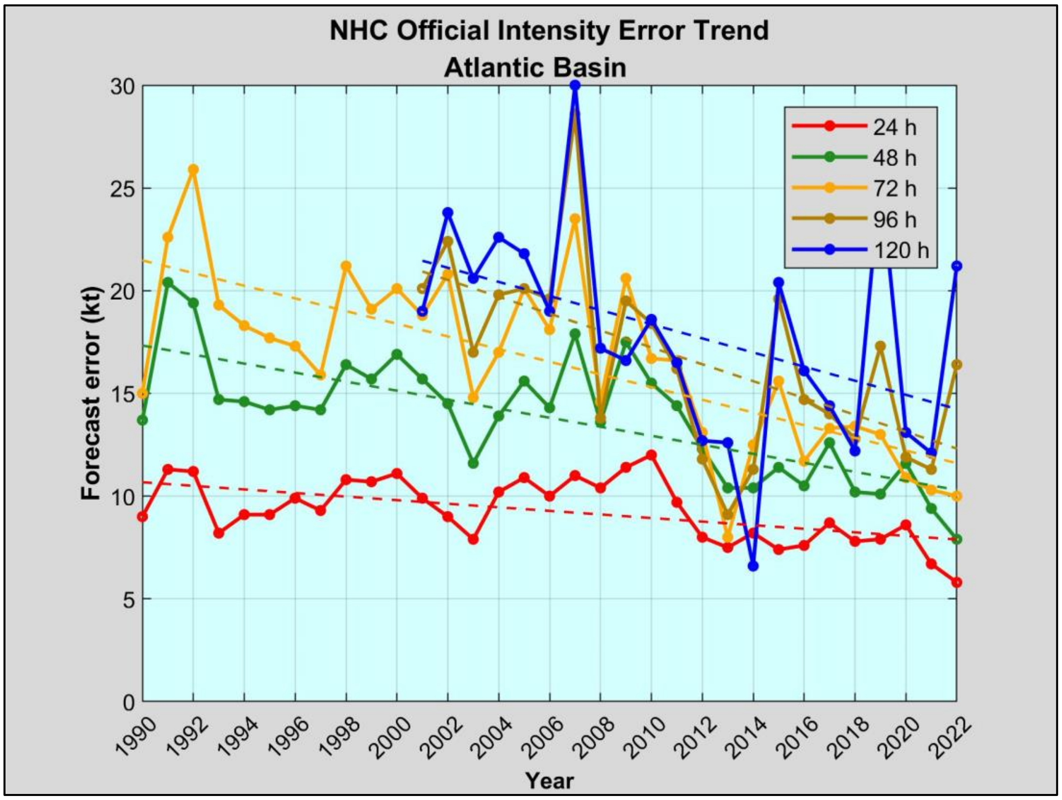


Figure 9. NHC official and Decay-SHIFOR5 (OCD5) Atlantic basin average intensity errors for 2022 (solid lines) and 2017-2021 (dashed lines).



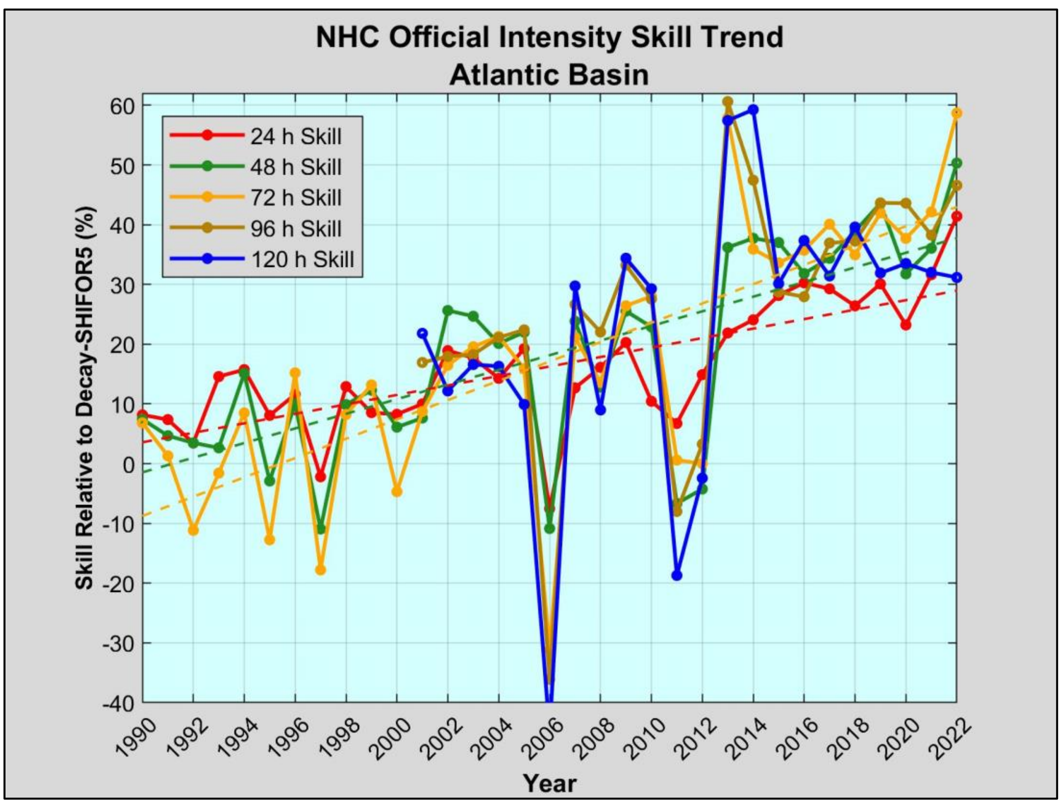


Figure 10. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the Atlantic basin.

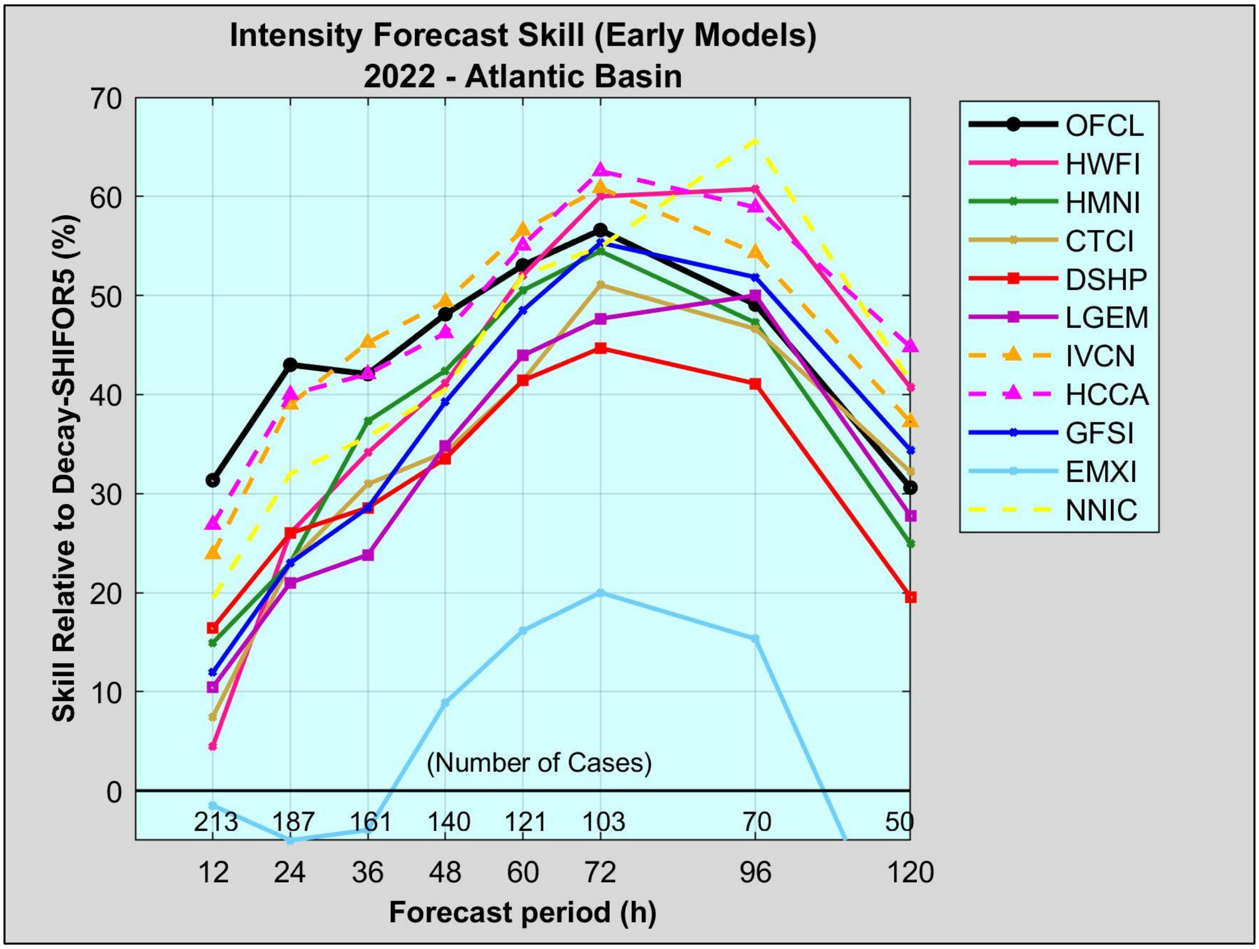


Figure 11. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2022.

