NATIONAL HURRICANE CENTER FORECAST VERIFICATION REPORT

2018 HURRICANE SEASON

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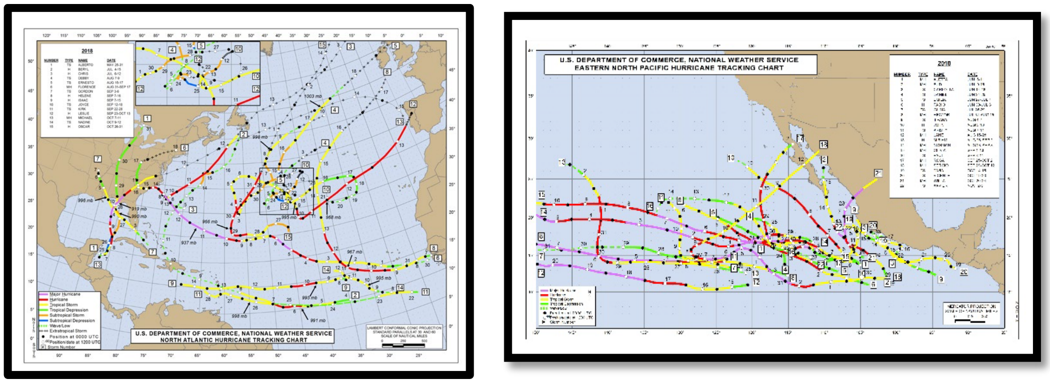

2018 HURRICANE SEASON TRACK MAP OF THE ATLANTIC BASIN (LEFT) AND THE EASTERN NORTH PACIFIC BASIN (RIGHT).

ABSTRACT

The 2018 Atlantic hurricane season had above-normal activity, with 390 official forecasts issued. The mean NHC official track forecast errors in the Atlantic basin were close to the previous 5-yr means at most forecast times. Although no records for track accuracy were set in 2018, track forecast skill was near or at all-time highs. However, the track forecasts were slightly beaten by the consensus models at some time periods. EMXI was the best-performing individual model overall. GFSI, AEMI, and HWFI were strong performers at the shorter lead times, and EGRI was the second best model at longer lead times. CMCI, NVGI, and HMNI performed less well. The Government Performance and Results Act of 1993 (GPRA) track goal was met.

Mean official intensity errors for the Atlantic basin in 2018 were lower than the 5-yr means at most forecast times. Decay-SHIFOR errors in 2018 were close to their 5-yr means in the short term, but were also lower than their 5-yr means at the longer forecast times. The official forecasts were quite skillful, but were slightly beaten by some of the consensus aids. Records for intensity accuracy were set at 36 and 48 h in 2018. Among the guidance, FSSE, IVCN, and HCCA were the best performers. HWFI was the best individual model in the short term, and GFSI was the best

individual model at the longer lead times. LGEM, HMNI, and DSHP were fair performers while EMXI lagged behind. The GPRA intensity goal was met.

There were 450 official forecasts issued in the eastern North Pacific basin in 2018, although only 161 of these verified at 120 h. This level of forecast activity was above average and the highest number of forecasts since 1992. No records for track accuracy were set in this basin in 2018. The official track forecasts were very skillful, but they were outperformed by TVCE and occasionally by HCCA and FSSE. EMXI was the best individual model in the short term, and AEMI, GFSI, and HMNI had similar or slightly more skill than EMXI at the longer lead times.

For intensity, the official forecast errors in the eastern North Pacific basin were higher than the 5-yr means at all forecast times, but Decay-SHIFOR errors were significantly higher than their 5-yr means, indicating that the season's storms were more difficult than average to predict. No records for intensity accuracy were set. The official forecasts were more skillful than the models at 12 and 120 h, but were slightly beaten by HCCA at some of the other forecast times. IVCN and HWFI were the next best models, followed by HMNI. DSHP, LGEM, and GFSI were fair performers, while EMXI was less skillful.

An evaluation of track performance during the 2016-18 period in the Atlantic basin indicates that HCCA, FSSE, and TVCA were the best models, and EMXI was competitive with those models from 72 to 120 h. The official track forecasts for the 3-yr sample had skill quite close to the best aids throughout the forecast period. For intensity in the Atlantic basin, the official track forecasts performed well, but were beaten by FSSE, HCCA, and IVCN at several time periods. HWFI was the best individual model at all forecast times for this sample.

A three-year evaluation from 2016-18 in the eastern North Pacific 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 models in that basin.

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 2018 indicate that the 48-h and 120-h probabilistic forecasts had a low bias (under-forecast) at most probabilities. In the eastern North Pacific basin, the 48-h probabilistic forecasts were well calibrated at both the high and low probabilities, but there was a notable low bias at the medium probabilities. A low bias was present at most 120-h 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 (designated as "potential tropical cyclones"), 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, 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 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.

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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.

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, 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

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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.

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. 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.

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

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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”.

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 FSU "super-ensemble", for example, combines its individual components on the basis of past performance and attempts to correct for biases in those components (Williford et al. 2003). 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. Potential tropical cyclones have been excluded from this verification. These statistics are based on forecast and best track data sets taken from the Automated Tropical Cyclone Forecast (ATCF) System[10] on 6 May 2019 for the Atlantic basin, and on 2 April 2019 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 2018 verification and previews anticipated changes for 2019.

2. Atlantic Basin

a. 2018 season overview – Track

Figure 1 and Table 2 present the results of the NHC official track forecast verification for the 2018 season, along with results averaged for the previous 5-yr period, 2013-2017. In 2018, the NHC issued 390 Atlantic basin tropical cyclone forecasts[11], a number well above the long-term average of 322 (Fig. 2). Mean track errors ranged from 24 n mi at 12 h to 186 n mi at 120

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[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.

[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.

h. The mean official track forecast errors in 2018 were slightly smaller than the previous 5-yr means from 24 to 48 h, but similar to or slightly larger than the means at the other forecast periods. The CLIPER errors for 2018 were larger than average, and significantly larger from 72 to 120 h, indicating that the season's storms were more challenging to forecast than normal. No records for track accuracy were set in 2018. The official track forecast vector biases were westward or west-northwestward (i.e., the official forecast tended to fall to the west or west-northwest of the verifying position) at most forecast periods. Track forecast skill ranged from 49% at 12 h to 76% at 48 h (Table 2). The track errors in 2018 increased from the record low errors set in 2017, however, over the past 25 to 30 years, the 24−72-h track forecast errors have been reduced by 70 to 75% (Fig. 3). Track forecast error reductions of about 60% have occurred over the past 15 years or so for the 96- and 120-h forecast periods. Although the track errors increased slightly in 2018, an evaluation of track skill indicates that the skill levels are at or near all-time highs for all forecast periods (Fig. 3). Figure 4 indicates that on average the NHC track errors are lower between 24 and 72 h for initially stronger cyclones (e.g., better for hurricanes than for tropical depressions and tropical storms), but that relationship breaks down after 72 h.

Note that the mean official error in Fig. 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 Fig. 1 contain both true analysis error and representativeness error.

Table 3a presents a homogeneous[12] verification for the official forecast along with a selection of early models for 2018. 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 forecast and the early track models in terms of skill are presented in Fig. 5. The figure shows that the official forecasts were highly skillful, and they were only slightly bested at some forecast times by the consensus models HCCA, FSSE, and TVCA. Among the individual models, EMXI was the best-performing aid, and it had similar skill levels to the official forecasts and the consensus aids from 72 to 120 h. GFSI, AEMI, and HWFI were strong performers early, however, their skill levels trailed for the longer lead times. Conversely, EGRI was less skillful early, but it was the second best individual model at 96 and 120 h. CMCI, NVGI, and HMNI were less skillful. In fact, HMNI and NVGI were outperformed by the simple TABM and TABS models at 96 and 120 h. An evaluation over the three years 2016-18 (Fig. 6) indicates that HCCA, FSSE, and TVCA were the best models, and they performed close to one another throughout the forecast period. EMXI had less skill early, but it was competitive with the consensus models from 48 to 120 h. The official forecast had skill that was

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[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.

quite close to the best aids throughout the forecast period. EGRI, GFSI, AEMI, and HWFI were fair performers and made up the next best models. CMCI and NVGI performed less well.

Vector biases of the guidance models for 2018 are given in Table 3b. The table shows that the official forecast had similar biases to the consensus aids. Much of the guidance, like the official forecast, had a west or northwest bias at most forecast time periods.

A separate homogeneous verification of the primary consensus models for 2018 is shown in Fig. 7. The figure shows that the skill of HCCA, FSSE, TVCA, TVDG, TVCX were similar to one another. GFEX was not quite as good, as it had skill values a few percent lower than the best consensus models for the shorter lead times. UEMI and AEMI had 5 to 10% less skill than the best models at most forecast periods.

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 2018, the GPRA goal was 65 n mi and the verification for this measure was 60.1 n mi.

b. 2018 season overview – Intensity

Figure 8 and Table 4 present the results of the NHC official intensity forecast verification for the 2018 season, along with results averaged for the preceding 5-yr period. Mean forecast errors in 2018 ranged from 5 kt at 12 h to 13 kt at 72 and 96 h. These errors were slightly lower than the 5-yr means at most forecast times, and well below the mean at 120 h. Records for accuracy were set at 36 and 48 h in 2018. The official forecasts had very little bias through 72 h, but a slight low bias (under-forecast) at 96 and 120 h. Decay-SHIFOR5 errors were close to its 5-yr means from 12 to 72 h, but they were slightly lower than its mean at 96 and 120 h, implying that season's storms were a little easier to predict than normal. Figure 9 indicates that the NHC official errors decreased from the 2017 values at most forecast times, and despite year-to-year variability, there has been a notable decrease in error that began at the start of the decade. Over the long term, the intensity predictions are gradually improving as the forecasts are generally more skillful in the current decade than they were in the previous one.

Table 5a presents a homogeneous verification for the official forecasts and the primary early intensity models for 2018. Intensity biases are given in Table 5b, and forecast skill is presented in Fig. 10. The official forecasts were quite skillful, but they were beaten by IVCN from 24 to 72 h, and occasionally by FSSE and HCCA. Among the individual models, HWFI was the best-performing model through 48 h, and GFSI was the best model from 72 to 120 h. HMNI was a fair performer, but it had less skill than GFSI at all forecast times. DSHP and LGEM were skillful throughout the forecast period, but they had less skill than most of the dynamical models. EMXI was not competitive for this sample. An inspection of the intensity biases (Table 5b) indicates that the majority of the models had little bias in 2018. The exceptions were HMNI and EMXI, which had notable low biases from 72 to 120 h.

An evaluation over the three years 2016-18 (Fig. 11) indicates that the official forecasts have been consistently performing quite well, but they were outperformed by IVCN and HCCA from 36 to 96 h, and by FSSE from 24 to 72 h. For this sample, HWFI was the best individual model at all forecast times, followed by LGEM, GFSI, and DSHP.

The 48-h official intensity error, evaluated for all tropical cyclones, is another GPRA measure for the NHC. In 2018, the GPRA goal was 12 kt and the verification for this measure was 10.2 kt.

c. Verifications for individual storms

Forecast verifications for individual storms are given in Table 6. Of note are the large track errors for Hurricane Helene at most forecast lead times. The NHC forecasts and many of the models had a large slow and left-of-track bias for Helene. It appears that a trough in the central Atlantic was stronger than expected, which resulted in a faster and more eastward track of Helene than predicted. Conversely, the official track forecast errors were quite low for some of the tropical cyclones that affected the United States in 2018, including Hurricanes Florence and Michael and Tropical Storm Gordon. Figure 12 shows an illustration of the official track errors stratified by storm.

With regards to intensity, Hurricane Isaac was one of the more challenging cyclones to predict in 2018. The official intensity forecast errors were higher than the 5-yr averages at all forecast times, and much higher than the mean from 72 to 120 h. The NHC intensity forecasts suffered from a pronounced high bias and generally missed the sudden halt to Isaac's intensification, as well as its subsequent gradual weakening. Figure 13 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=2018&basin=atl**

3. Eastern North Pacific Basin

a. 2018 season overview – Track

The NHC track forecast verification for the 2018 season in the eastern North Pacific, along with results averaged for the previous 5-yr period is presented in Figure 14 and Table 7. There were 450 forecasts issued for the eastern Pacific basin in 2018, which was the highest number of forecasts in this basin since 1992 (Fig. 15). However, only 161 of these forecasts verified at 120 h due to the short lifecycle of some of the tropical cyclones. Mean track errors ranged from 21 n mi at 12 h to 103 n mi at 120 h. These errors were lower than the 5-yr means at all forecast times and substantially lower, by 30%, at 120 h. The CLIPER errors were slightly lower than their respective 5-yr means at 12 and 24 h. However, the CLIPER errors were notably larger than the means from 48 to 120 h, implying that the season's storms were more challenging to forecast than average at the longer lead times, which makes the low official track forecasts errors at the long lead times quite impressive. No records for accuracy were set in this basin in 2018, however. The official track forecast vector biases were small through 72 h, but a more notable north-northeastward bias existed at 96 and 120 h.

Figure 16 shows recent trends in track forecast accuracy and skill for the eastern North Pacific. Errors have been reduced by about 70% for the 24 to 72 h forecasts since 1990, though there has been little change in the errors during the past few years. At the 96 and 120 h forecast times, errors have dropped by about 60% since 2001. Forecast skill in 2018 increased at all forecast times from the 2017 values, and skill levels are at all-time highs from 48 through 120 h.

Table 8a presents a homogeneous verification for the official forecast and the early track models for 2018, with vector biases of the guidance models given in Table 8b. Skill comparisons of selected models are shown in Fig. 17. The official forecasts were very skillful and were near the best models, the consensus aids. TVCE was the best aid, and the only model that consistently beat the official forecasts. HCCA was the next best model, also beating the official forecasts from 12 to 72 h. FSSE was competitive with TVCE and HCCA early, edging out the official forecasts at 12 and 24 h, but its performance trailed the official forecasts and the best aids at forecast times beyond that. EMXI was the best individual model in the short term, but that model had similar errors to GFSI, AEMI, and HMNI from 48 to 120 h. In fact, HMNI was the best individual model at 72 h and beyond. HWFI was a fair performer, but it had slightly less skill than GFSI, AEMI, and HMNI throughout the forecast period. EGRI, NVGI, and CMCI trailed in 2018, and these models had less skill than the simple TABM model beyond 36 h. An evaluation of the three years 2016-18 (Fig. 18) indicates that the official forecasts were very skillful, and they were near the performance of the consensus models. HCCA slightly bested the official forecasts in the short term and TVCE edged out the official forecasts at the longer lead times. Among the individual models, EMXI was the best performer at 12 and 24 h, but AEMI had slightly more skill from 48 to 120 h. GFSI and HWFI were close behind, but EGRI and CMCI performed less well. The official forecasts had similar biases to TVCE and HCCA. Most of the global models, including GFSI, EGRI, NVGI, and CMCI had larger track biases than the official forecasts.

A separate verification of the primary consensus aids is given in Figure 19. The skill of the consensus models was tightly clustered, but TVCE, TVCX, and GFEX were the best aids at 96 and 120 h. AEMI was less skillful (about 5 to 10% lower skill) than the highest performers, but UEMI had considerably less skill.

b. 2018 season overview – Intensity

Figure 20 and Table 9 present the results of the NHC eastern North Pacific intensity forecast verification for the 2018 season, along with results averaged for the preceding 5-yr period. Mean forecast errors were 6 kt at 12 h and increased to 19 kt at 120 h. The errors were slightly higher than the 5-yr means at most forecast times, but around 30% higher than the 5-yr means at 120 h. The Decay-SHIFOR forecast errors were significantly higher than their 5-yr means, especially at 96 and 120 h, indicating that the season’s storms were more challenging than normal to predict. No records for accuracy were set in 2018. A review of error and skill trends (Fig. 21) indicates that although there is considerable year-to-year variability in intensity errors, there has been a slight decrease in error over the past couple of decades at most forecast times. Forecast skill has changed little during the last several years, however. Intensity forecast biases were slightly low (under-forecast) from 12 to 72 h, and more notably low at 96 and 120 h.