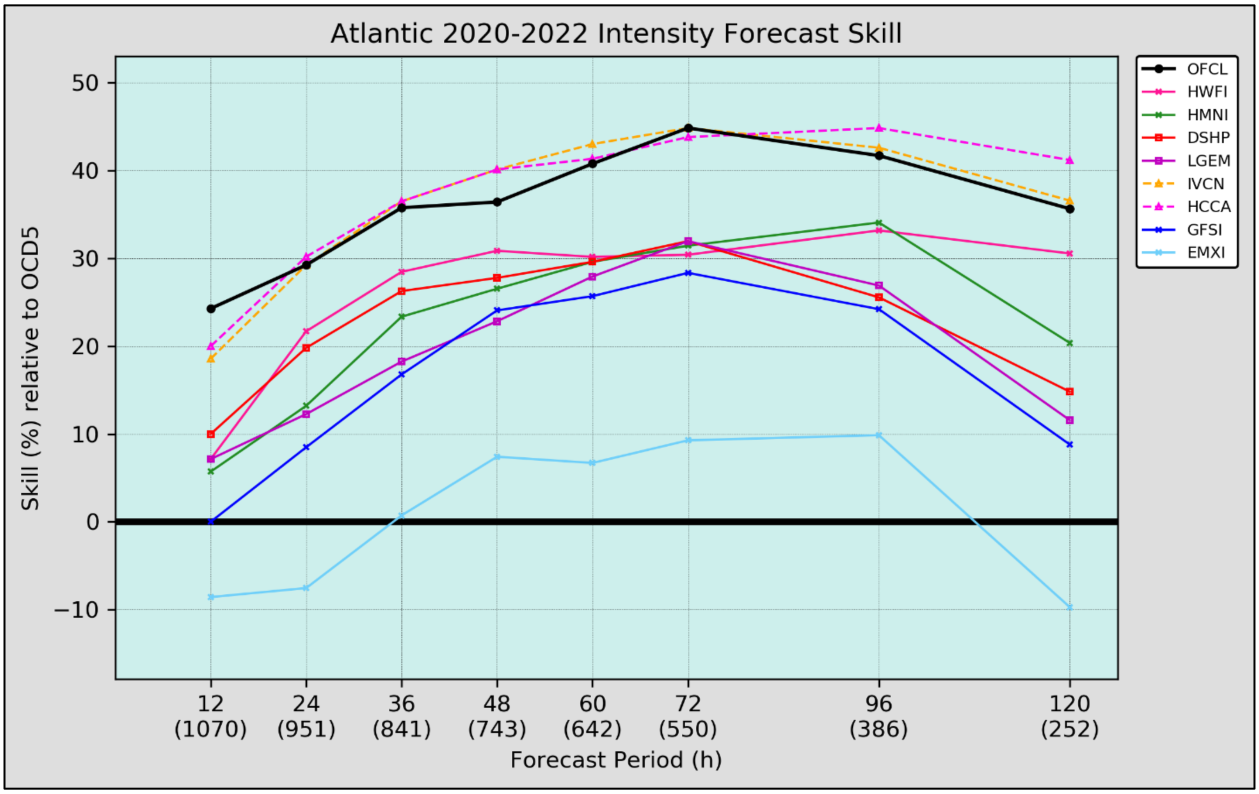


Figure 12. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2020-2022.

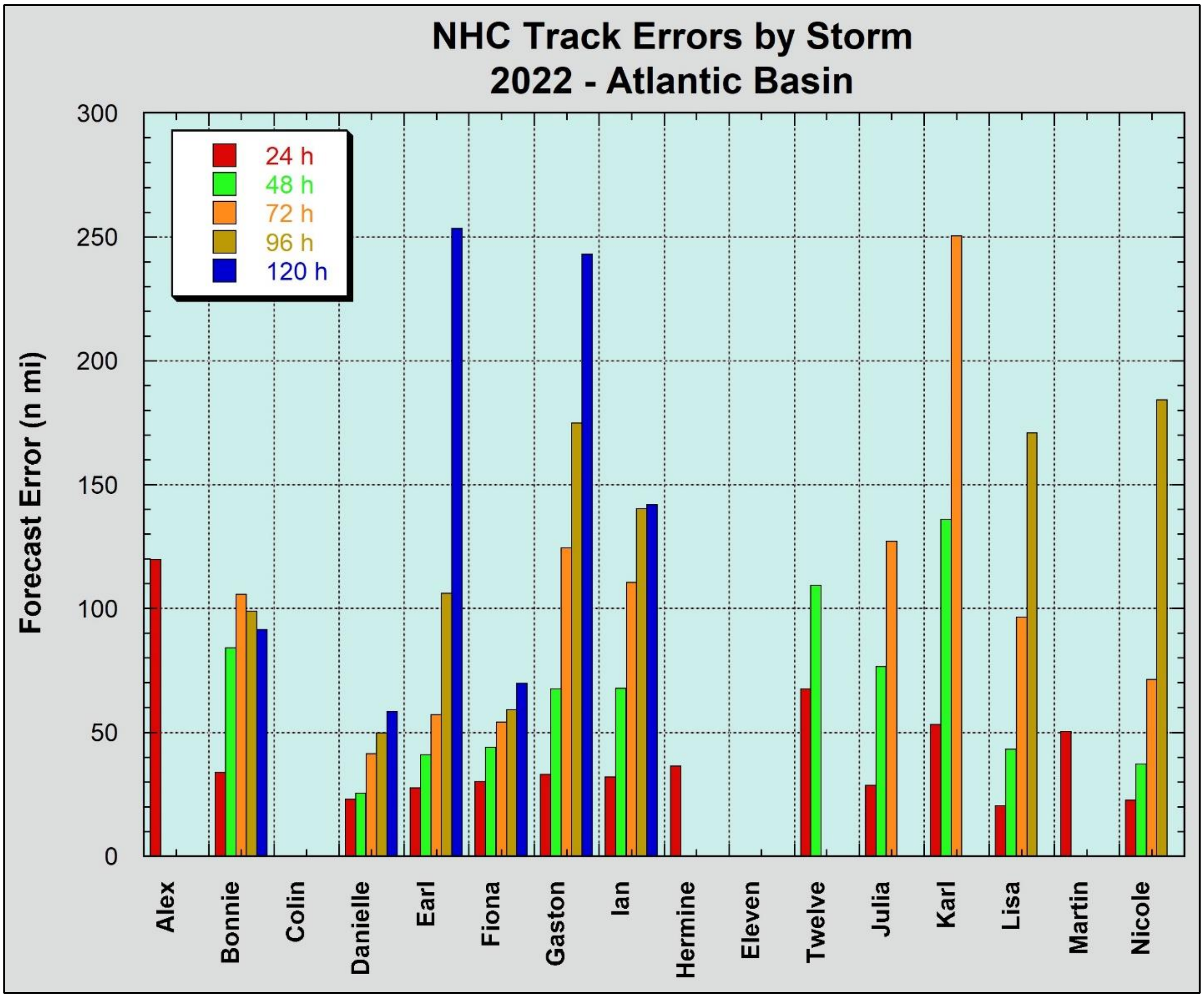


Figure 13. 2022 NHC official track errors by tropical cyclone at 24, 48, 72, 96 and 120 h.