Figure 22 and Table 10a present a homogeneous verification for the primary early intensity models for 2018. Forecast biases are given in Table 10b. The official forecasts were more skillful than the majority of the guidance. In fact, the official forecasts outperformed all of the models at 12 and 120 h, but HCCA performed a little better at many of the other forecast times. FSSE was a good performer at the short lead times, but its skill trailed after 48 h. IVCN was a strong performer, but it did not beat HCCA or the official forecast at any time period. HWFI was the best individual model at all forecast times and had skill levels close to the official forecast and the consensus aids from 72 to 120 h. HMNI was not as good as HWFI, as it had about 5 to 10% less skill than that model at most forecast times. HMNI did beat the statistical-dynamical DSHP and LGEM, which had limited skill throughout the forecast period. Although GFSI was not skillful early, it had similar skill values to DSHP and LGEM from 72 to 120 h. EMXI was less skillful. All of the models had a significant low bias, especially at the longer lead times, and no model had smaller biases than the official forecasts. An evaluation over the three years 2016-18 (Fig. 23) indicates a similar result to the 2018 sample with the official forecasts outperforming all of the guidance at 12 and 120 h and being competitive with best aids, HCCA and IVCN, at the other forecast times. HWFI was the next best model, followed by DSHP and LGEM. GFSI had little skill while EMXI was not skillful.

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=2018&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 assigned 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- 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 2018 are given in Table 12 and illustrated in Fig. 24. In the Atlantic basin, a total of 581 genesis forecasts were made. These 48-h forecasts had a low bias at most probabilities. In the eastern Pacific, a total of 804 genesis forecasts were made. The forecasts in this basin had a low bias at probabilities between 40 and 70%, but were well calibrated at the low and high ranges.

Verification of the 120-h outlook for the Atlantic and eastern North Pacific basins for 2018 are given in Table 13 and illustrated in Fig. 25. In the Atlantic basin, the 120-h forecasts also had a low bias at most probabilities. In the eastern North Pacific, a slight low bias was noted at most 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 here suggest an intermediate level of forecaster confidence.

5. Looking Ahead to 2019

a. Track Forecast Cone Sizes

The National Hurricane Center 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 2019 for the Atlantic and eastern North Pacific basins (based on error distributions for 2014-18) are given in Table 14. In the Atlantic basin, the cone circles will be slightly smaller (by up to 8%) at the 24-72 h forecast periods, but are unchanged at the other leads times. In the eastern Pacific basin, the cone circles will be smaller (by up to 10%) at 24 h and beyond.

b. Consensus Models

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 2019 is given in Table 15. In 2019, EMNI was added to the consensus aid composition of TVCA given that in previous years EMNI would have improved the consensus model, especially at the longer range forecast times. Also for 2019, TCON (TCOA/TCOE) has been retired. An assessment of this fixed model over the past few years shows that it has not been competitive with the variable track consensus models, and therefore, it will no longer be computed.

Acknowledgments

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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/North American Mesoscale Forecast System	Multi-level regional dynamical	L	Trk, Int
CTX	COAMPS-TC using GFS initial and boundary conditions	Multi-layer regional dynamical	L	Trk, Int
EMX	European Centre for Medium Range Forecasting (ECMWF) global model	Multi-layer global dynamical	L	Trk, Int

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
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
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

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
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
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
TVDG	EMXI, GFSI, EGRI, and average of at least two of GFSI EMXI EGRI HWFI CTCI	Consensus	E	Trk
TVCC	Version of TVCN corrected for model biases	Corrected consensus	E	Trk
HCCA	Weighted average of AEMI, GFSI, CTCI, DSHP, EGRI, EMNI, EMXI,HWFI, LGEM	Corrected consensus	E	Trk, Int

ID	Name/Description	Type	Timeliness (E/L)	Parameters forecast
ICON	Average of DSHP, LGEM, CTCI, HMNI, and HWFI	Consensus	E	Int
IVCN	Average of at least two of DSHP LGEM HWFI CTCI HMNI	Consensus	E	Int
IVDR	HWFI, CTCI, HMNI, and average of at least two of DSHP LGEM HWFI CTCI HMNI	Consensus	E	Int

Table 2. Homogenous comparison of official and CLIPER5 track forecast errors in the Atlantic basin in 2018 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

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	Forecast Period (h)						
	12	24	36	48	72	96	120
2018 mean OFCL error (n mi)	24.2	35.2	45.4	60.1	100.6	144.7	185.5
2018 mean CLIPER5 error (n mi)	47.0	104.9	173.1	250.3	408.2	526.2	662.9
2018 mean OFCL skill relative to CLIPER5 (%)	48.5	66.4	73.8	76.0	75.4	72.5	72.0
2018 mean OFCL bias vector (°/n mi)	338/003	297/005	272/009	265/014	264/022	263/012	296/027
2018 number of cases	354	318	286	254	202	160	127
2013-2017 mean OFCL error (n mi)	24.1	37.4	50.5	66.7	97.5	134.3	176.7
2013-2017 mean CLIPER5 error (n mi)	44.5	95.8	152.8	210.5	319.8	419,9	490.4
2013-2017 mean OFCL skill relative to CLIPER5 (%)	45.8	61.0	67.0	68.3	69.5	68.0	64.0
2013-2017 mean OFCL bias vector (°/n mi)	045/002	040/003	046/004	048/005	064/009	044/007	258/018
2013-2017 number of cases	1141	1012	893	777	576	435	349
2018 OFCL error relative to 2013-2017 mean (%)	0.4	-5.9	-10.1	-9.9	3.2	7.7	5.0
2018 CLIPER5 error relative to 2013-2017 mean (%)	5.6	9.5	13.3	18.9	27.6	25.3	35.2

Table 3a. Homogenous comparison of Atlantic basin early track guidance model errors (n mi) for 2018. Errors smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	22.8	33.8	44.3	58.4	102.0	148.6	186.2
OCD5	45.3	103.4	173.0	250.7	410.6	528.0	669.3
GFSI	24.5	37.0	51.4	69.7	127.4	185.5	237.5
HMNI	25.6	39.7	55.0	77.9	148.7	245.8	325.6
HWFI	25.2	38.6	52.3	70.4	129.4	205.3	266.7
EMXI	23.9	38.8	53.3	67.7	107.3	**148.1**	194.4
CMCI	28.0	45.6	63.8	84.6	137.0	190.8	240.5
EGRI	25.5	41.1	58.3	77.0	124.6	174.6	225.3
NVGI	28.8	42.5	58.6	81.4	143.7	235.5	326.7
AEMI	24.3	36.7	53.0	70.9	125.6	191.2	238.0
FSSE	**22.0**	**33.0**	44.4	**57.5**	**97.0**	153.6	205.9
TVCA	**22.3**	**32.7**	**44.1**	58.8	103.7	156.2	193.4
HCCA	**21.7**	**32.2**	**43.6**	**57.1**	102.5	155.5	198.8
TABD	36.4	71.9	108.6	144.9	213.4	289.4	388.5
TABM	32.4	54.1	75.3	97.5	145.2	209.0	249.9
TABS	44.7	82.5	113.2	135.7	180.0	237.8	277.6
TCLP	47.8	108.1	176.4	248.8	395.4	490.2	599.8
# Cases	282	258	235	210	168	125	98

Table 3b. Homogenous comparison of Atlantic basin early track guidance model bias vectors (º/n mi) for 2018.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	324/002	267/006	252/011	252/014	251/023	234/014	286/032
OCD5	289/006	298/013	324/021	352/036	017/092	038/207	043/324
GFSI	347/006	329/008	318/008	323/007	324/008	084/039	050/065
HMNI	339/008	319/014	313/017	313/018	306/014	065/035	049/076
HWFI	348/006	312/010	289/015	275/012	270/029	256/009	350/038
EMXI	266/005	254/014	249/023	246/030	245/052	255/058	283/085
CMCI	259/004	244/011	237/015	23/016	238/018	149/019	102/062
EGRI	222/001	221/006	215/010	217/013	197/018	157/025	112/015
NVGI	323/006	293/006	258/005	225/003	118/013	114/050	115/087
AEMI	318/005	291/007	276/009	271/009	249/008	086/028	054/053
FSSE	241/001	233/007	230/014	234/021	234/037	241/035	285/047
TVCA	342/004	298/006	272/009	261/011	248/017	169/010	349/015
HCCA	221/001	223/007	226/013	227/019	231/033	221/038	258/046
TABD	067/010	061/031	050/056	046/079	044/119	053/160	040/252
TABM	336/003	007/007	007/013	015/016	066/025	072/063	046/088
TABS	297/021	276/045	256/063	236/072	196/074	126/055	072/046
TCLP	257/009	261/023	268/033	287/039	326/056	029/114	040/211
# Cases	282	258	235	210	168	125	98

Table 4. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the Atlantic basin for the 2018 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)						
	12	24	36	48	72	96	120
2018 mean OFCL error (kt)	4.9	7.8	9.2	10.2	13.4	12.8	12.2
2018 mean Decay-SHIFOR5 error (kt)	6.4	10.6	14.1	16.7	20.6	20.4	20.2
2018 mean OFCL skill relative to Decay-SHIFOR5 (%)	23.4	26.4	34.8	38.9	35.0	37.3	39.6
2018 OFCL bias (kt)	0.0	0.4	0.4	-0.4	0.1	-1.4	-2.7
2018 number of cases	354	318	286	254	202	160	127
2013-17 mean OFCL error (kt)	5.4	7.9	10.1	11.4	12.9	14.7	14.9
2013-17 mean Decay-SHIFOR5 error (kt)	7.0	10.8	14.2	17.4	20.9	22.7	24.1
2013-17 mean OFCL skill relative to Decay-SHIFOR5 (%)	22.9	26.9	28.9	34.5	38.3	35.2	38.2
2013-17 OFCL bias (kt)	-0.8	-1.0	-1.2	-1.5	-2.2	-1.1	0.1
2013-17 number of cases	1141	1012	893	777	576	435	349
2018 OFCL error relative to 2013-17 mean (%)	-9.3	-1.3	-8.9	-10.5	3.9	-12.9	-18.1
2018 Decay-SHIFOR5 error relative to 2013-17 mean (%)	-8.6	-1.9	-0.7	-4.0	-1.4	-10.1	-16.2

Table 5a. Homogenous comparison of selected Atlantic basin early intensity guidance model errors (kt) for 2018. Errors smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	5.0	7.8	9.2	10.2	13.2	12.9	11.3
OCD5	6.7	10.8	14.3	17.0	20.1	21.2	20.9
HWFI	6.1	8.1	9.3	10.7	13.7	15.6	15.8
HMNI	6.6	9.4	10.9	11.3	13.2	15.2	17.7
DSHP	6.3	8.7	11.1	12.7	15.7	17.4	16.1
LGEM	6.2	8.6	10.8	12.2	14.3	15.6	14.3
IVCN	5.7	**7.4**	**8.8**	**9.9**	**12.0**	13.1	12.4
FSSE	5.7	**7.9**	9.5	10.5	**12.8**	13.9	12.8
HCCA	5.8	**7.7**	9.5	10.3	**12.4**	13.2	11.3
GFSI	6.2	8.9	10.6	11.2	**12.2**	13.9	14.0
EMXI	7.2	11.0	12.9	13.8	16.2	19.4	20.8
TCLP	6.5	10.3	13.1	15.4	19.0	20.7	21.5
# Cases	296	275	250	224	173	129	99

Table 5b. Homogenous comparison of selected Atlantic basin early intensity guidance model biases (kt) for 2018. Biases smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	0.4	1.3	1.5	0.6	1.7	-0.5	-2.0
OCD5	-0.5	**-0.5**	**-0.7**	-0.9	**0.1**	2.3	2.1
HWFI	-2.0	-1.7	-2.1	-2.0	**-0.5**	2.5	**0.6**
HMNI	-0.9	-1.8	-3.4	-4.4	-7.6	-8.9	-11.9
DSHP	**-0.2**	**0.3**	**0.2**	**-0.1**	**0.1**	-1.1	**-0.8**
LGEM	-0.5	**-0.3**	**-0.4**	-0.7	**0.1**	-1.0	**-1.9**
IVCN	-0.9	**-1.0**	-1.5	-1.6	**-1.6**	-1.9	-3.7
FSSE	**-0.1**	**1.0**	**1.4**	1.7	2.5	**0.4**	**-0.5**
HCCA	-0.9	**-0.7**	**-1.3**	-0.7	**0.0**	1.0	**-0.3**
GFSI	-0.9	**-0.6**	**-1.1**	-1.6	-1.9	-1.0	**0.1**
EMXI	-2.5	-4.0	-6.2	-8.1	-9.6	-13.3	-17.9
TCLP	-1.2	-2.3	-3.0	-3.4	-4.0	-3.8	-3.2
# Cases	296	275	250	224	173	129	99

Table 6. Official Atlantic track and intensity forecast verifications (OFCL) for 2018 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:    AL012018                 ALBERTO

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         16    18.2    18.2      16     1.9     1.9
     012         16    39.8    69.3      16     5.9     6.6
     024         16    34.1   126.5      16     5.9     8.8
     036         16    40.1   185.5      16     6.9     7.6
     048         15    47.9   248.5      15     9.3     7.9
     072         11    70.4   347.2      11    10.5     5.3
     096          7   158.9   458.7       7     4.3     3.1
     120          3   288.2   648.4       3    10.0     3.7

Verification statistics for:    AL022018                   BERYL

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         18     2.9     2.9      18     2.2     2.2
     012         14    41.2    53.9      14     9.3     9.8
     024         10    71.0    85.8      10    16.0    17.7
     036          6    63.1    77.2       6    22.5    25.7
     048          4    67.1   104.2       4    15.0    26.2
     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:    AL032018                   CHRIS

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         24     7.9     8.1      24     1.2     1.5
     012         22    22.0    42.1      22     6.4     5.6
     024         20    34.6   107.1      20     7.5     8.9
     036         18    54.7   179.7      18     5.6    10.6
     048         16    85.5   254.3      16     4.7    11.1
     072         12   149.7   332.2      12    10.4    16.7
     096          8   180.0   324.5       8    13.8    21.1
     120          4   160.9   203.4       4     7.5    21.5

Verification statistics for:    AL042018                   DEBBY

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000          9     8.4     8.4       9     0.6     1.1
     012          7    32.6    67.2       7     4.3     3.4
     024          5    37.5   151.4       5     6.0     5.8
     036          3    52.9   256.6       3    11.7     7.7
     048          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
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Verification statistics for:    AL052018                ERNESTO

         VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
         000           11      5.6      5.6        11      0.0      0.5
         012            9     18.5     45.8         9      1.7      2.9
         024            7     16.7    110.6         7      3.6      3.3
         036            5     16.2    222.1         5      3.0      8.8
         048            3     14.2    365.0         3      5.0     16.7
         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:    AL062018               FLORENCE

         VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
         000           67      4.0      4.3        67      2.5      2.5
         012           65     18.3     33.4        65      6.3      8.7
         024           63     30.8     77.8        63     12.7     15.0
         036           61     40.8    136.2        61     16.1     18.9
         048           59     50.2    203.6        59     18.1     22.2
         072           55     71.5    372.9        55     22.5     27.2
         096           51    115.7    538.5        51     17.3     29.2
         120           47    155.7    707.8        47     13.3     27.1

Verification statistics for:    AL072018                 GORDON

         VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
         000           14      8.5      8.5        14      2.1      2.5
         012           12     16.6     32.2        12      5.8      7.8
         024           10     19.7     74.1        10      6.5     12.8
         036            8     28.0    119.0         8     10.0     15.8
         048            6     45.1    189.2         6      6.7     14.2
         072            2     73.2    393.7         2     10.0     12.0
         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:    AL082018                 HELENE

         VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
         000           36     12.9     13.5        36      1.4      1.8
         012           34     25.5     40.7        34      4.0      5.9
         024           32     45.1     89.1        32      4.8     10.0
         036           30     68.0    139.6        30      4.5     14.3
         048           28     94.2    200.1        28      4.8     17.4
         072           24    150.7    359.4        24      7.9     23.8
         096           20    231.3    510.3        20      9.5     25.9
         120           16    357.9    634.0        16      7.5     24.5
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Verification statistics for:    AL092018                  ISAAC

     VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
     000          30     8.6     8.8       30     1.3     1.3
     012          28    23.1    35.4       28     4.1     4.7
     024          26    30.0    67.1       26     8.8     9.9
     036          24    28.3   111.3       24    12.7    16.2
     048          22    29.2   167.8       22    15.0    21.3
     072          18    49.8   328.3       18    21.4    27.6
     096          14    57.2   536.1       14    26.1    26.1
     120          10    62.2   774.4       10    31.0    27.2

Verification statistics for:    AL102018                  JOYCE

     VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
     000          25     9.8     9.8       25     0.4     0.4
     012          23    25.7    64.5       23     2.8     4.3
     024          21    40.3   161.5       21     5.0     6.8
     036          19    58.3   267.8       19     5.3     9.2
     048          17    77.0   387.0       17     3.8    13.3
     072          13   147.1   623.1       13     3.5    25.2
     096           3   191.8   698.5        3    10.0    38.3
     120           0  -999.0  -999.0        0  -999.0  -999.0