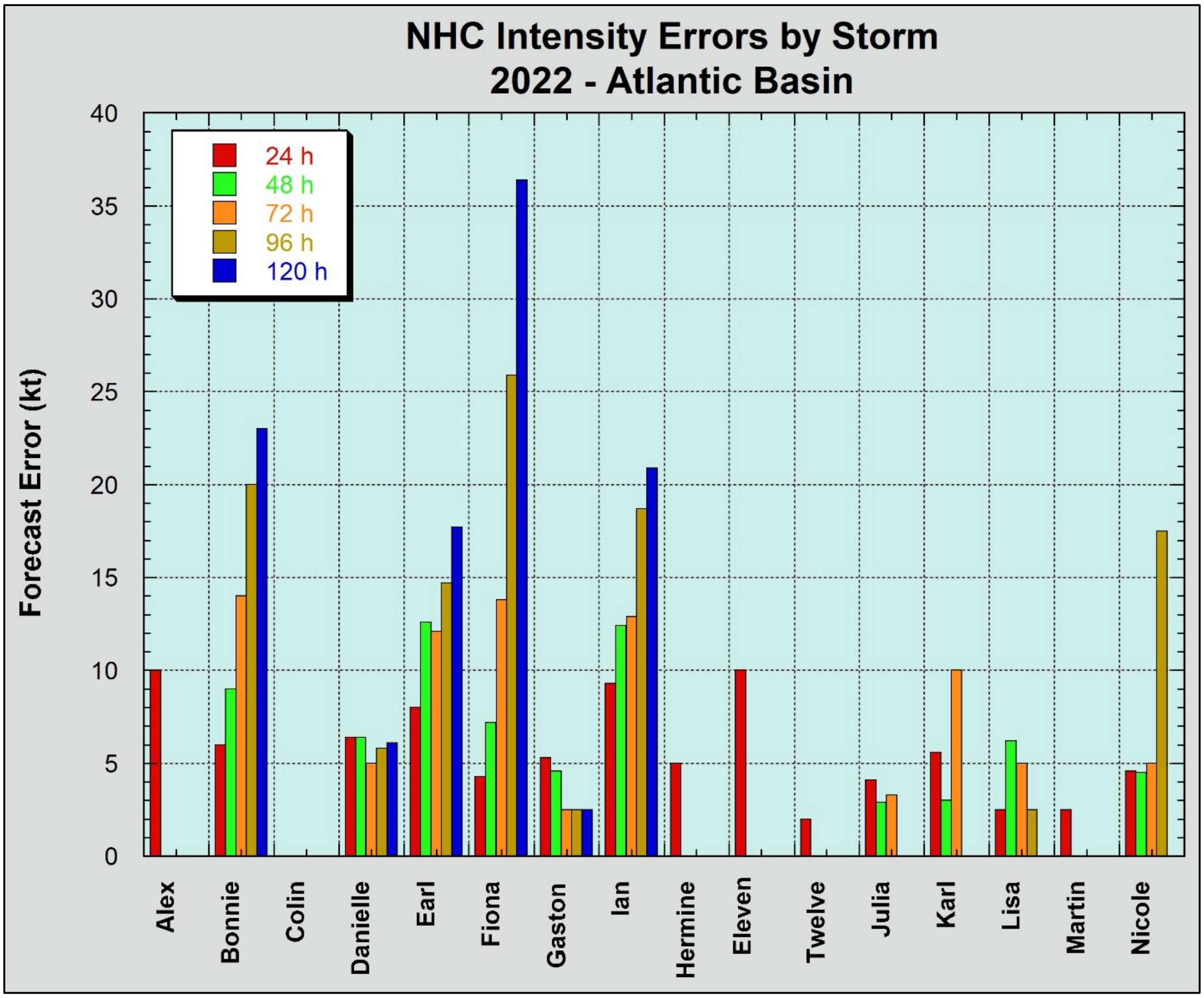


Figure 14. 20212 NHC official intensity errors by tropical cyclone at 24, 48, 72, 96 and 120 h.

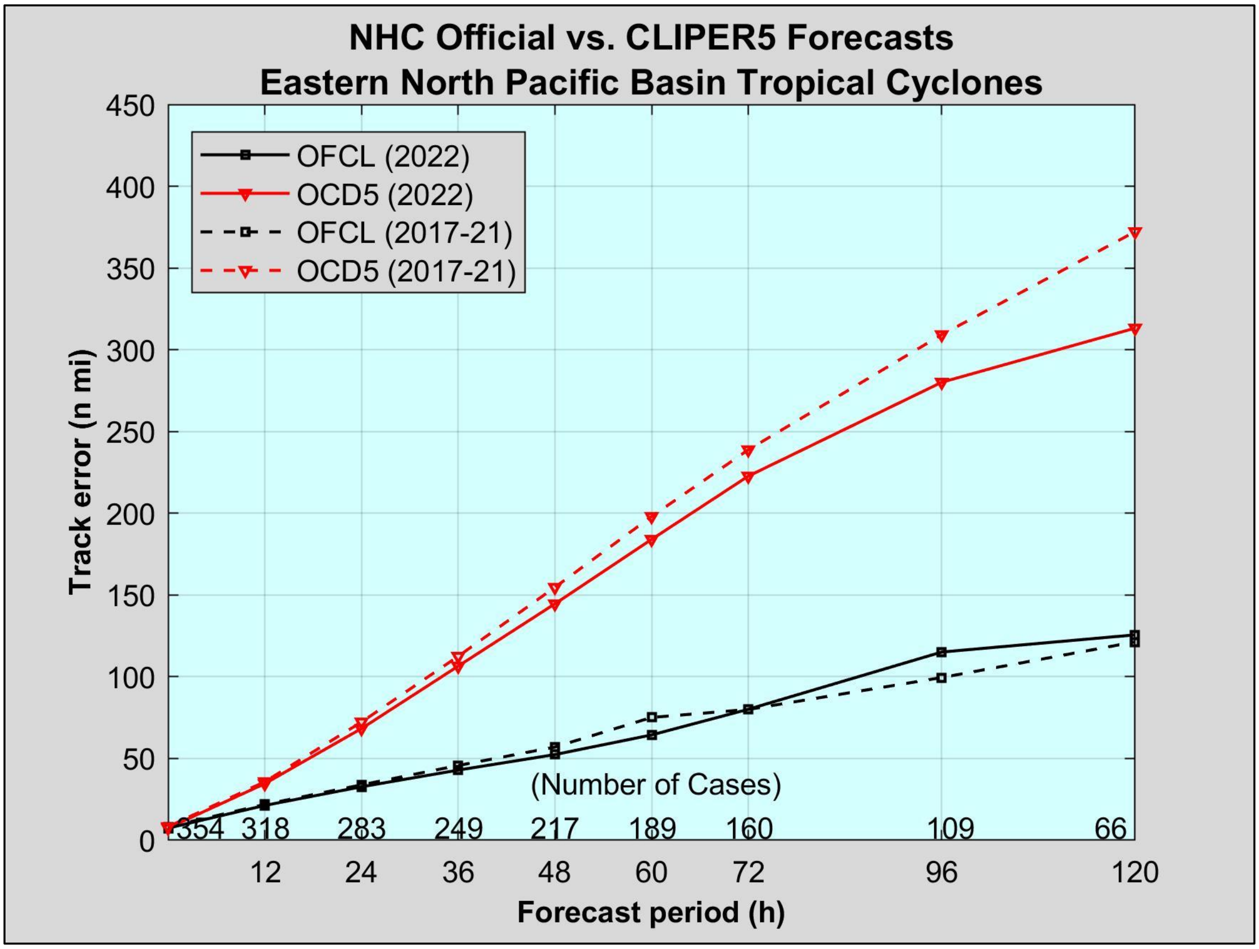


Figure 15. NHC official and CLIPER5 (OCD5) eastern North Pacific basin average track errors for 2022 (solid lines) and 2017-2021 (dashed lines).

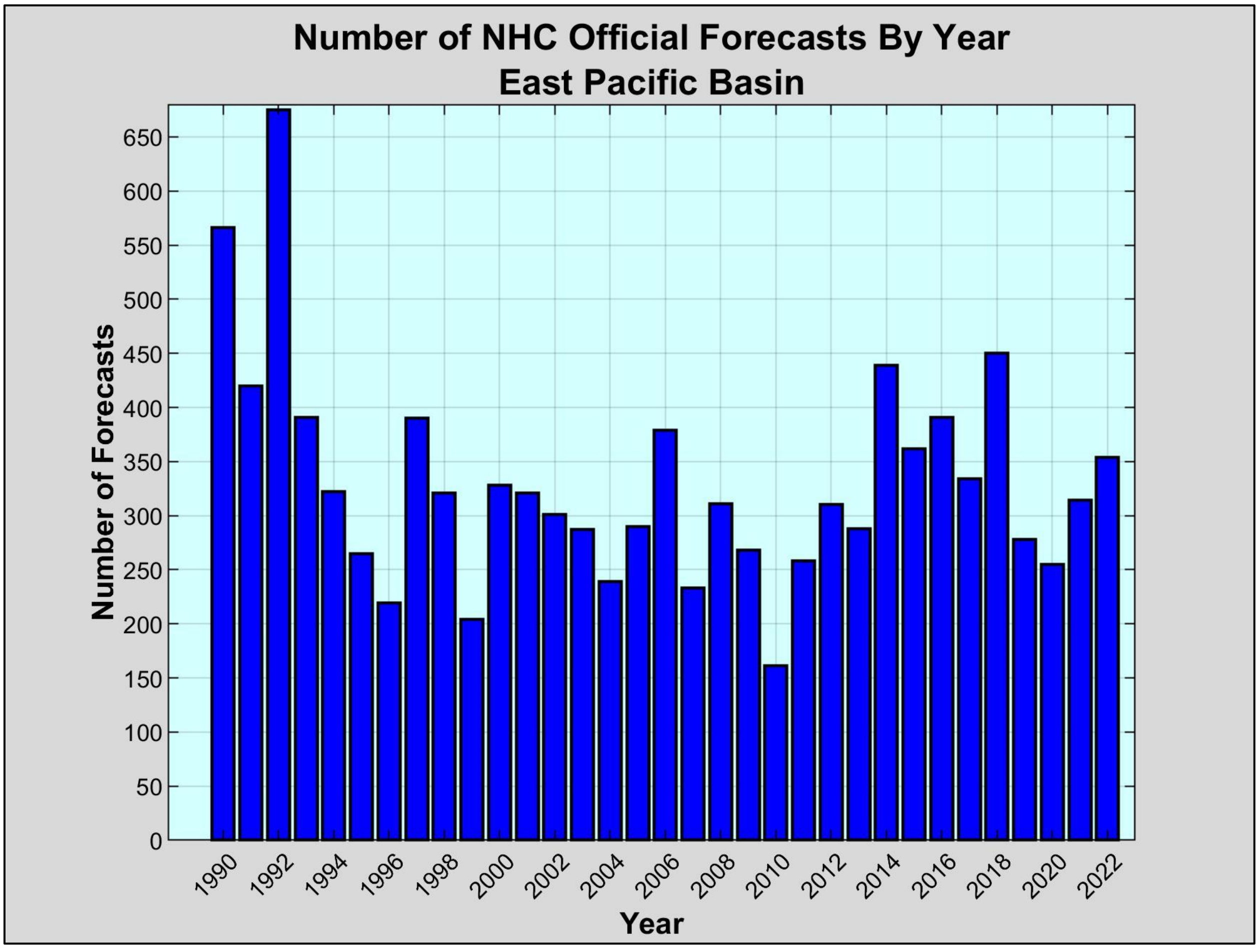


Figure 16. Number of NHC official forecasts for the eastern North Pacific basin stratified by year.

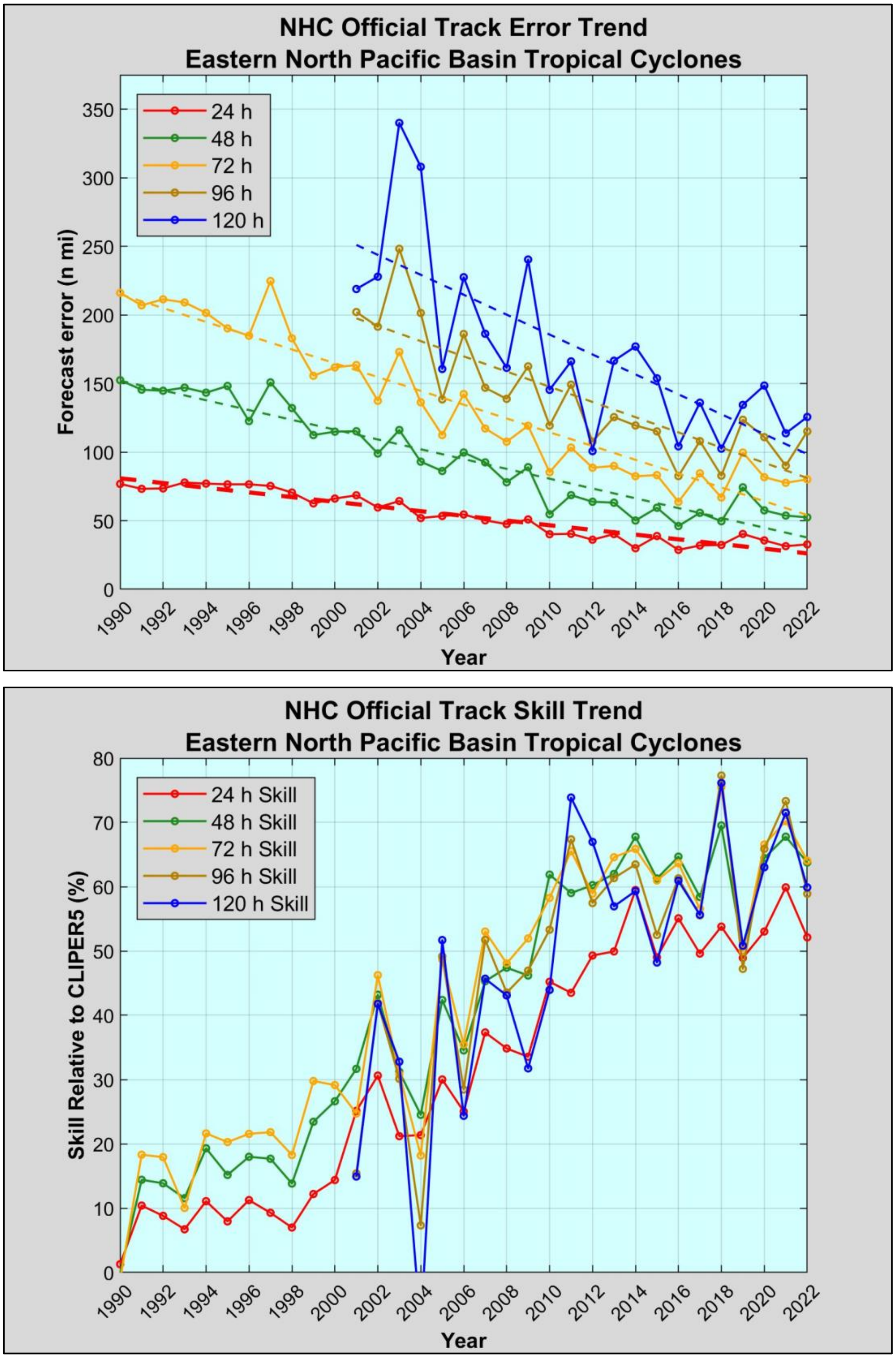


Figure 17. Recent trends in NHC official track forecast error (top) and skill (bottom) for the eastern North Pacific basin.