Verification statistics for:    AL112018                 ELEVEN

     VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
     000           4     2.9     2.9        4     0.0     0.0
     012           2    29.2    51.5        2     5.0     8.0
     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
     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:    AL122018                   KIRK

     VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
     000          15     5.4     5.4       15     3.0     3.3
     012          11    29.2    38.4       11     4.5     5.9
     024           7    45.9    65.2        7     4.3     8.3
     036           5    67.7    89.3        5     4.0    16.2
     048           3    93.3   106.4        3     3.3    25.7
     072           2    75.8   512.3        2     5.0     8.5
     096           4    88.0   567.5        4     7.5    11.2
     120           4    57.0   539.5        4     7.5    11.2
```

```
Verification statistics for:    AL132018                    LESLIE

    VT  (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
    000            68      6.5      6.7        68      0.4      0.4
    012            64     20.2     54.1        64      3.0      4.2
    024            60     30.8    133.0        60      4.2      6.2
    036            56     46.6    226.3        56      4.7      8.1
    048            52     69.5    329.8        52      4.7      9.5
    072            48    123.9    467.2        48      6.1     10.4
    096            47    162.8    545.7        47      8.2      9.8
    120            43    189.8    653.9        43      9.4     11.3

Verification statistics for:    AL142018                   MICHAEL

    VT  (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
    000            19      5.5      6.5        19      1.8      2.1
    012            17     20.0     39.0        17      6.8      9.9
    024            15     34.5     86.7        15     12.3     18.7
    036            13     47.1    143.6        13     14.6     27.8
    048            11     45.9    186.8        11     19.1     32.5
    072             7     64.4    334.0         7     24.3     43.3
    096             3     85.2    567.1         3      3.3     12.0
    120             0   -999.0   -999.0         0   -999.0   -999.0

Verification statistics for:    AL152018                    NADINE

    VT  (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
    000            15      7.4      8.3        15      5.3      5.3
    012            13     32.0     40.2        13      5.8      9.9
    024            11     44.1     73.1        11      5.0     13.5
    036             9     43.6    112.6         9      3.3     16.7
    048             7     44.8    146.6         7      5.0     19.0
    072             3     64.5    332.1         3      5.0     16.3
    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:    AL162018                     OSCAR

    VT  (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
    000            19      4.5      4.5        19      2.1      2.1
    012            17     33.3     80.7        17      4.4      7.6
    024            15     36.9    175.5        15      8.3     11.3
    036            13     17.9    289.2        13     11.2     14.0
    048            11     31.3    427.4        11     13.6     14.6
    072             7     72.4    563.6         7     14.3     17.3
    096             3    144.1    517.3         3      3.3     12.7
    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 2018 for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)						
	12	24	36	48	72	96	120
2018 mean OFCL error (n mi)	20.5	32.3	42.0	49.6	66.9	82.8	102.5
2018 mean CLIPER5 error (n mi)	33.2	69.9	113.6	162.8	273.5	364.7	429.5
2018 mean OFCL skill relative to CLIPER5 (%)	38.3	53.8	63.0	69.5	75.5	77.3	76.1
2018 mean OFCL bias vector (°/n mi)	326/002	101/001	098/003	072/004	030/008	013/018	018/034
2018 number of cases	413	373	337	300	242	196	161
2013-2017 mean OFCL error (n mi)	21.9	33.3	43.2	53.9	79.8	109.0	146.7
2013-2017 mean CLIPER5 error (n mi)	35.0	71.2	110.1	147.1	213.9	267.6	337.4
2013-2017 mean OFCL skill relative to CLIPER5 (%)	37.4	53.3	60.8	63.4	62.7	59.3	56.5
2013-2017 mean OFCL bias vector (°/n mi)	328/003	325/004	328/004	344/004	043/007	060/014	021/013
2013-2017 number of cases	1647	1472	1302	1153	903	698	523
2018 OFCL error relative to 2013-2017 mean (%)	-6.4	-2.8	-2.8	-8.0	-16.2	-24.0	-30.1
2018 CLIPER5 error relative to 2013-2017 mean (%)	-5.1	-1.8	3.2	10.7	27.9	36.3	27.3

Table 8a. Homogenous comparison of eastern North Pacific basin early track guidance model errors (n mi) for 2018. Errors smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	18.8	29.7	38.8	48.0	65.4	80.9	104.3
OCD5	31.7	68.3	114.1	166.7	281.5	382.6	454.2
GFSI	22.2	36.5	48.9	59.3	82.4	109.7	137.0
HWFI	23.0	37.9	50.8	60.6	89.1	128.6	150.4
HMNI	23.5	37.6	49.1	60.1	78.5	105.1	133.0
EMXI	20.9	32.7	44.0	57.4	83.3	108.6	139.5
CMCI	29.1	47.5	65.0	81.1	111.7	144.9	189.9
EGRI	22.6	38.6	56.2	73.6	111.1	142.3	175.9
NVGI	26.9	45.0	61.7	77.4	118.2	156.1	194.9
AEMI	21.5	35.5	47.0	56.7	81.3	103.8	124.3
FSSE	19.0	**29.5**	**38.3**	48.6	73.2	100.2	131.4
TVCE	**18.6**	**29.0**	**38.0**	**46.0**	**64.3**	**79.7**	**95.2**
HCCA	**18.1**	**27.6**	**36.2**	**44.9**	**64.7**	81.0	108.9
TABD	27.4	53.4	77.0	93.1	113.1	148.1	195.0
TABM	25.3	45.4	62.5	73.9	95.8	117.8	144.1
TABD	32.6	63.0	86.7	103.5	134.6	173.9	199.4
TCLP	31.2	68.0	112.7	163.6	270.1	367.9	424.4
# Cases	299	272	250	225	185	154	126

Table 8b. Homogenous comparison of eastern North Pacific basin early track guidance model bias vectors (º/n mi) for 2018.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	324/002	338/003	002/004	012/008	004/015	008/026	012/044
OCD5	298/004	292/009	275/020	273/036	268/072	273/006	016/053
GFSI	042/004	061/009	066/016	069/025	062/041	050/047	038/061
HWFI	044/003	052/007	055/012	059/020	057/038	054/053	046/066
HMNI	335/005	350/007	009/008	029/012	020/025	013/043	003/061
EMXI	288/008	278/014	270/019	266/023	271/030	285/035	308/037
CMCI	027/004	041/011	042/018	042/028	032/048	024/066	019/066
EGRI	298/005	283/008	278/014	274/020	271/036	279/035	307/031
NVGI	314/008	302/014	297/020	301/025	320/046	336/085	340/126
AEMI	028/001	055/005	057/012	057/019	047/033	036/038	021/046
FSSE	345/001	091/004	090/007	078/011	041/021	029/038	026/072
TVCE	327/003	331/004	346/005	003/007	357/014	357/022	357/035
HCCA	303/001	336/001	015/003	022/005	004/014	004/022	022/044
TABD	016/006	043/016	044/029	047/040	041/058	029/087	031/134
TABM	340/009	342/013	348/014	017/011	052/025	048/039	032/068
TABD	337/013	328/020	320/020	306/020	237/011	111/035	052/057
TCLP	299	272	250	225	185	154	126

Table 9. Homogenous comparison of official and Decay-SHIFOR5 intensity forecast errors in the eastern North Pacific basin for the 2018 season for all tropical cyclones. Averages for the previous 5-yr period are shown for comparison.

	Forecast Period (h)						
	12	24	36	48	72	96	120
2018 mean OFCL error (kt)	6.1	10.4	12.7	14.1	15.3	16.4	18.8
2018 mean Decay-SHIFOR5 error (kt)	8.0	14.0	18.2	21.1	25.0	28.4	31.1
2018 mean OFCL skill relative to Decay-SHIFOR5 (%)	23.8	25.7	30.2	33.2	38.8	42.3	39.5
2018 OFCL bias (kt)	-0.3	-0.6	-1.2	-1.5	-2.7	-6.3	-12.2
2018 number of cases	413	373	337	300	242	196	161
2013-17 mean OFCL error (kt)	6.0	9.8	12.1	13.5	15.4	15.1	14.5
2013-17 mean Decay-SHIFOR5 error (kt)	7.7	12.7	15.9	18.2	20.3	20.7	19.0
2013-17 mean OFCL skill relative to Decay-SHIFOR5 (%)	22.1	22.8	25.3	25.8	24.1	27.1	23.7
2013-17 OFCL bias (kt)	-0.8	-1.2	-2.0	-3.0	-3.3	-2.9	-2.7
2013-17 number of cases	1647	1472	1302	1153	903	698	523
2018 OFCL error relative to 2013-17 mean (%)	1.7	6.1	5.0	4.4	-0.6	8.6	29.7
2018 Decay-SHIFOR5 error relative to 2013-17 mean (%)	3.9	10.2	14.5	15.9	23.2	37.2	63.7

Table 10a. Homogenous comparison of eastern North Pacific basin early intensity guidance model errors (kt) for 2018. Errors smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	6.7	11.1	13.4	14.2	15.0	16.3	19.1
OCD5	8.6	15.1	19.3	21.7	24.6	28.4	30.3
HWFI	7.8	12.1	14.8	16.0	15.8	16.4	20.8
HMNI	7.9	12.6	15.7	17.7	17.7	19.6	23.0
DSHP	8.0	13.6	17.5	19.7	20.9	23.4	25.0
LGEM	7.8	13.0	16.9	18.7	19.5	22.9	26.9
IVCN	6.9	11.1	13.6	14.6	15.1	17.7	21.2
HCCA	6.8	**10.9**	13.4	**14.1**	**14.7**	**16.1**	20.1
FSSE	6.8	**10.8**	**13.3**	14.6	17.0	20.3	25.3
GFSI	9.3	15.2	19.0	19.9	19.8	22.9	26.4
EMXI	10.2	16.5	21.0	23.2	23.0	24.4	30.2
TCLP	8.3	15.7	21.8	25.7	29.7	32.2	34.9
# Cases	331	307	282	257	208	173	142

Table 10b. Homogenous comparison of eastern North Pacific basin early intensity guidance model biases (kt) for 2018. Biases smaller than the NHC official forecast are shown in boldface.

	Forecast Period (h)						
Model ID	12	24	36	48	72	96	120
OFCL	-0.1	0.0	-0.7	-1.1	-2.7	-7.1	-13.0
OCD5	-2.0	-4.9	-8.8	-12.3	-18.1	-21.7	-26.6
HWFI	-2.7	-3.3	-3.9	-4.6	-6.3	-9.2	-13.2
HMNI	-2.3	-4.5	-6.6	-8.2	-11.2	-14.7	-20.1
DSHP	-1.2	-2.2	-3.6	-4.6	-6.5	-11.2	-17.5
LGEM	-2.2	-5.5	-8.7	-10.3	-13.0	-17.4	-22.8
IVCN	-2.0	-3.9	-5.4	-6.3	-7.9	-11.4	-16.7
HCCA	-0.7	-1.6	-2.8	-2.1	-3.5	-7.4	-13.5
FSSE	-0.9	-1.8	-3.2	-4.2	-8.3	-13.4	-21.2
GFSI	-0.7	-0.6	-1.6	-2.5	-6.0	-10.6	-17.9
EMXI	-4.3	-7.0	-9.6	-12.2	-16.6	-20.2	-28.0
TCLP	-3.4	-9.2	-14.4	-18.6	-24.3	-27.2	-31.9
# Cases	331	307	282	257	208	173	142

Table 11. Official eastern North Pacific track and intensity forecast verifications (OFCL) for 2018 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:    EP012018                      ONE

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000           4     6.5     6.5        4     0.0     0.0
    012           2    51.6    40.4        2     0.0     4.0
    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
    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:    EP022018                   ALETTA

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          22     5.9     5.9       22     0.5     0.5
    012          20    23.4    27.6       20     8.0    11.4
    024          18    42.6    53.1       18    16.9    23.6
    036          16    52.8    80.4       16    21.2    33.9
    048          14    65.9   105.7       14    22.5    42.3
    072          10    71.7   178.3       10    16.0    29.5
    096           6    49.2   251.1        6    20.8     9.2
    120           2    47.9   283.7        2    22.5     4.0

Verification statistics for:    EP032018                      BUD

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          23    11.5    11.8       23     1.3     1.3
    012          21    19.4    39.1       21     6.4     8.9
    024          19    24.0    71.1       19    13.2    17.6
    036          17    26.9   113.0       17    16.8    25.5
    048          15    30.7   156.3       15    16.0    27.0
    072          11    37.9   265.9       11    13.6    17.9
    096           7    55.9   341.8        7    16.4     8.3
    120           3   107.4   496.6        3    10.0    11.0

Verification statistics for:    EP042018                 CARLOTTA

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          17     9.2     9.0       17     0.3     0.3
    012          15    27.8    36.5       15     4.7     6.1
    024          12    59.7    79.4       12     7.5    10.8
    036           9    86.2   124.3        9     6.7    15.1
    048           4    80.2   163.9        4     6.2     7.2
    072           3   138.6   165.2        3    10.0    15.3
    096           1   162.8   271.9        1     5.0    13.0
    120           0  -999.0  -999.0        0  -999.0  -999.0
```

```
Verification statistics for:    EP052018                  DANIEL

    VT (h)        NT    OFCL     OCD5        NI    OFCL     OCD5
    000            9     7.7      7.7         9     0.6      0.6
    012            7    18.9     30.5         7     2.1      4.9
    024            5    21.5     48.7         5     2.0      6.8
    036            3    10.7     74.9         3     5.0      4.0
    048            1     6.0    116.2         1     5.0      8.0
    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:    EP062018                  EMILIA

    VT (h)        NT    OFCL     OCD5        NI    OFCL     OCD5
    000           17     6.4      6.7        17     0.0      0.0
    012           15    18.4     23.8        15     3.3      4.7
    024           13    34.3     50.4        13     9.2      7.9
    036           11    42.3     66.4        11    13.6     12.1
    048            9    42.0     78.6         9    16.7     14.7
    072            5    48.4    139.7         5    18.0     20.8
    096            1    82.6    147.3         1    15.0     23.0
    120            0  -999.0   -999.0         0  -999.0   -999.0

Verification statistics for:    EP072018                   FABIO

    VT (h)        NT    OFCL     OCD5        NI    OFCL     OCD5
    000           22     6.6      6.6        22     1.1      1.1
    012           20    26.5     33.0        20     5.5      5.2
    024           18    33.3     50.5        18     9.2      9.8
    036           16    45.8     74.9        16    10.0     11.4
    048           14    53.2    102.5        14    10.0     13.3
    072           10    59.2    188.3        10    14.0     18.5
    096            6    62.9    218.3         6    16.7     14.5
    120            2    50.4    280.5         2    15.0     15.5

Verification statistics for:    EP082018                   GILMA

    VT (h)        NT    OFCL     OCD5        NI    OFCL     OCD5
    000           11    13.3     13.3        11     1.8      1.8
    012            9    35.3     36.5         9     2.8      2.8
    024            7    52.8     48.1         7     7.1      5.9
    036            5    83.0     56.5         5    10.0      9.2
    048            3   120.2     56.6         3    11.7     11.7
    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:    EP092018                   NINE

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000           4     5.9     5.9        4     0.0     0.0
    012           3    10.0    31.8        3     1.7     7.7
    024           1    13.4    75.7        1     5.0    17.0
    036           0  -999.0  -999.0        0  -999.0  -999.0
    048           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:    EP102018                 HECTOR

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          23     5.3     5.6       23     0.7     0.7
    012          23    12.4    19.8       23     8.3     9.9
    024          23    19.2    40.9       23    12.8    18.9
    036          23    24.3    67.3       23    15.0    25.7
    048          23    29.9    98.1       23    18.3    34.1
    072          23    43.3   157.8       23    20.4    45.7
    096          23    48.9   237.4       23    24.3    55.3
    120          23    59.7   336.3       23    28.9    58.3

Verification statistics for:    EP112018                 ILEANA

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          11    10.2    10.2       11     1.4     1.4
    012           9    20.9    52.8        9     8.3     6.0
    024           7    37.5   112.1        7    13.6     9.1
    036           5    58.2   150.8        5    12.0    12.2
    048           3    87.5   173.8        3     6.7    20.0
    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:    EP122018                   JOHN

    VT (h)       NT    OFCL    OCD5       NI    OFCL    OCD5
    000          19    10.0    10.0       19     1.3     1.3
    012          17    25.6    39.2       17     5.9     7.7
    024          15    30.1    72.4       15     9.7    12.6
    036          13    31.6   119.9       13    15.8    14.3
    048          11    35.1   161.7       11    19.5    15.4
    072           7    53.2   269.2        7    20.0    14.0
    096           3    73.8   343.1        3    15.0     7.7
    120           0  -999.0  -999.0        0  -999.0  -999.0
```

```
Verification statistics for:   EP132018                  KRISTY

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         19     6.4     6.4      19     1.8     1.8
     012         19    17.3    35.5      19     6.6     7.8
     024         18    35.0    84.9      18     9.2    11.2
     036         16    56.1   143.1      16    12.2    14.1
     048         14    71.2   221.4      14    11.1    12.1
     072         10    82.3   451.0      10     8.0    11.0
     096          6    70.4   668.5       6    15.8    23.5
     120          2    54.2   606.4       2    15.0    27.5
```

```
Verification statistics for:   EP142018                    LANE

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         16     3.9     3.9      16     0.6     0.6
     012         16    18.9    22.1      16     3.4     7.0
     024         16    25.7    40.5      16     6.6    11.1
     036         16    27.7    57.8      16     7.8    14.9
     048         16    29.0    77.0      16     8.1    19.9
     072         16    48.4   123.3      16    18.1    33.0
     096         16    69.2   174.6      16    28.4    51.2
     120         16    80.7   222.5      16    38.1    58.0
```

```
Verification statistics for:   EP152018                  MIRIAM

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         15     8.5     8.5      15     0.0     0.0
     012         15    19.3    29.0      15     4.7     3.9
     024         15    29.9    62.5      15     9.7     6.9
     036         15    36.3   106.8      15    15.3     9.5
     048         15    47.3   169.6      15    22.0    11.1
     072         15    68.1   328.9      15    18.3    11.3
     096         14    76.5   456.7      14     9.6    15.9
     120         10   100.5   459.7      10     7.5    19.8
```

```
Verification statistics for:   EP162018                  NORMAN

     VT  (h)     NT    OFCL    OCD5      NI    OFCL    OCD5
     000         27     4.2     5.1      27     1.7     1.9
     012         27    17.0    35.7      27     8.5    12.6
     024         27    33.4    81.5      27    13.9    22.6
     036         27    47.1   138.1      27    17.6    30.5
     048         27    59.2   197.3      27    20.2    34.5
     072         27    86.5   311.1      27    18.5    35.5
     096         27   119.5   392.7      27    15.9    34.2
     120         27   141.0   467.1      27    18.9    31.1
```

```
Verification statistics for:    EP172018               OLIVIA

    VT (h)      NT    OFCL    OCD5      NI    OFCL    OCD5
    000         32     8.1     8.1      32     1.1     1.2
    012         32    17.5    28.6      32     8.0    10.2
    024         32    26.7    58.8      32    10.6    15.9
    036         32    32.3    95.9      32    11.7    18.8
    048         32    38.1   137.1      32    13.8    20.7
    072         32    49.4   227.3      32    15.0    25.5
    096         32    57.0   323.0      32    16.2    26.0
    120         32    61.3   441.3      32    16.2    21.1

Verification statistics for:    EP182018                 PAUL

    VT (h)      NT    OFCL    OCD5      NI    OFCL    OCD5
    000         14    10.5    10.5      14     0.4     0.4
    012         12    12.7    34.7      12     1.2     2.9
    024         10    22.3    79.0      10     4.5     4.6
    036          8    26.3   133.2       8     8.1     5.6
    048          6    37.4   188.9       6    15.0     8.3
    072          2    59.4   243.1       2    32.5    21.5
    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:    EP192018             NINETEEN

    VT (h)      NT    OFCL    OCD5      NI    OFCL    OCD5
    000          4    14.5    14.5       4     0.0     0.0
    012          2    46.0    49.0       2     2.5     4.0
    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
    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:    EP202018                 ROSA

    VT (h)      NT    OFCL    OCD5      NI    OFCL    OCD5
    000         30     4.0     4.0      30     1.0     1.3
    012         28    20.1    28.8      28     8.2     9.9
    024         26    31.5    72.6      26    11.9    17.3
    036         24    43.4   125.9      24    11.9    19.2
    048         22    52.0   181.9      22     8.9    18.9
    072         18    64.2   283.8      18    14.2    24.4
    096         14    94.4   409.8      14    11.8    20.9
    120         10   146.4   470.9      10    16.0    12.6
```

```
Verification statistics for:    EP212018              SERGIO

     VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
     000           54      8.1      7.8        54      1.8      1.9
     012           52     16.6     37.2        52      5.7      6.0
     024           50     26.6     93.0        50      9.0     10.3
     036           48     35.5    165.8        48     10.5     12.4
     048           46     47.9    245.1        46     10.7     13.0
     072           42     76.0    398.8        42      9.5     18.5
     096           38    107.8    485.9        38      9.7     21.1
     120           34    146.2    529.0        34     10.4     22.8

Verification statistics for:    EP222018                TARA

     VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
     000           10     14.2     14.2        10      0.0      0.0
     012            8     23.2     36.8         8      6.2      8.9
     024            6     45.9     69.5         6     10.8     11.5
     036            4     69.6    119.5         4     10.0      9.8
     048            2    117.9    154.0         2      7.5      1.5
     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:    EP232018             VICENTE

     VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
     000           17      5.7      5.7        17      1.2      1.2
     012           15     31.5     43.7        15      4.0      7.4
     024           13     48.3    100.9        13      3.8     11.4
     036           11     59.8    153.0        11      3.2     14.5
     048            9     58.1    207.0         9      7.8     19.8
     072            5    101.2    320.6         5     16.0      3.4
     096            1    117.4    366.0         1     30.0      2.0
     120            0   -999.0   -999.0         0   -999.0   -999.0

Verification statistics for:    EP242018               WILLA

     VT (h)        NT     OFCL     OCD5        NI     OFCL     OCD5
     000           17      3.7      2.3        17      4.4      4.1
     012           15     18.1     36.2        15      9.3     17.5
     024           13     31.2     69.5        13     17.3     29.3
     036           11     48.1    107.3        11     20.0     37.9
     048            9     67.0    176.0         9     18.3     45.9
     072            5    168.8    357.7         5     16.0     41.8
     096            1    384.7    654.8         1     55.0      6.0
     120            0   -999.0   -999.0         0   -999.0   -999.0
```

```
Verification statistics for:    EP252018                 XAVIER

         VT (h)        NT     OFCL     OCD5       NI     OFCL     OCD5
         000           13      6.0      6.0       13      3.1      3.1
         012           11     29.8     33.7       11      5.9      5.4
         024            9     56.5     71.0        9      7.8      6.4
         036            7     80.1     96.6        7      8.6      7.3
         048            5     87.9    122.9        5      9.0      6.6
         072            1     93.4     55.8        1     10.0      1.0
         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 2018.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	6	291
10	23	96
20	33	63
30	53	38
40	75	27
50	28	20
60	80	11
70	89	17
80	100	8
90	100	9
100	100	1

Table 12b. Verification of 48-h probabilistic genesis forecasts for the eastern North Pacific basin in 2018.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	1	339
10	13	165
20	20	97
30	23	53
40	71	28
50	74	19
60	82	33
70	87	30
80	81	16
90	95	19
100	100	5

Table 13a. Verification of 120-h probabilistic genesis forecasts for the Atlantic basin in 2018.

Atlantic Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	0	40
10	32	166
20	44	108
30	51	61
40	58	45
50	66	59
60	76	25
70	67	24
80	91	11
90	97	36
100	100	1

Table 13b. Verification of 120-h probabilistic genesis forecasts for the eastern North Pacific basin in 2018.

Eastern North Pacific Basin Genesis Forecast Reliability Table		
Forecast Likelihood (%)	**Verifying Genesis Occurrence Rate (%)**	**Number of Forecasts**
0	0	20
10	19	163
20	31	137
30	38	126
40	38	90
50	71	48
60	69	48
70	81	31
80	94	32
90	100	96
100	100	13

Table 14. NHC forecast cone circle radii (n mi) for 2019. Change from 2018 values expressed in n mi and percent are given in parentheses.

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	41 (-2: -5%)	38 (-1: -3%)
36	54 (-2: -4%)	48 (-2: -4%)
48	68 (-6: -8%)	62 (-4: -6%)
72	102 (-1: -1%)	88 (-6: -6%)
96	151 (0: 0%)	115 (-10: -8%)
120	198 (0: 0%)	145 (-17: -10%)

Table 15. Composition of NHC consensus models for 2019. It is intended that TVCA would be the primary consensus aids for the Atlantic basin and TVCE would be primary for the eastern Pacific.

NHC Consensus Model Definitions For 2019			
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 EMNI
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

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22. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2018. This verification includes only those models that were available at least 2/3 of the time (see text).
23. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2016-18.
24. Reliability diagram for Atlantic (top) and eastern North Pacific (bottom) probabilistic tropical cyclogenesis 48-h forecasts for 2018. 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.
25. As described for Fig. 24, but for 120-h forecasts.

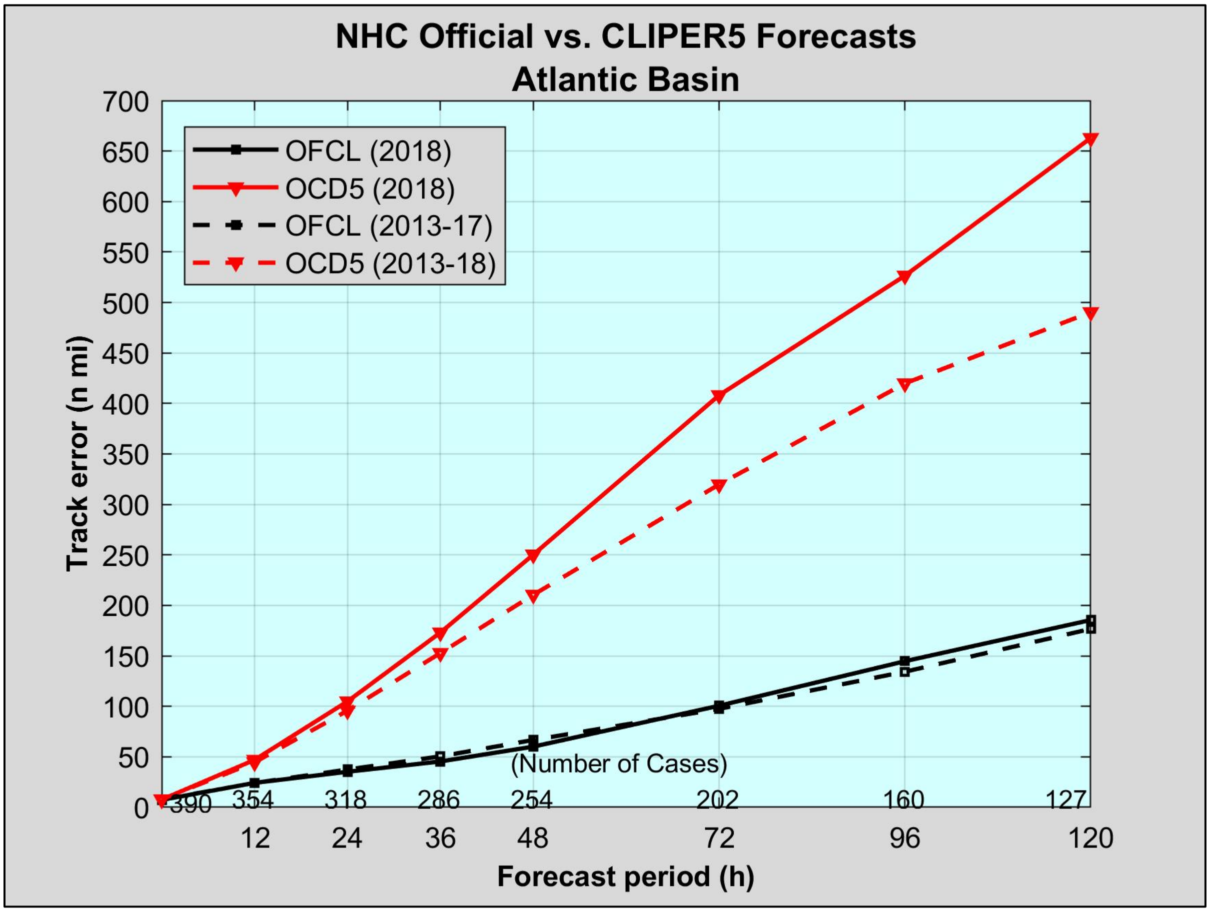


Figure 1. NHC official and CLIPER5 (OCD5) Atlantic basin average track errors for 2018 (solid lines) and 2013-2017 (dashed lines).

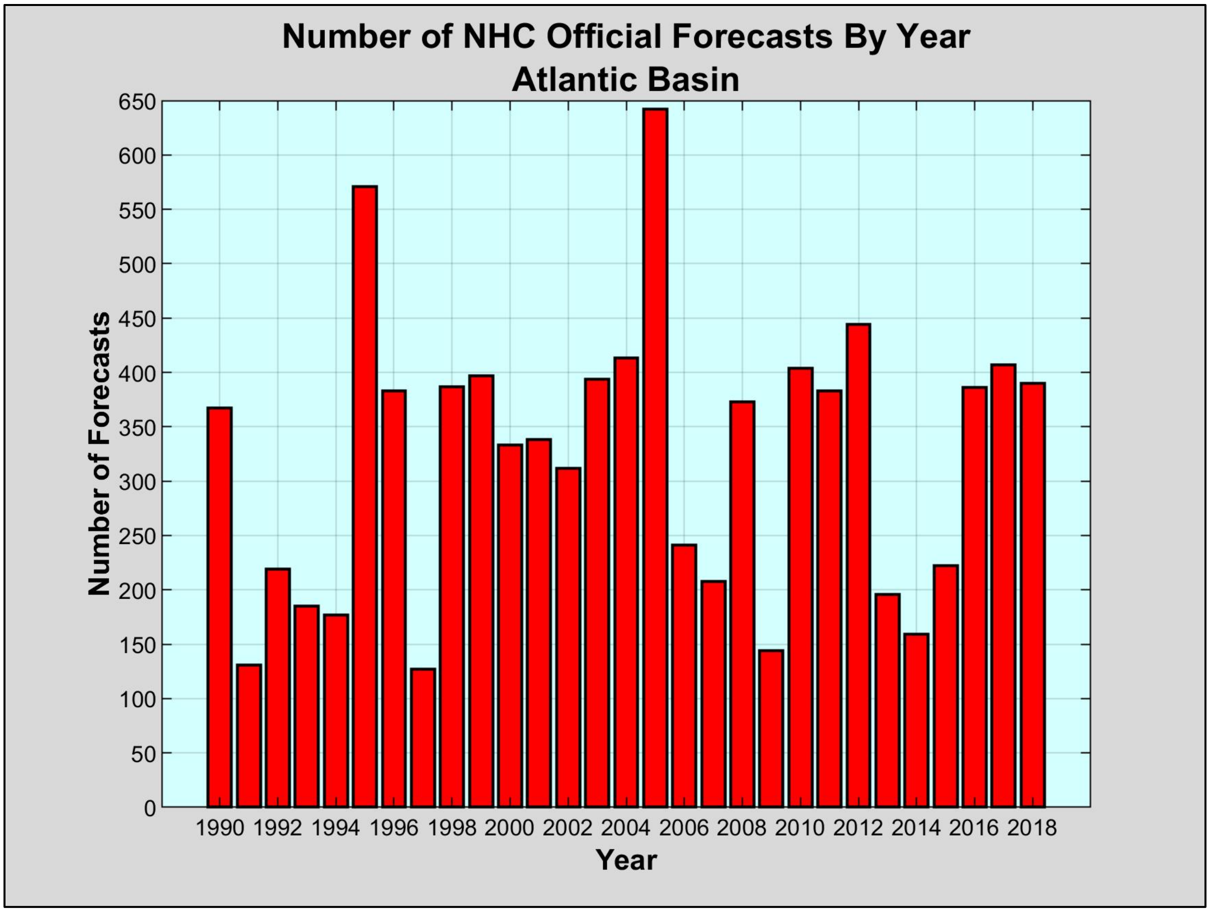
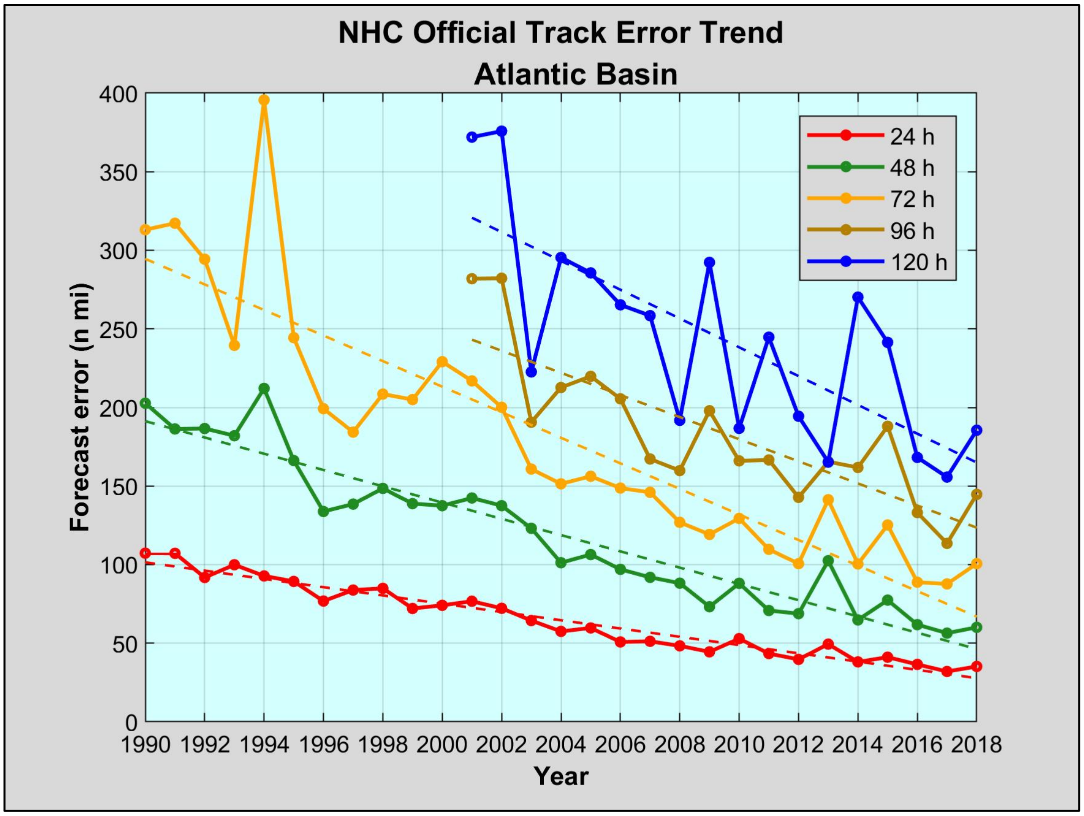


Figure 2. Number of NHC official forecasts for the Atlantic basin stratified by year.