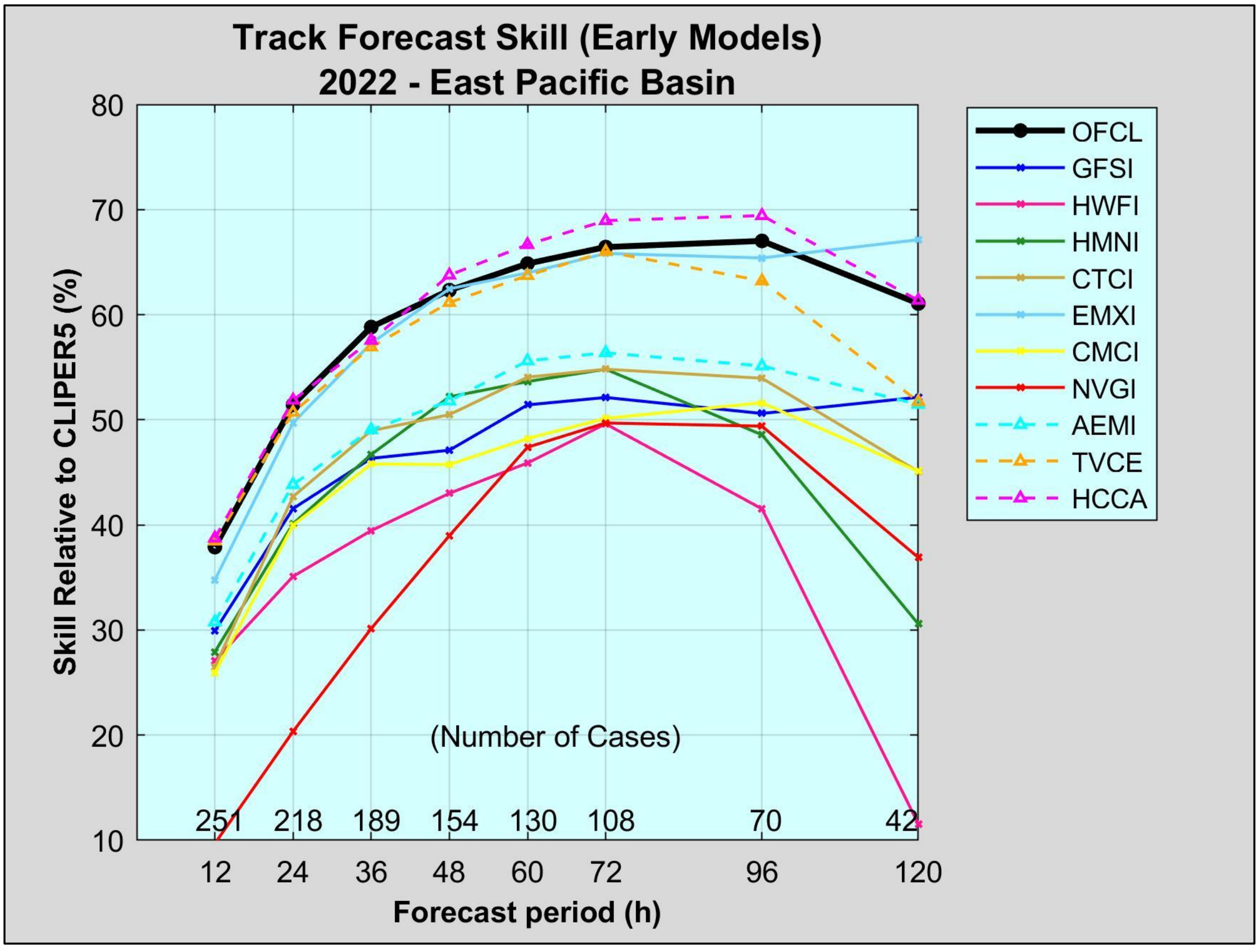


Figure 18. Homogenous comparison for selected eastern North Pacific early track models for 2022. This verification includes only those models that were available at least 2/3 of the time (see text).

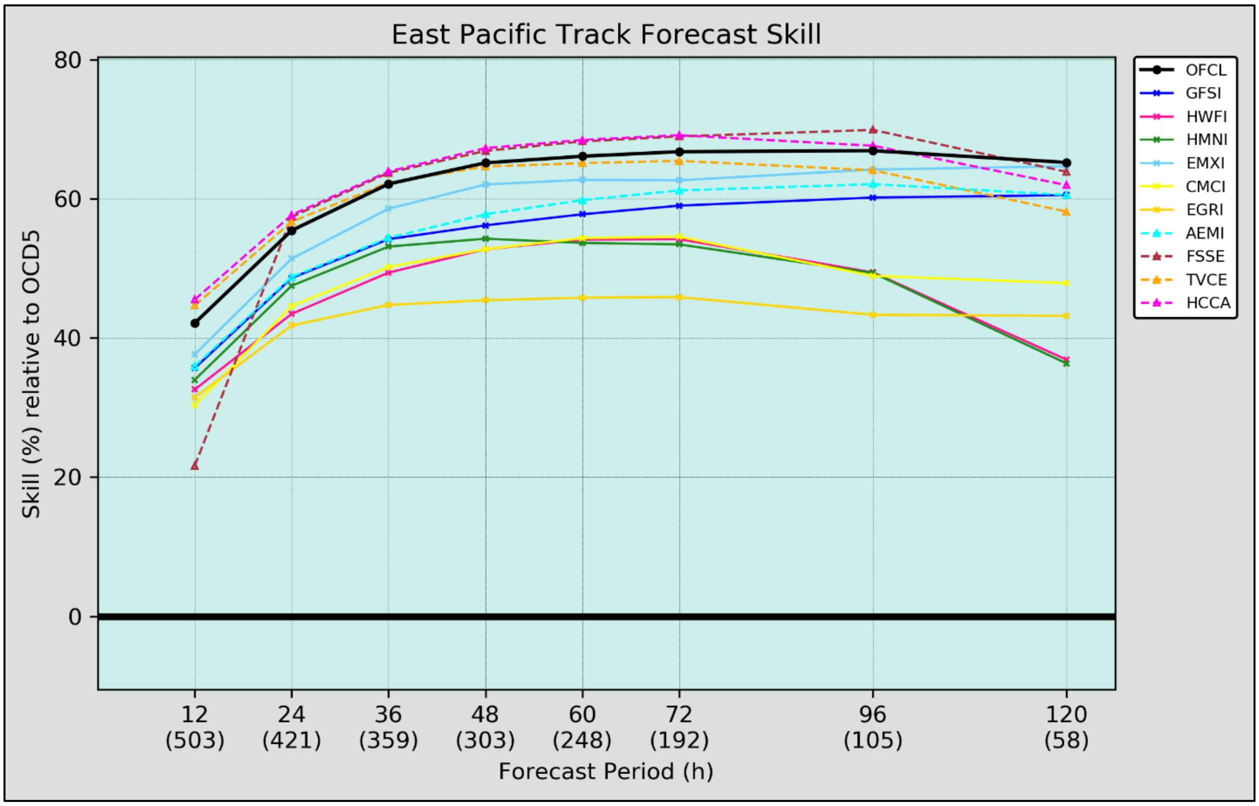


Figure 19. Homogenous comparison of track forecast skill for selected eastern North Pacific basin early models for 2020-2022.

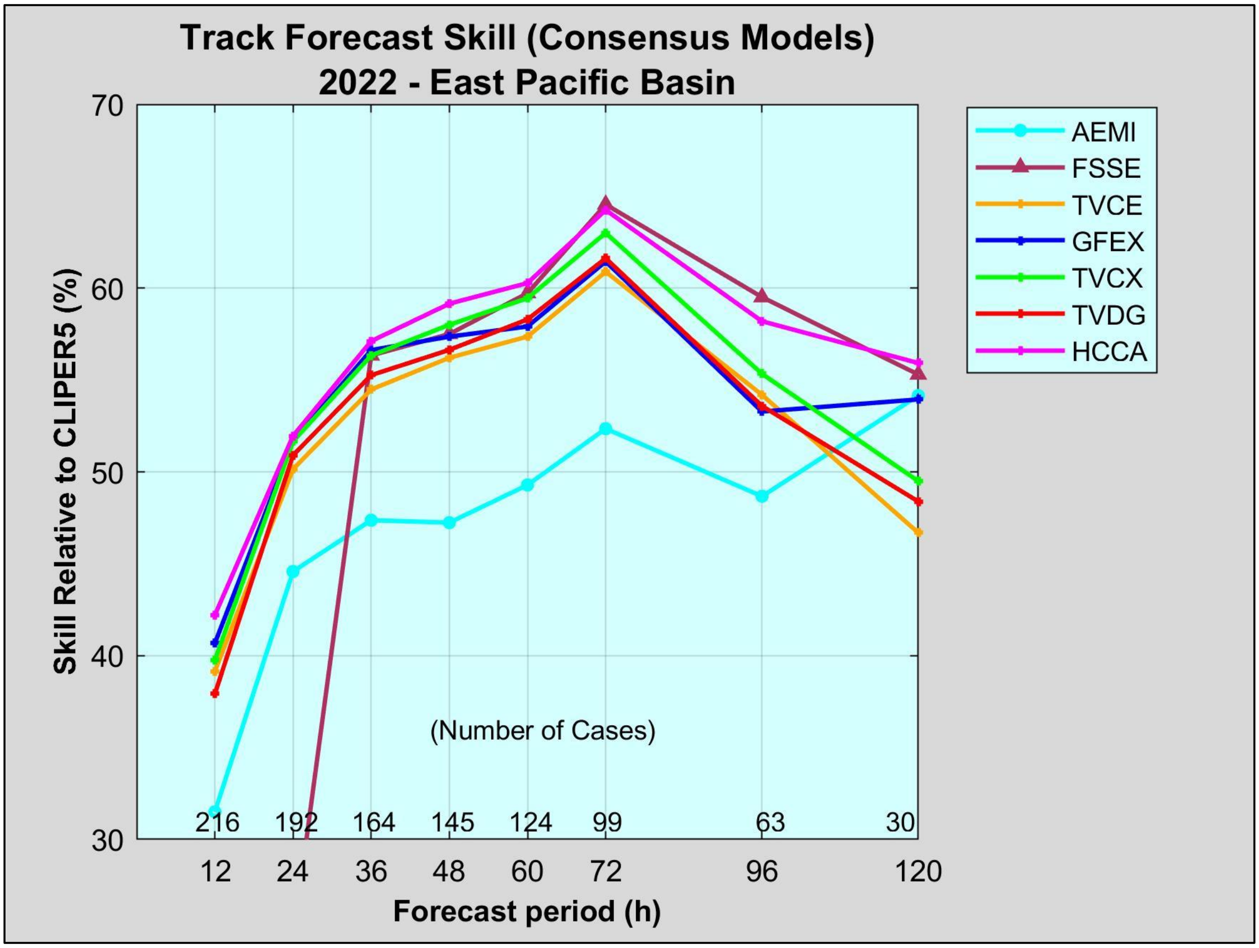


Figure 20. Homogenous comparison of the primary eastern North Pacific basin track consensus models for 2022.