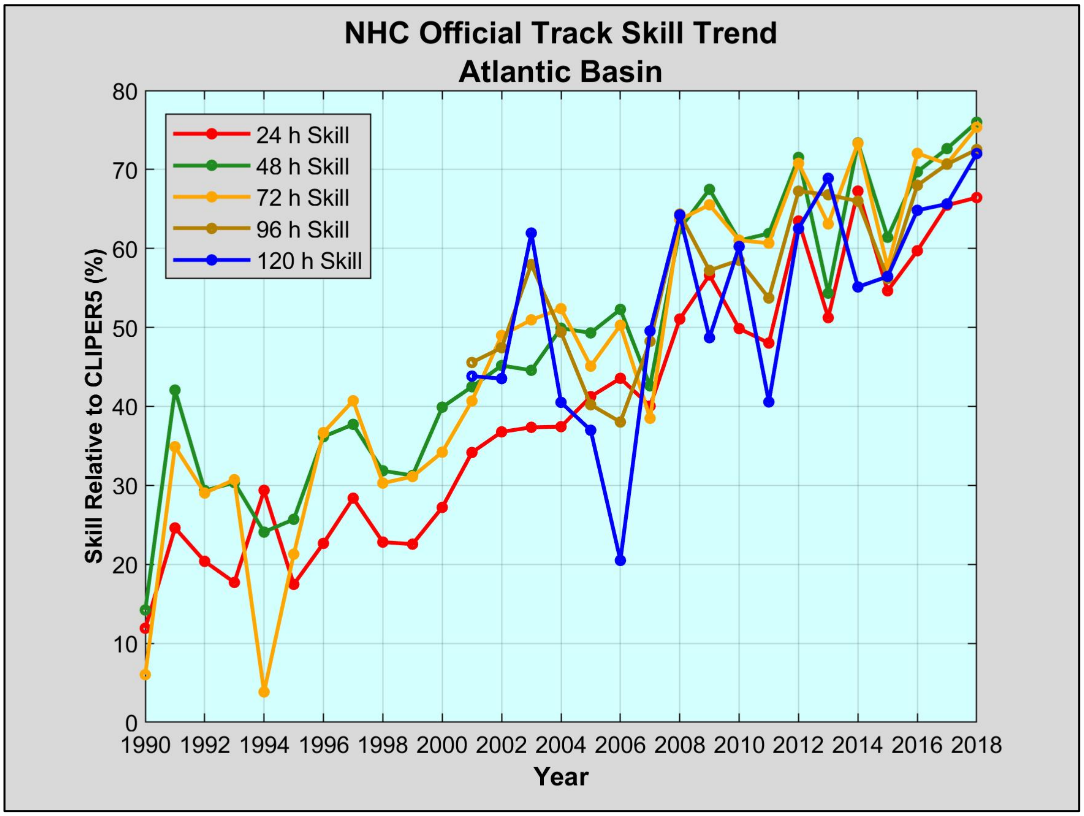


Figure 3. Recent trends in NHC official track forecast error (top) and skill (bottom) for the Atlantic basin.

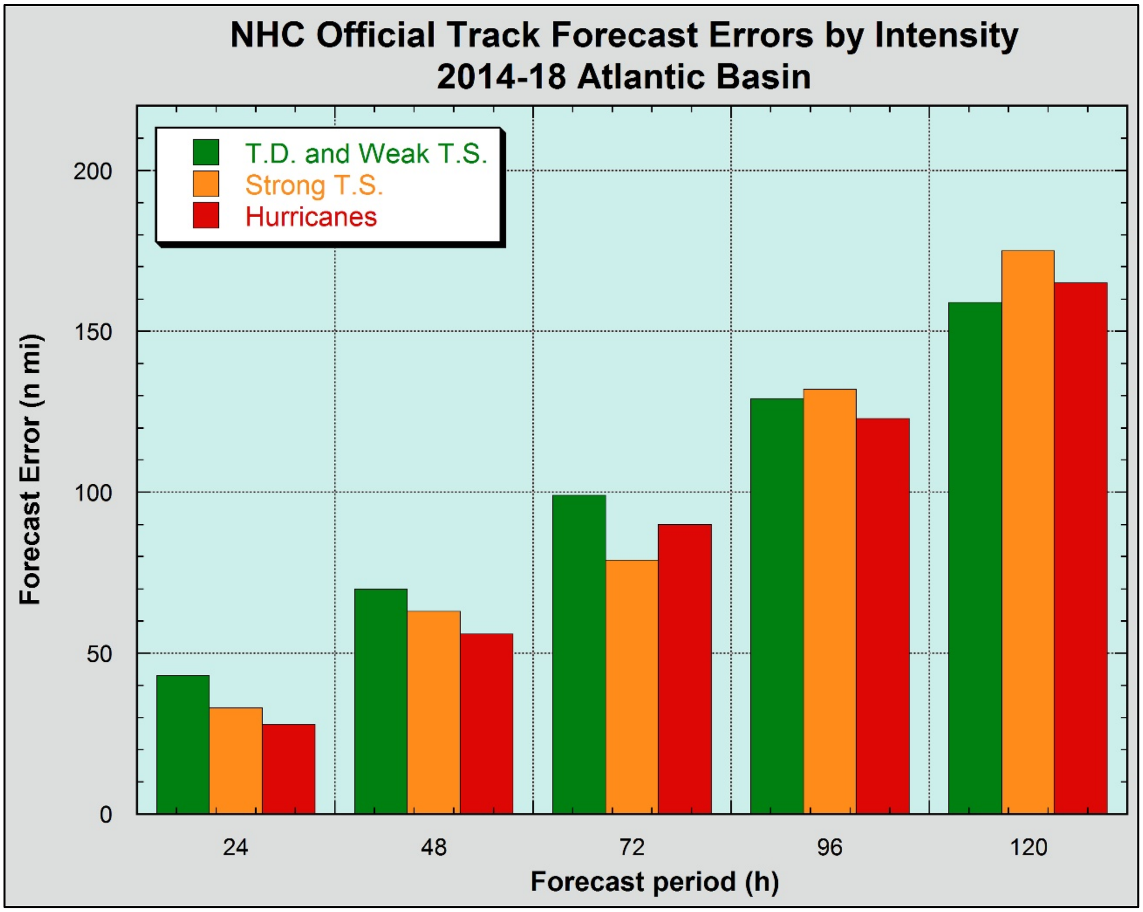


Figure 4. 2014-18 NHC official track forecast error binned by initial intensity for the Atlantic basin. Weak tropical storms are in the 35-45 kt range and strong tropical storms are in the 50-60 kt range.

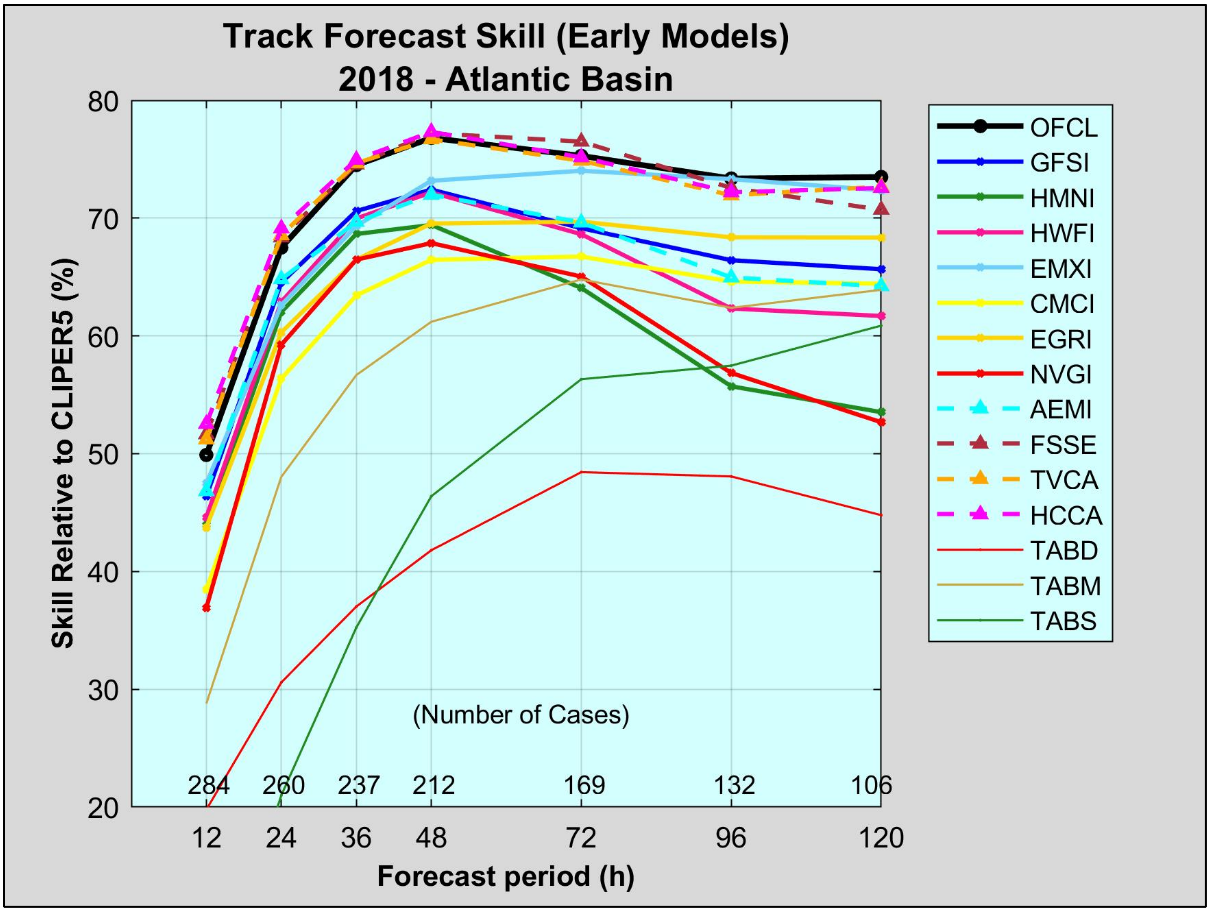


Figure 5. Homogenous comparison for selected Atlantic basin early track models for 2018. This verification includes only those models that were available at least 2/3 of the time (see text).

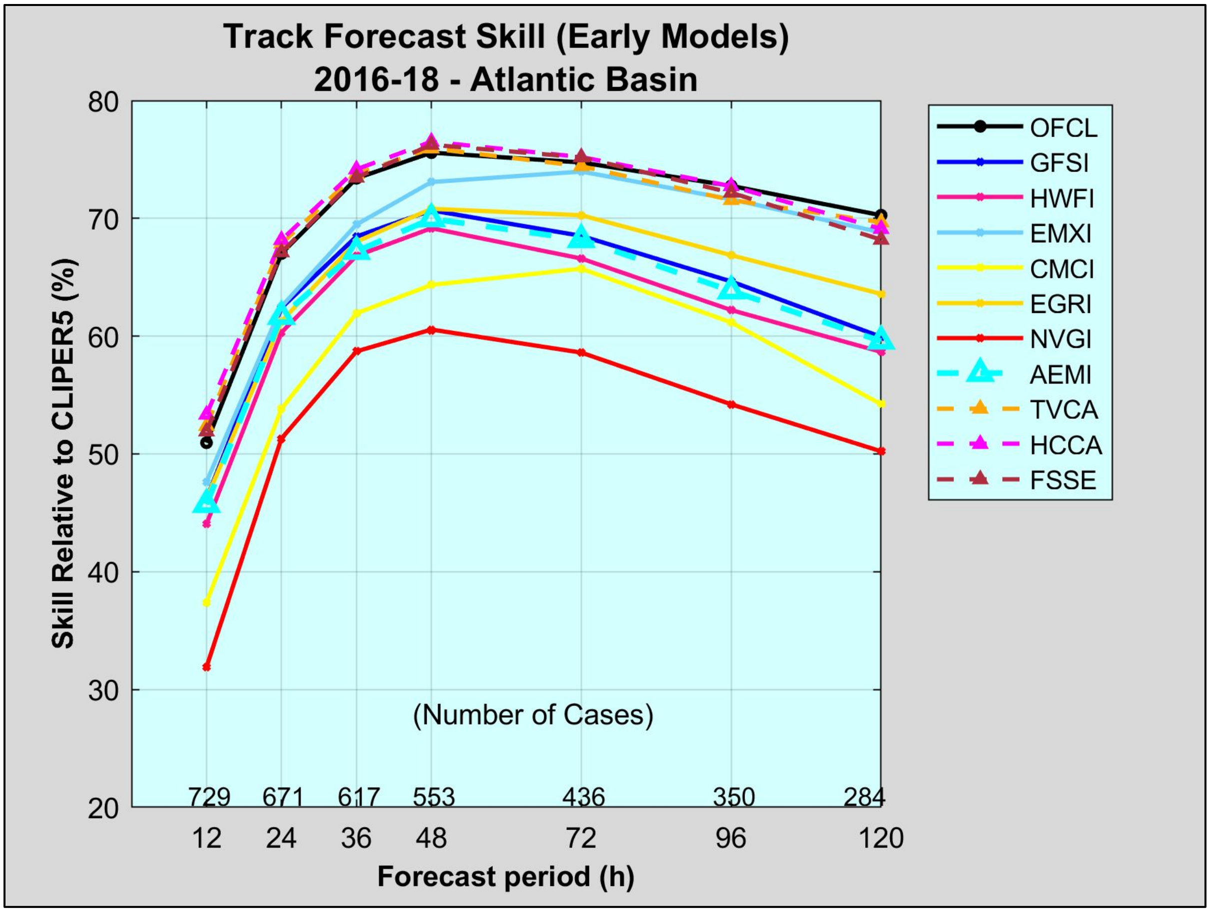


Figure 6. Homogenous comparison for selected Atlantic basin early track models for 2016-2018.

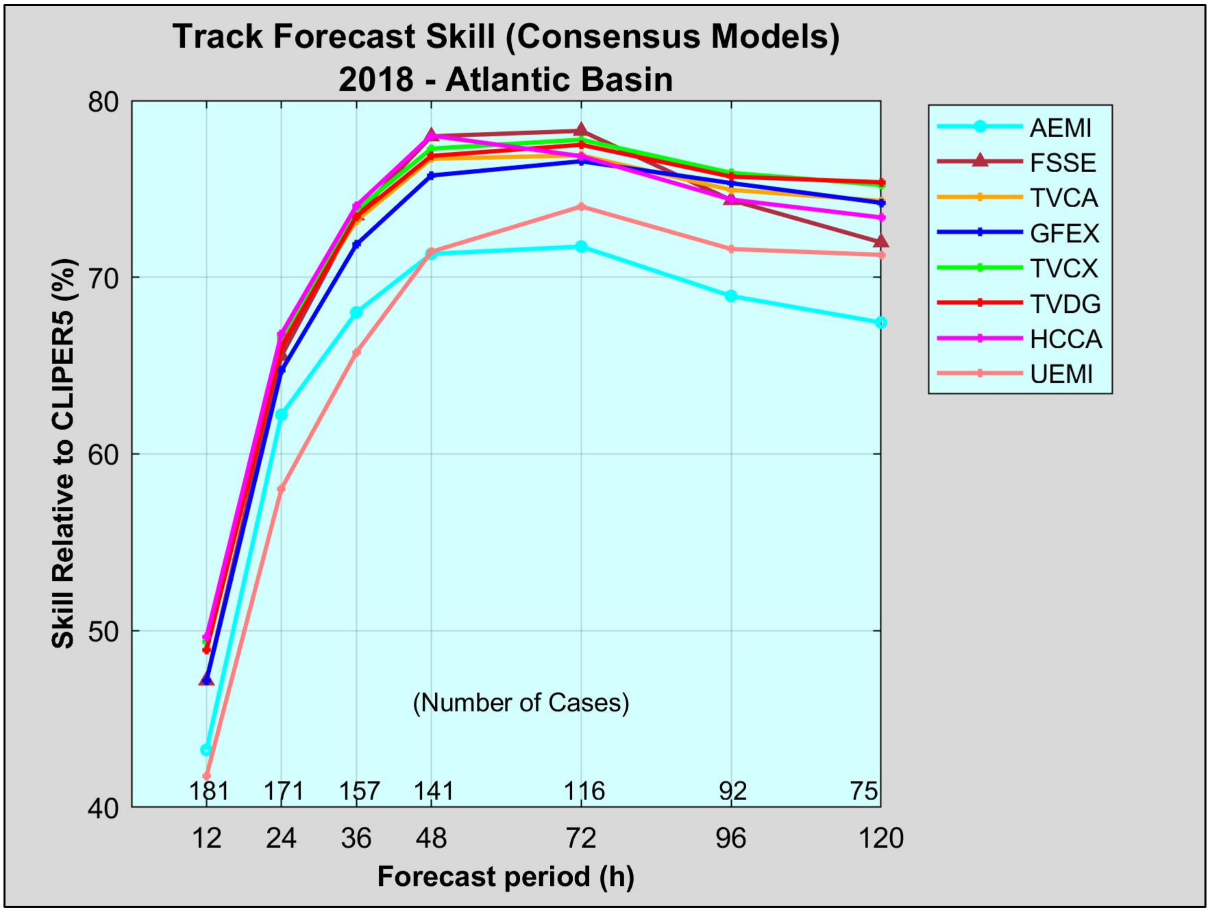


Figure 7. Homogenous comparison of the primary Atlantic basin track consensus models for 2018.

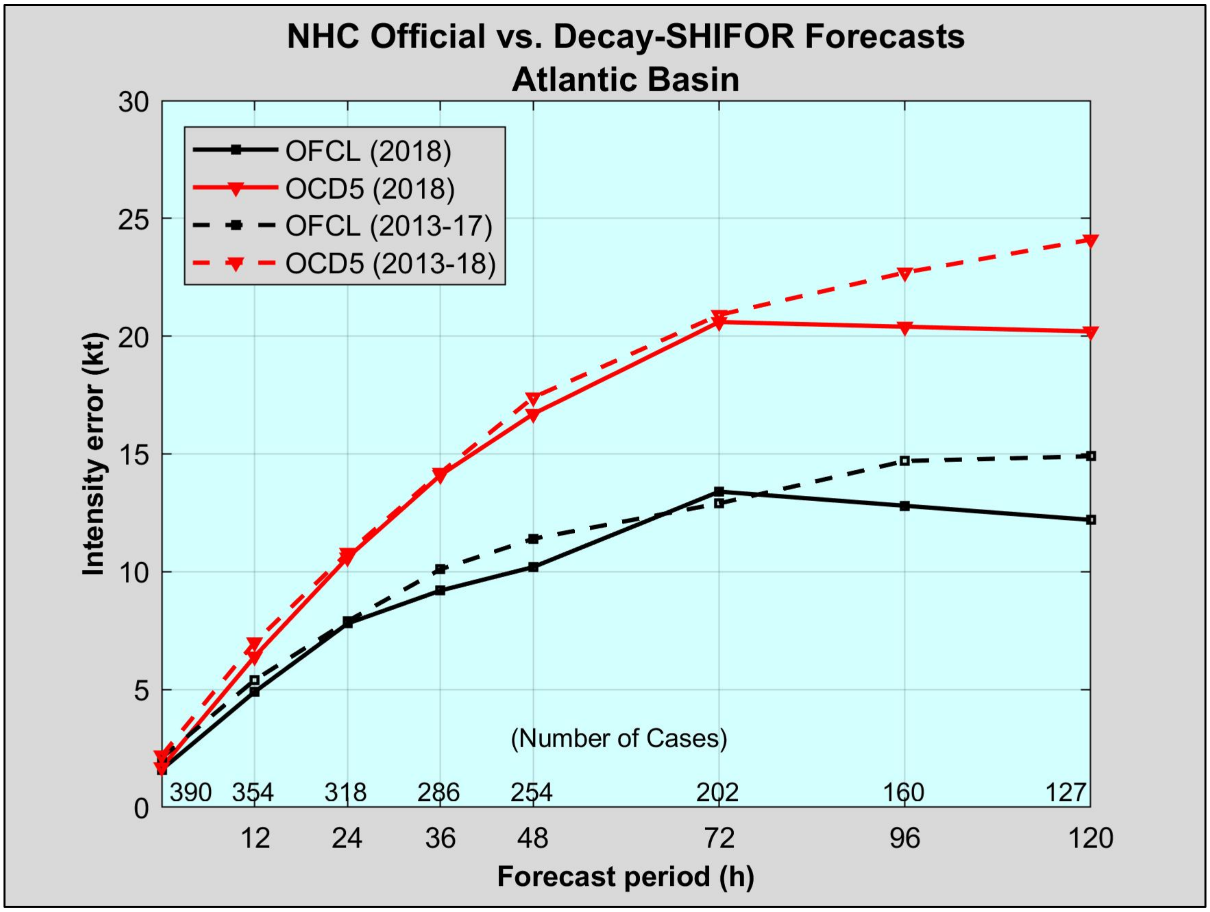
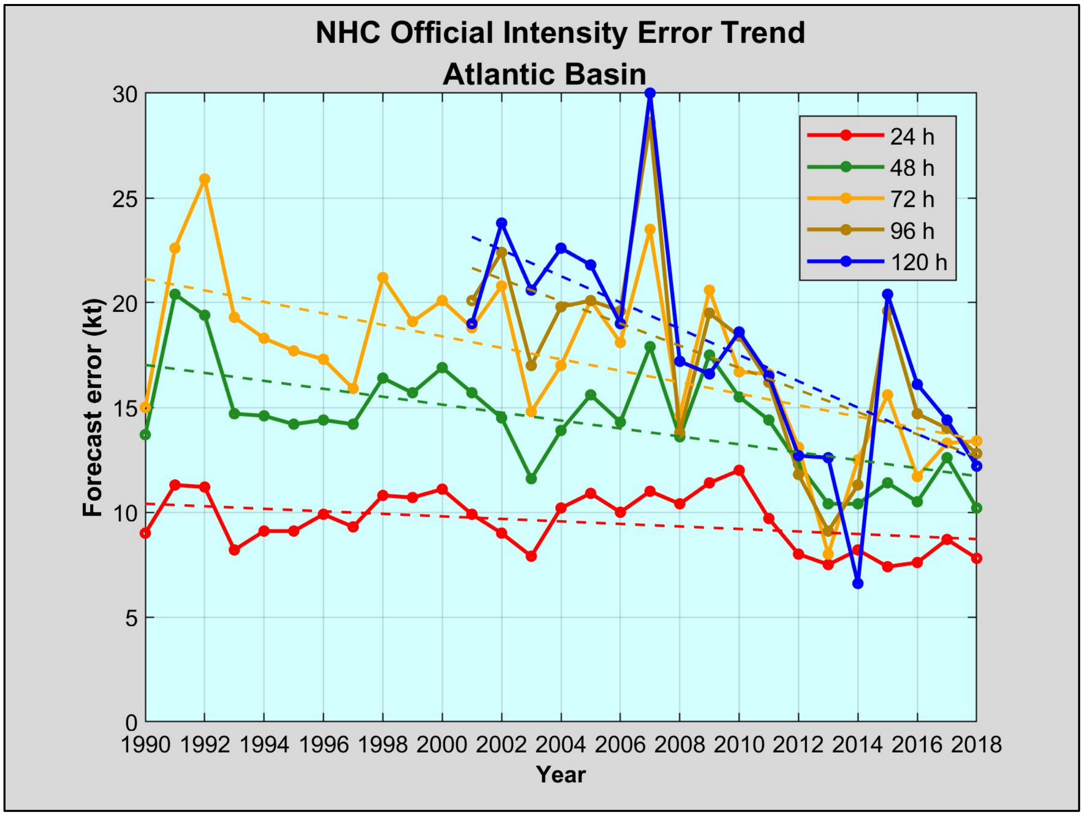


Figure 8. NHC official and Decay-SHIFOR5 (OCD5) Atlantic basin average intensity errors for 2018 (solid lines) and 2013-2017 (dashed lines).



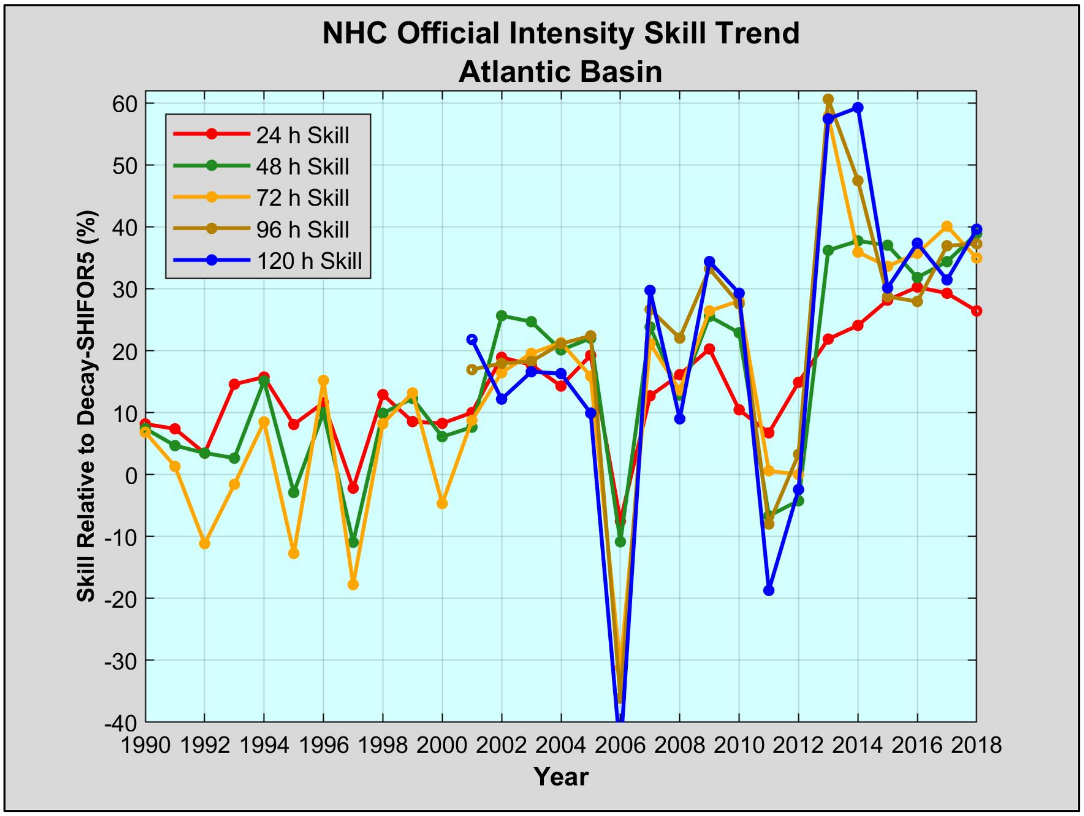


Figure 9. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the Atlantic basin.

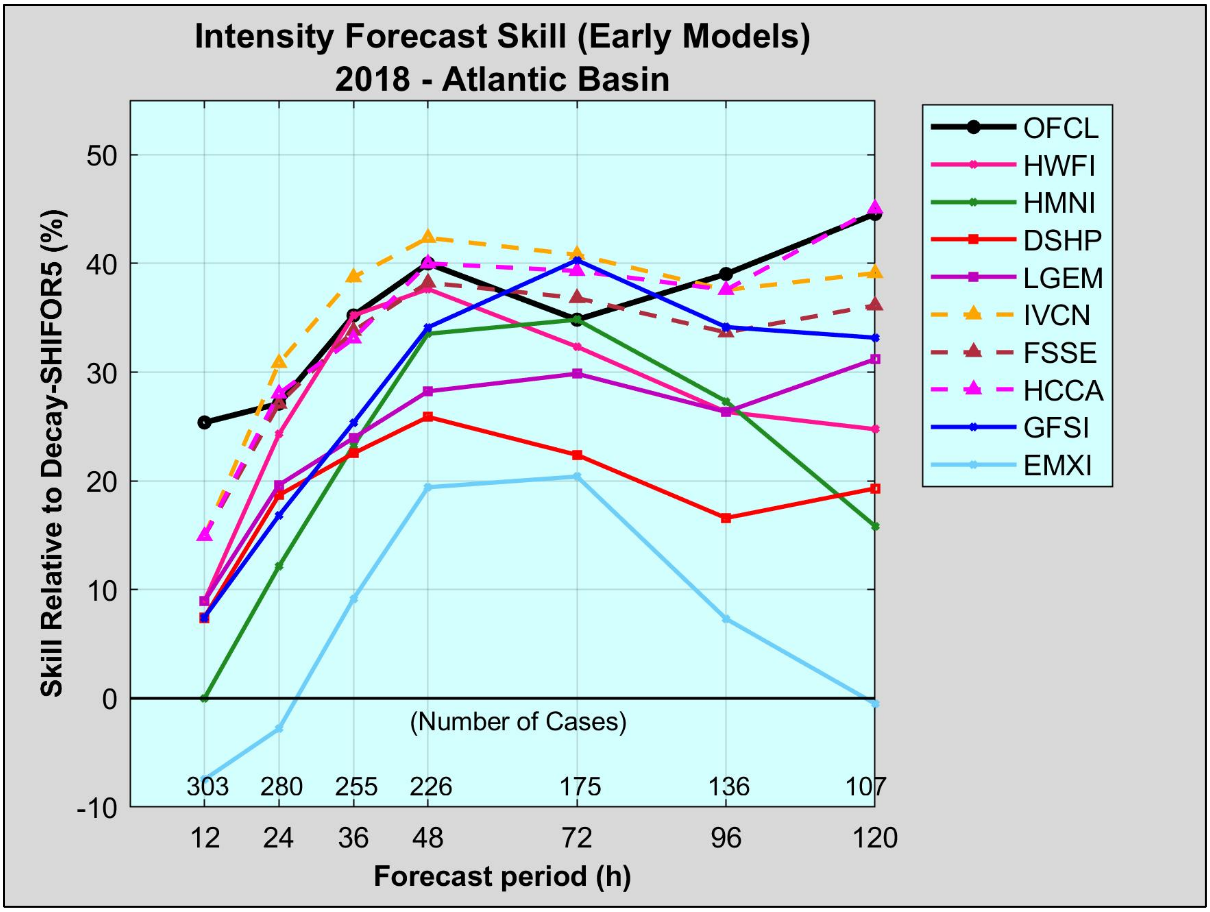


Figure 10. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2018.