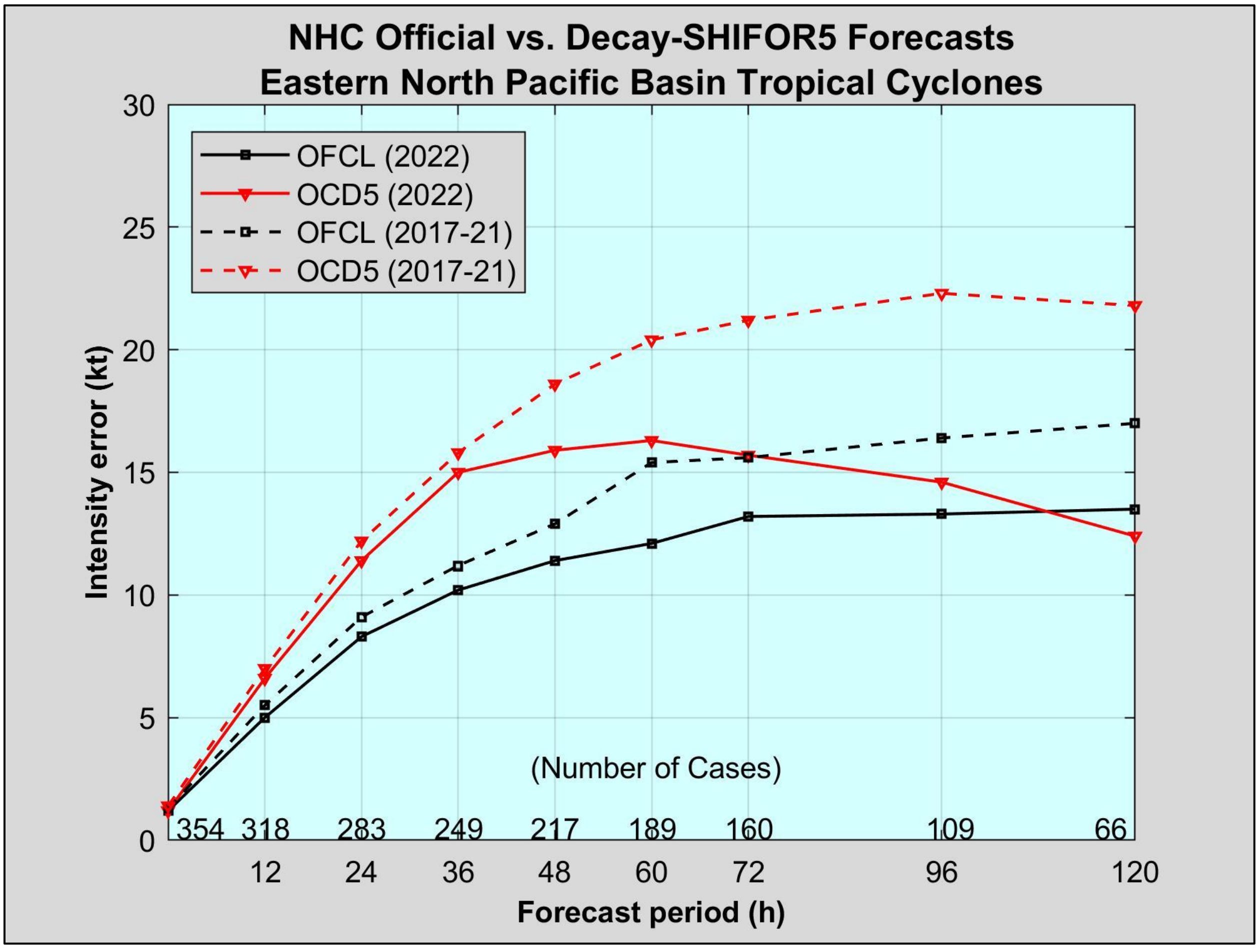
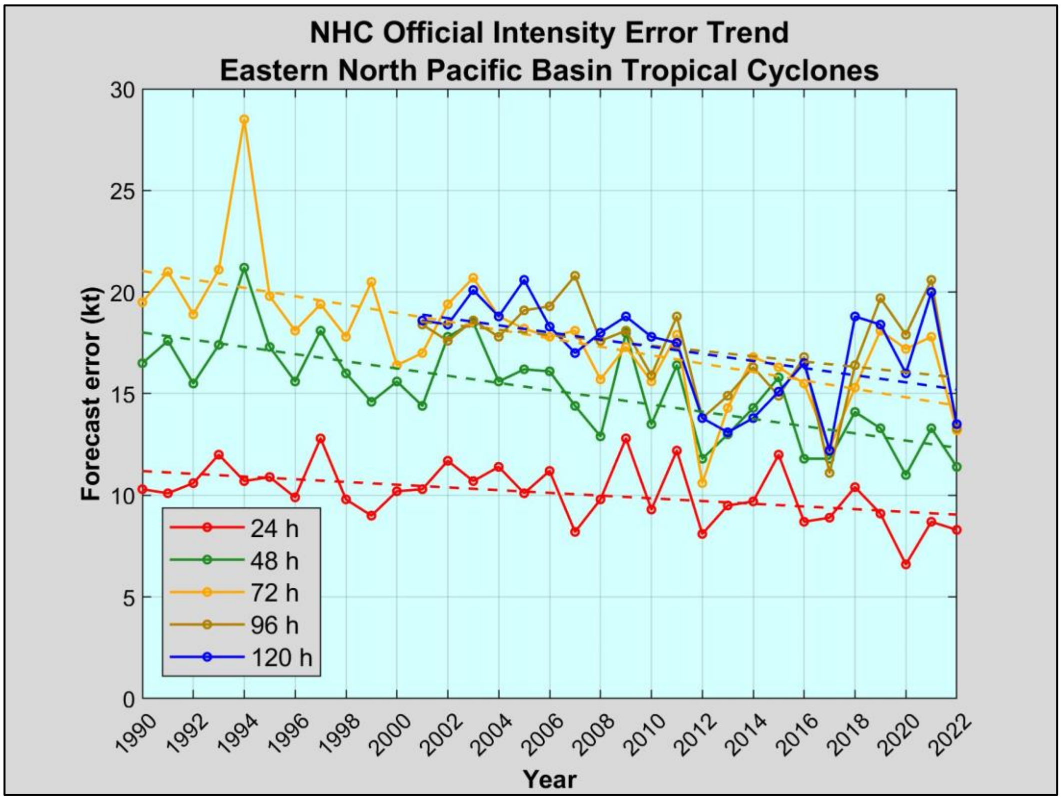


Figure 21. NHC official and Decay-SHIFOR5 (OCD5) eastern North Pacific basin average intensity errors for 2022 (solid lines) and 2017-2021 (dashed lines).



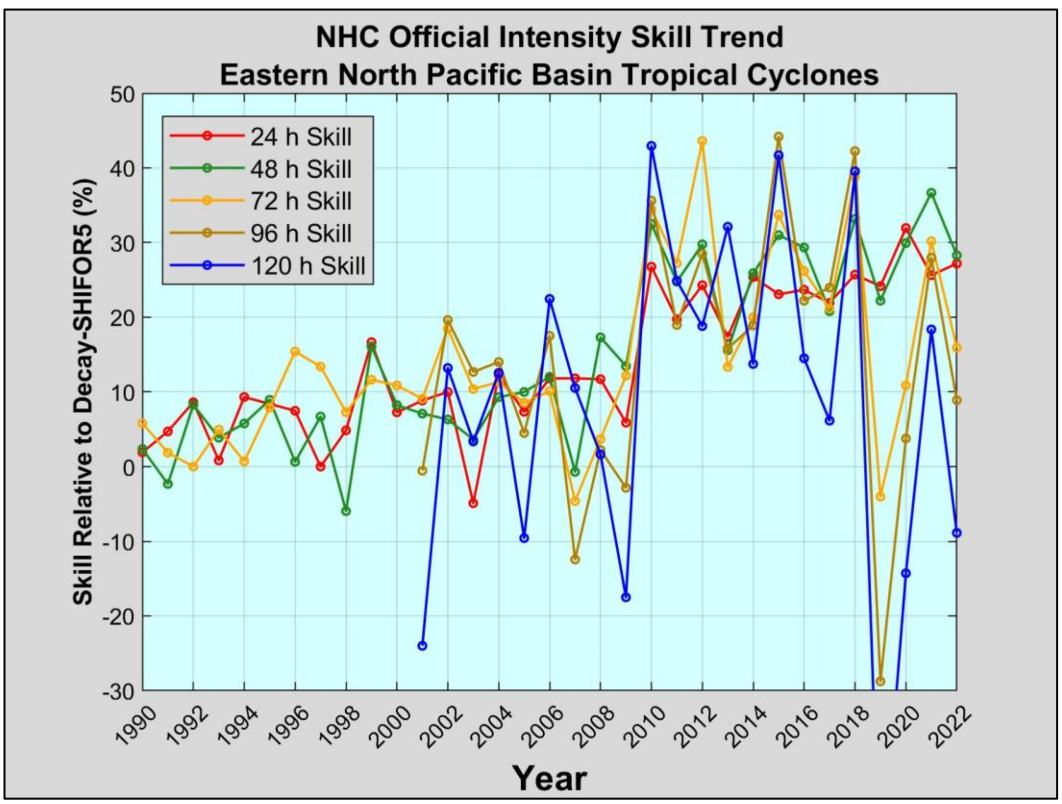


Figure 22. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the eastern North Pacific basin.