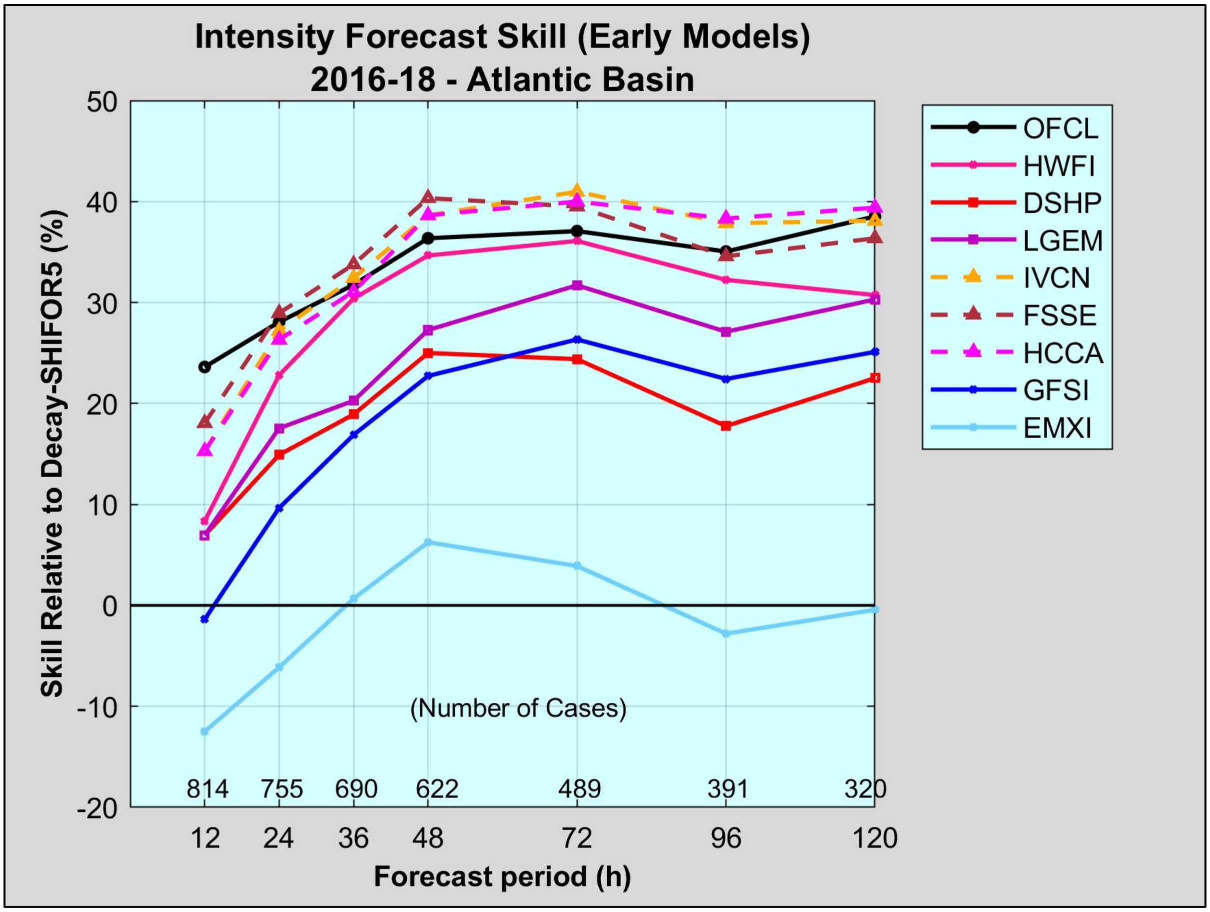


Figure 11. Homogenous comparison for selected Atlantic basin early intensity guidance models for 2016-2018.

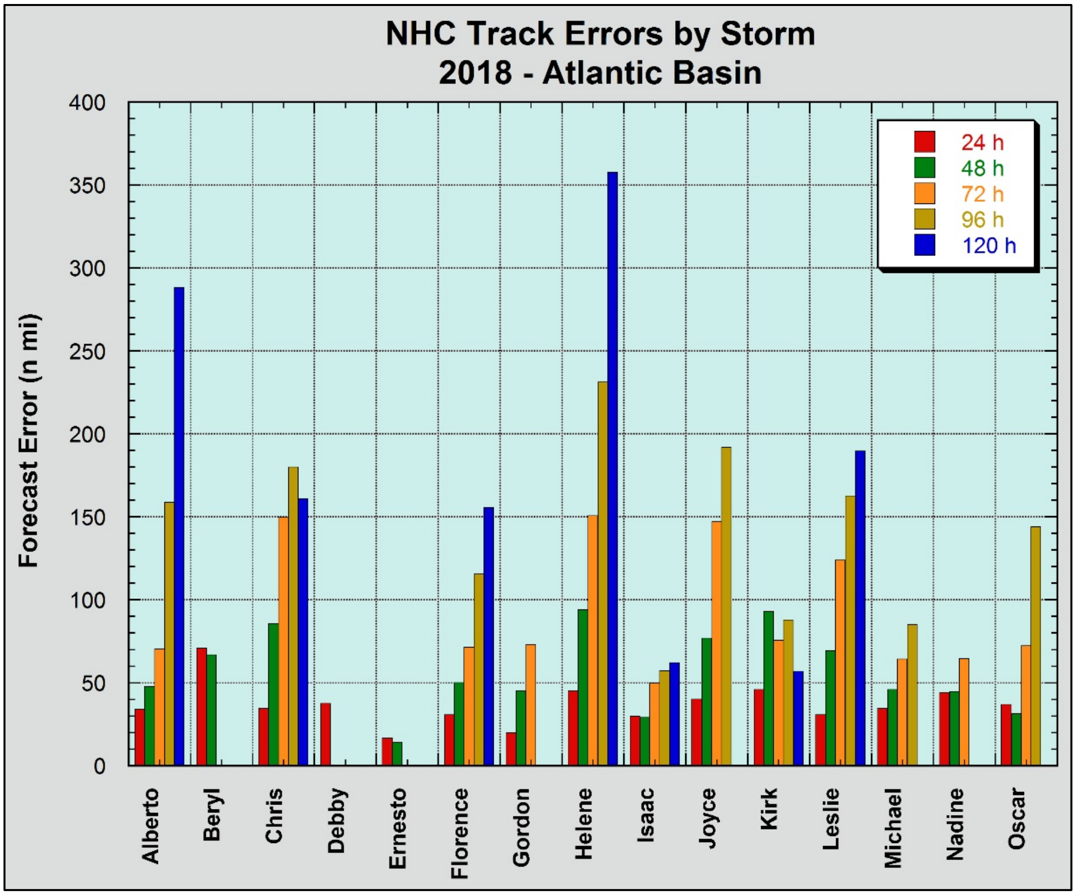


Figure 12. 2018 NHC official track errors by tropical cyclone.

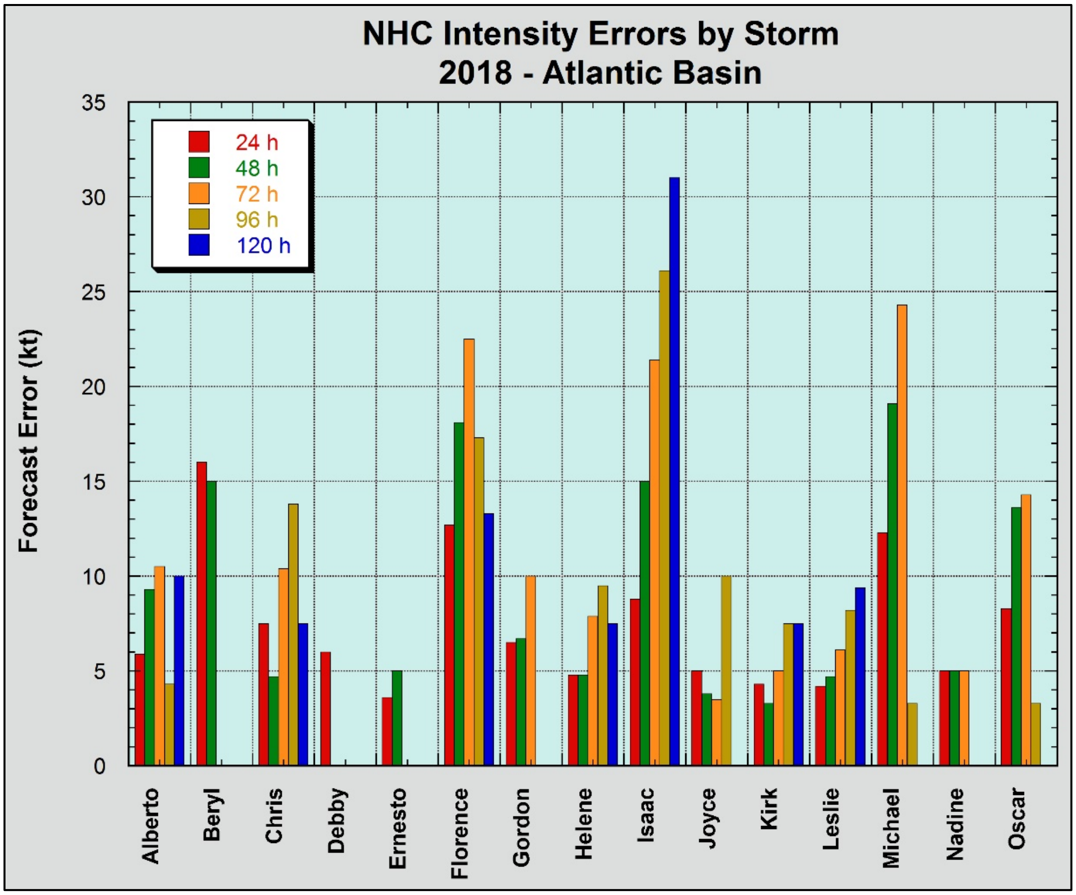


Figure 13. 2018 NHC official intensity errors by tropical cyclone.

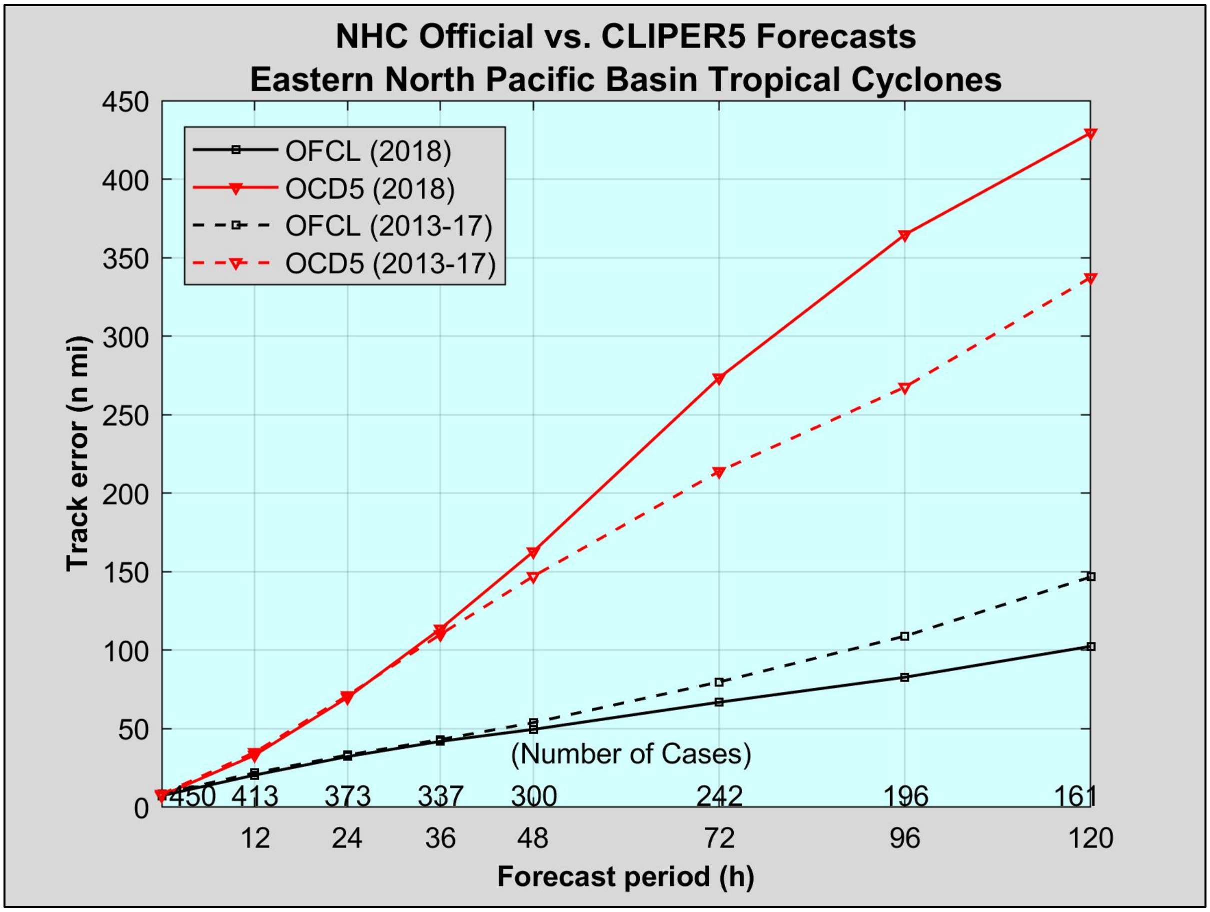


Figure 14. NHC official and CLIPER5 (OCD5) eastern North Pacific basin average track errors for 2018 (solid lines) and 2013-2017 (dashed lines).

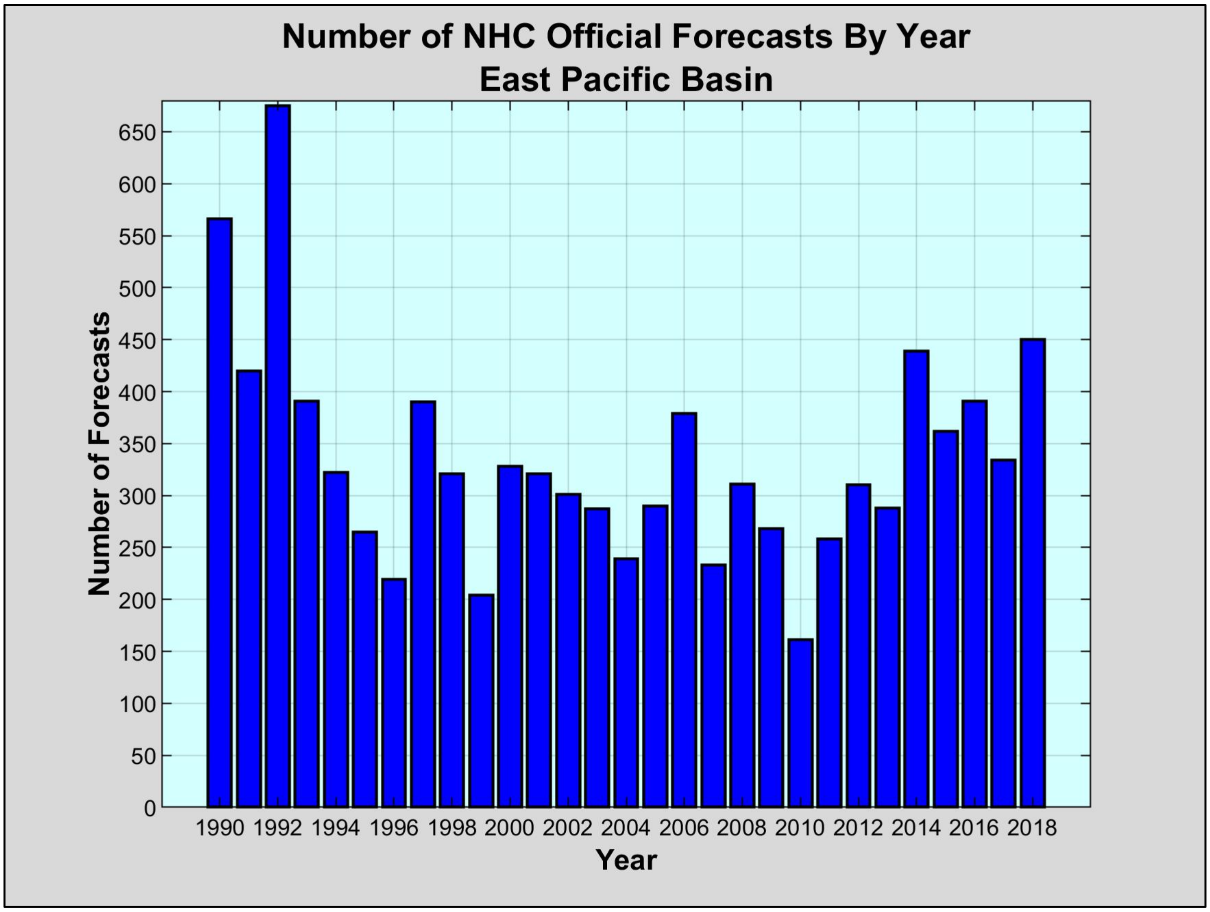
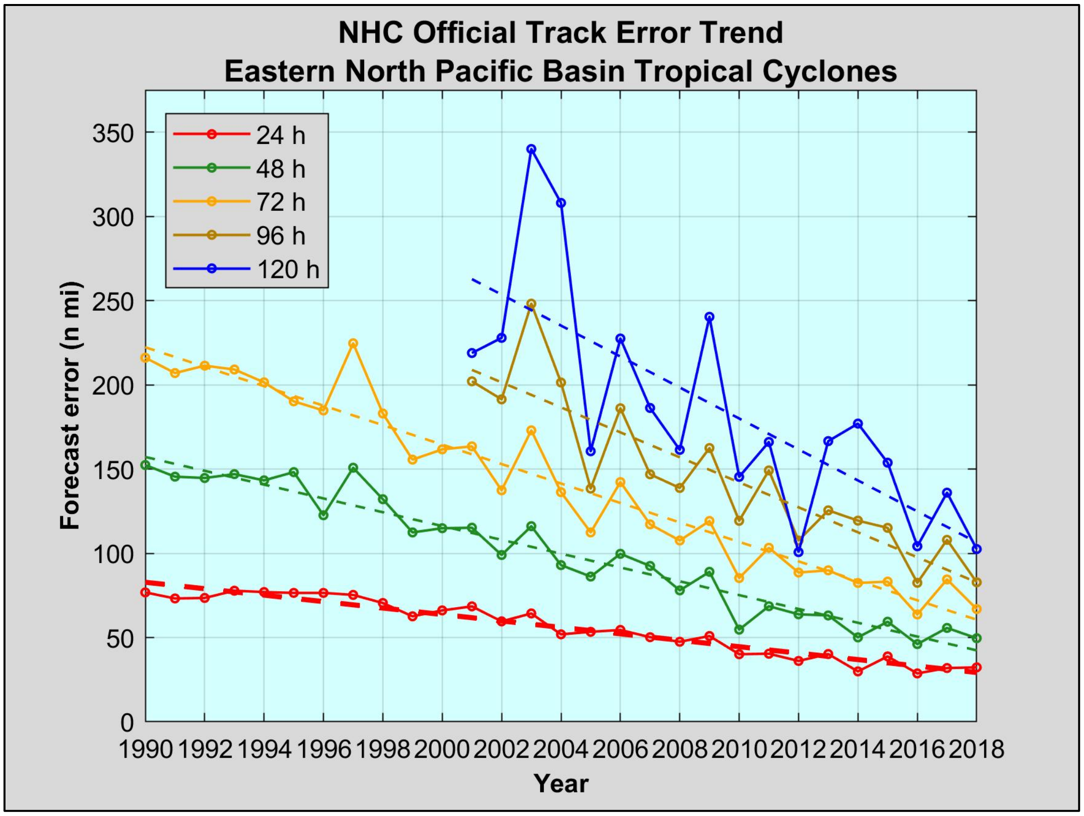