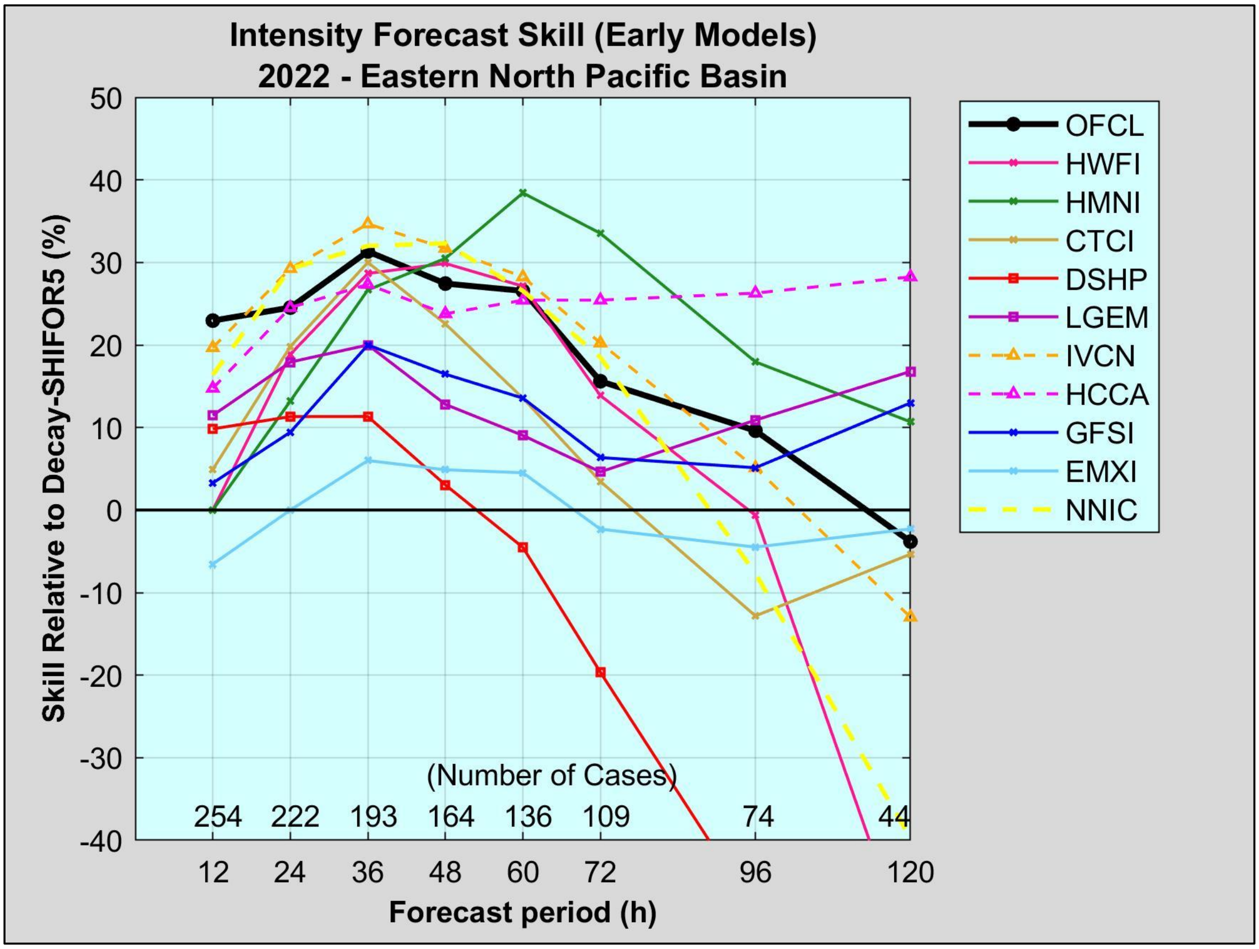


Figure 23. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2022.

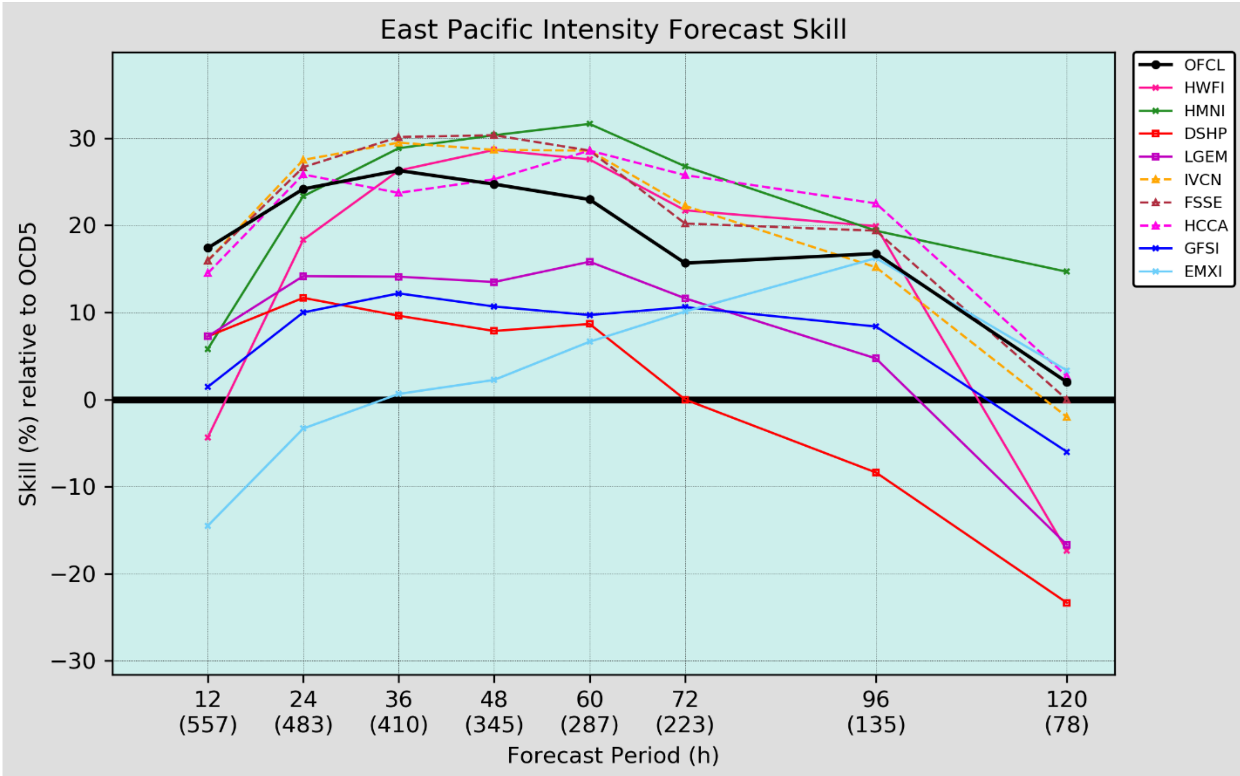
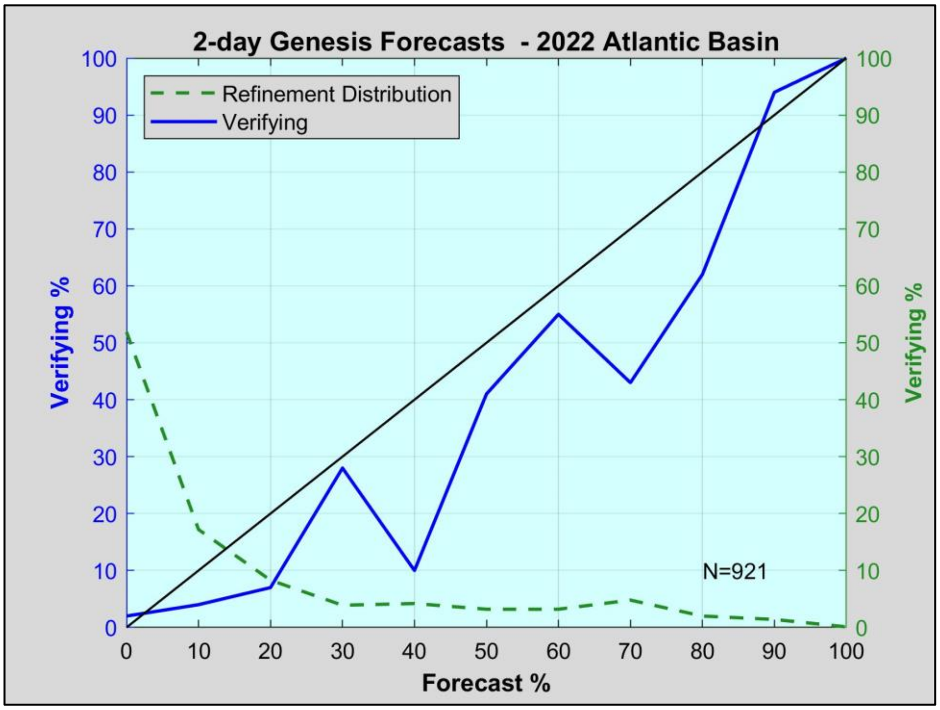


Figure 24. Homogenous comparison of forecast intensity skill for selected eastern North Pacific basin early guidance models for 2020-2022.



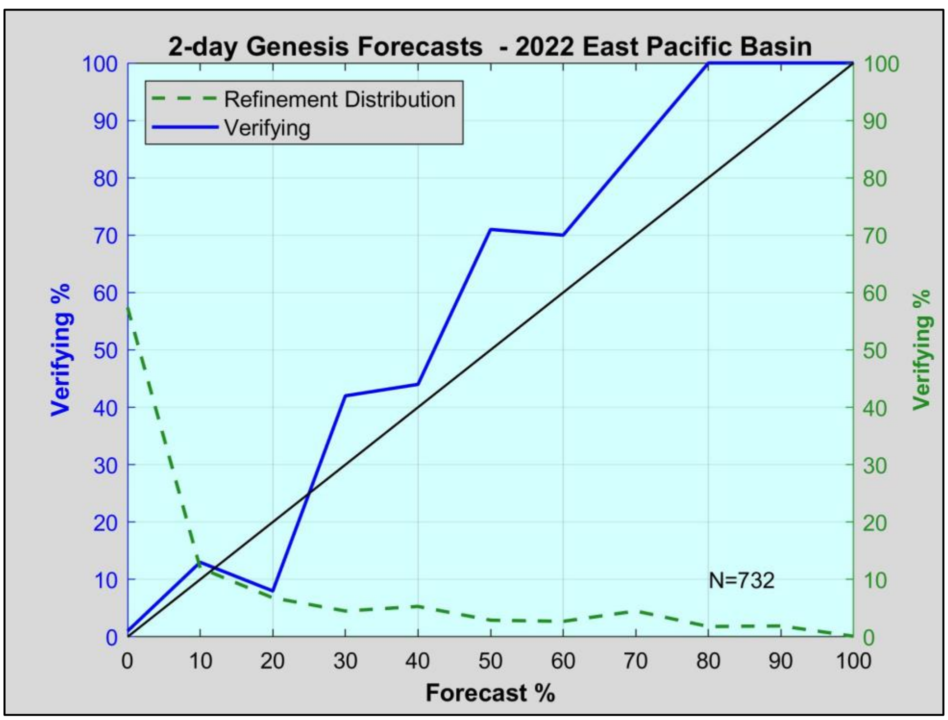
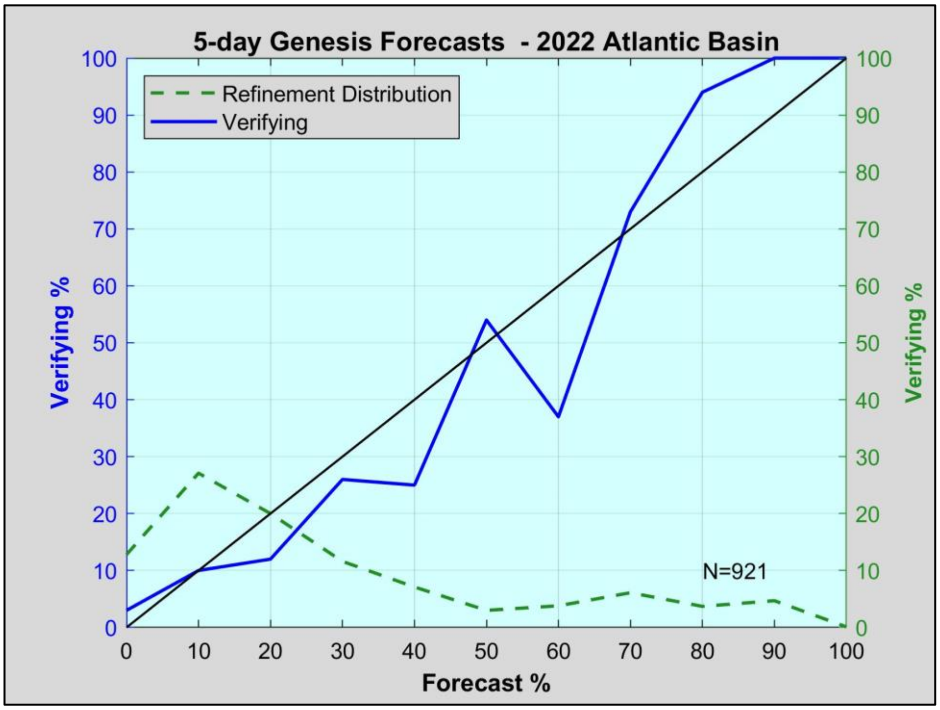


Figure 25. Reliability diagram for Atlantic (top) and eastern North Pacific (bottom) probabilistic tropical cyclogenesis 48-h forecasts for 2022. The solid lines indicate the relationship between the forecasts and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the forecasts were distributed among the possible forecast values.



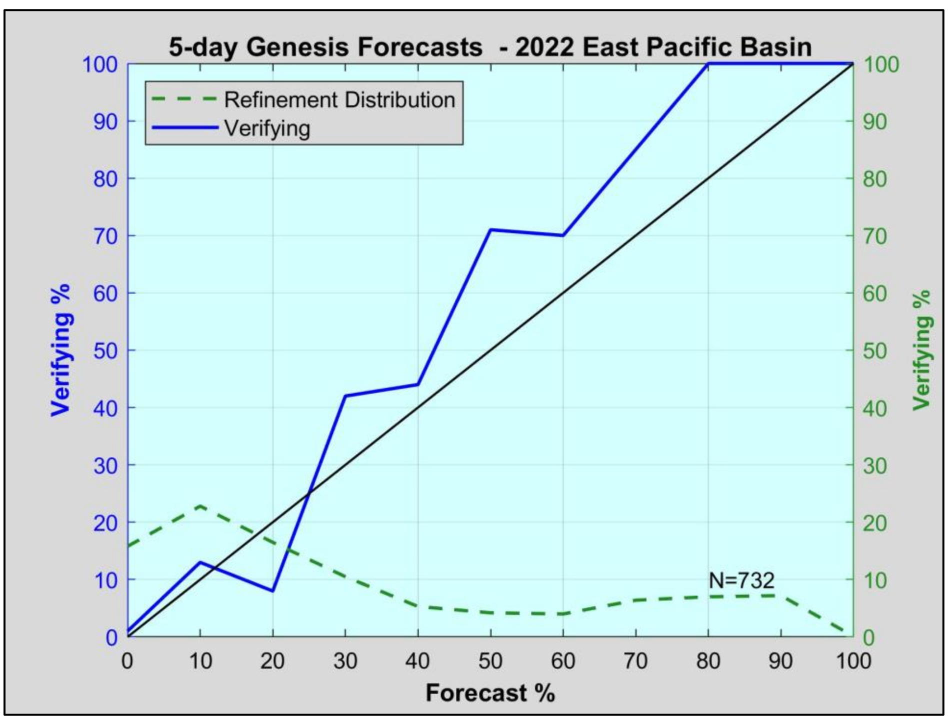


Figure 26. As described for Fig. 25, except for 120-h forecasts.