Figure 15. Number of NHC official forecasts for the eastern North Pacific basin stratified by year.



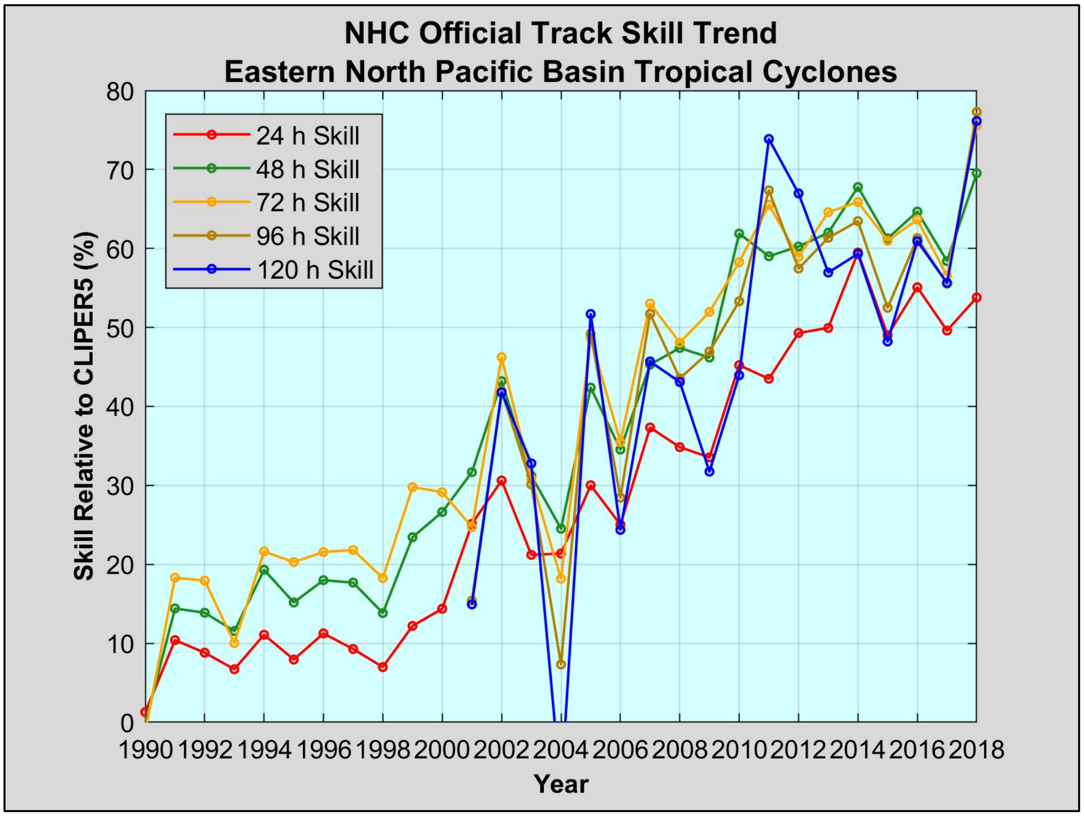


Figure 16. Recent trends in NHC official track forecast error (top) and skill (bottom) for the eastern North Pacific basin.

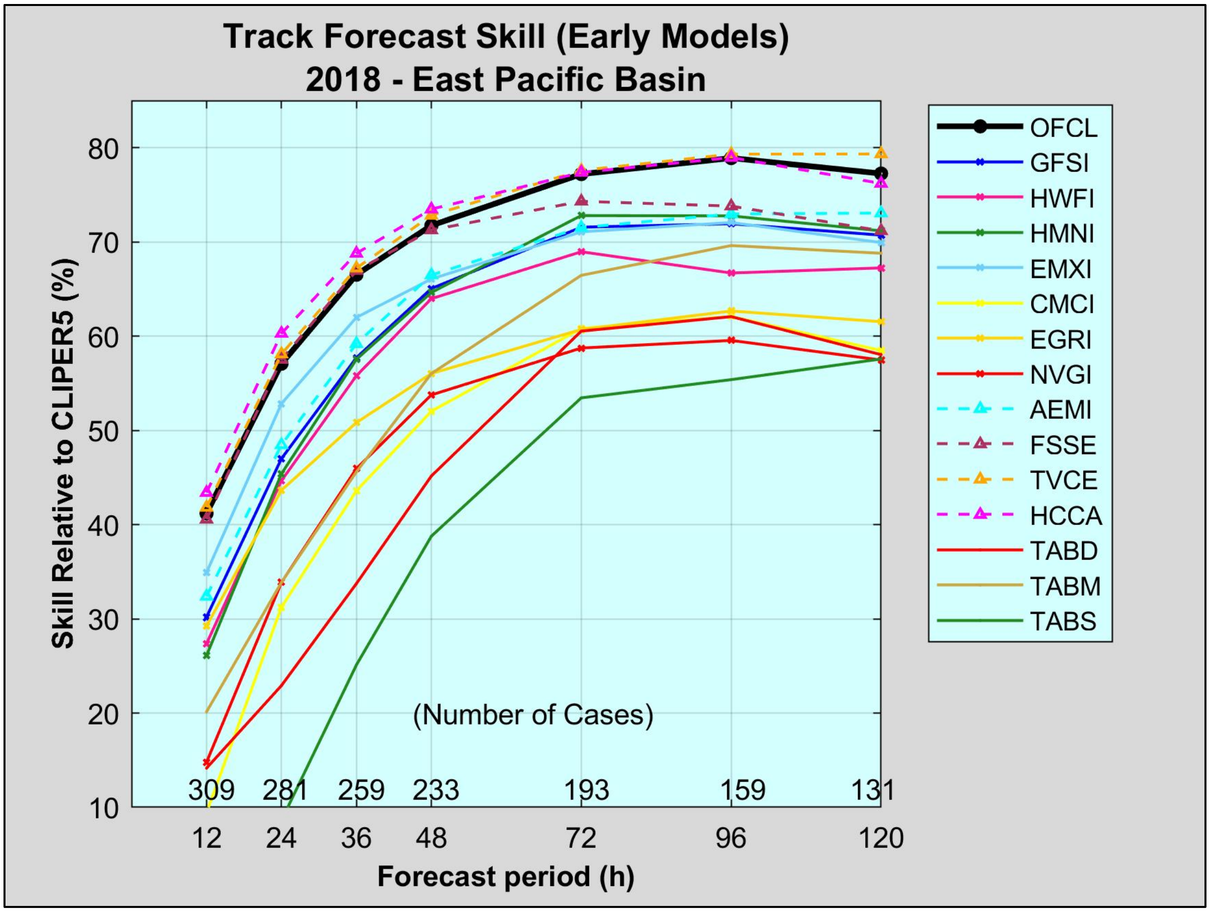


Figure 17. Homogenous comparison for selected eastern North Pacific early track models for 2018. This verification includes only those models that were available at least 2/3 of the time (see text).

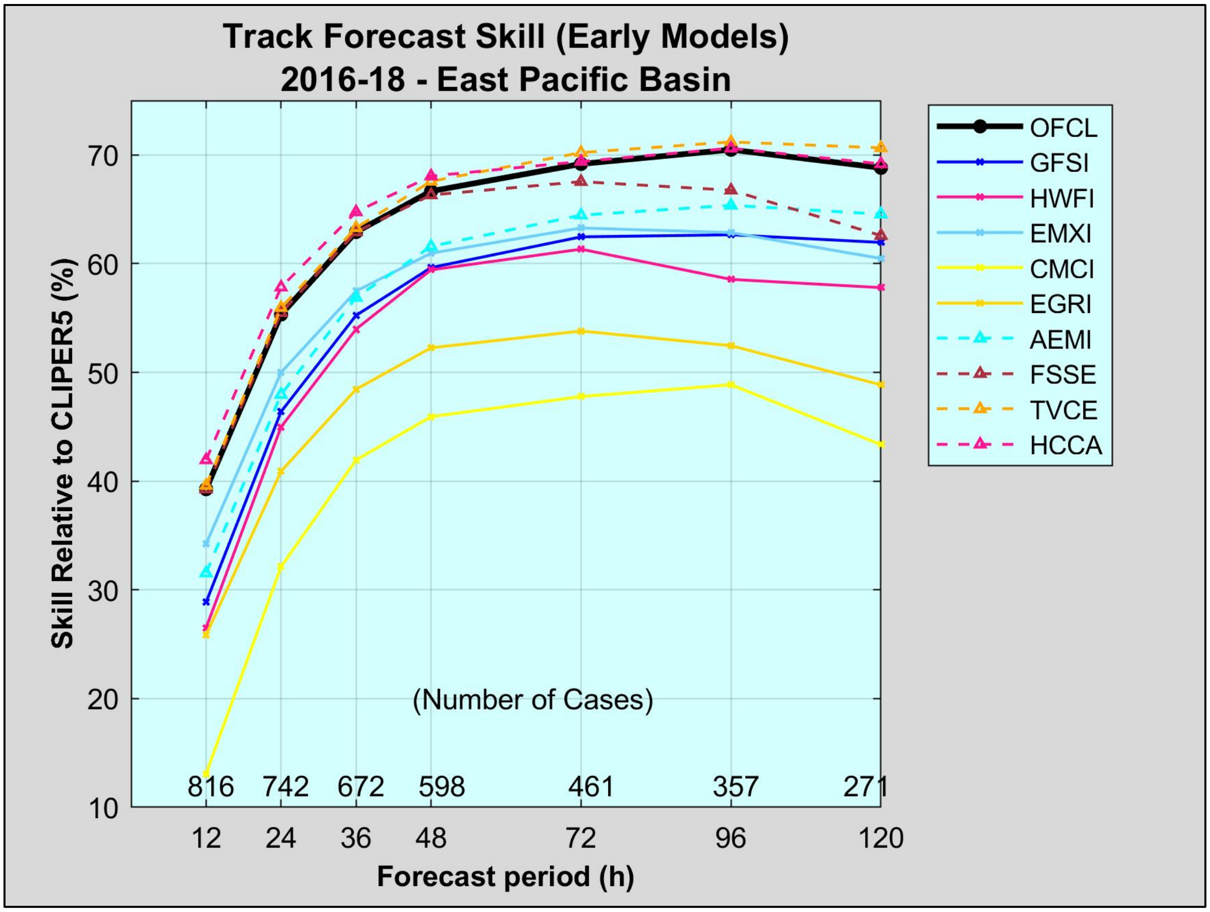


Figure 18. Homogenous comparison for selected eastern North Pacific basin early track models for 2016-2018.

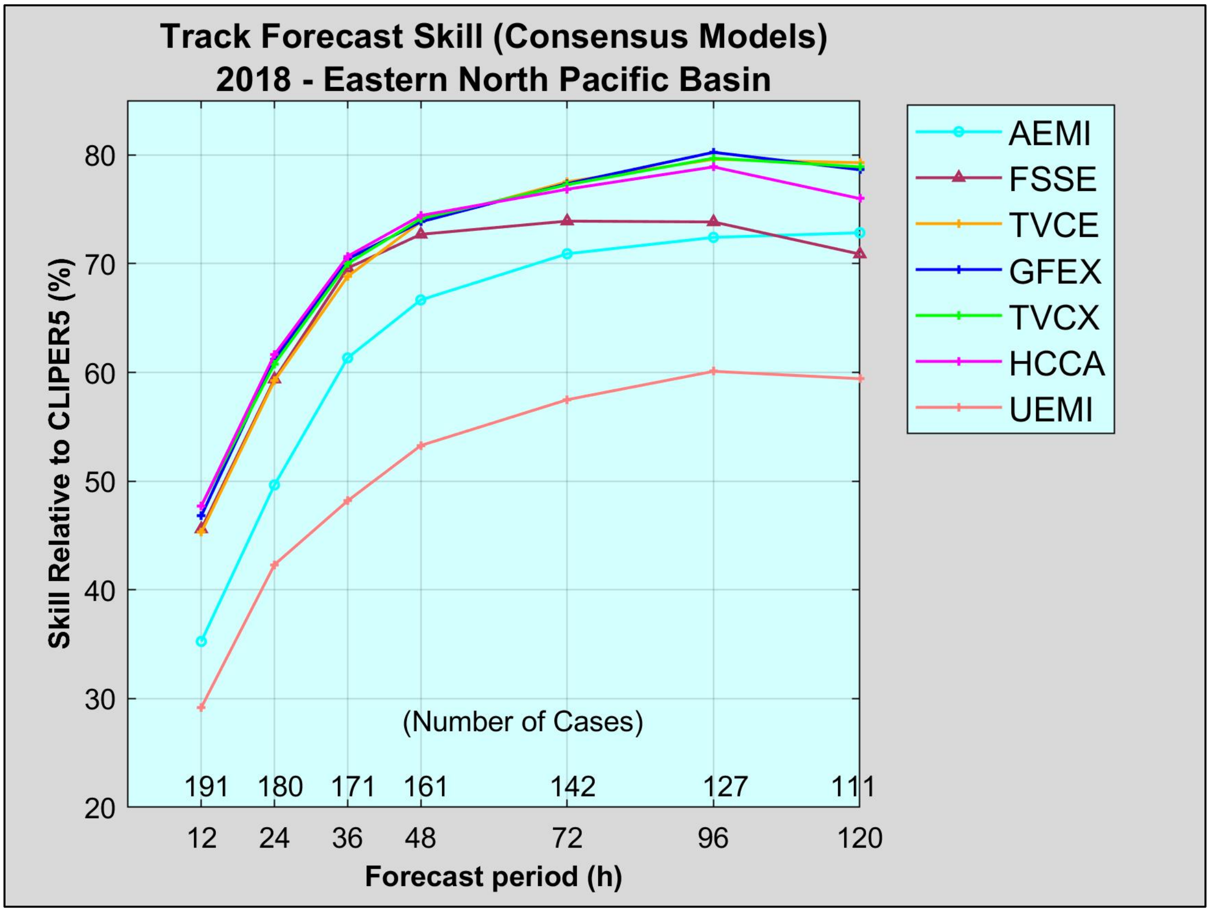


Figure 19. Homogenous comparison of the primary eastern North Pacific basin track consensus models for 2018.

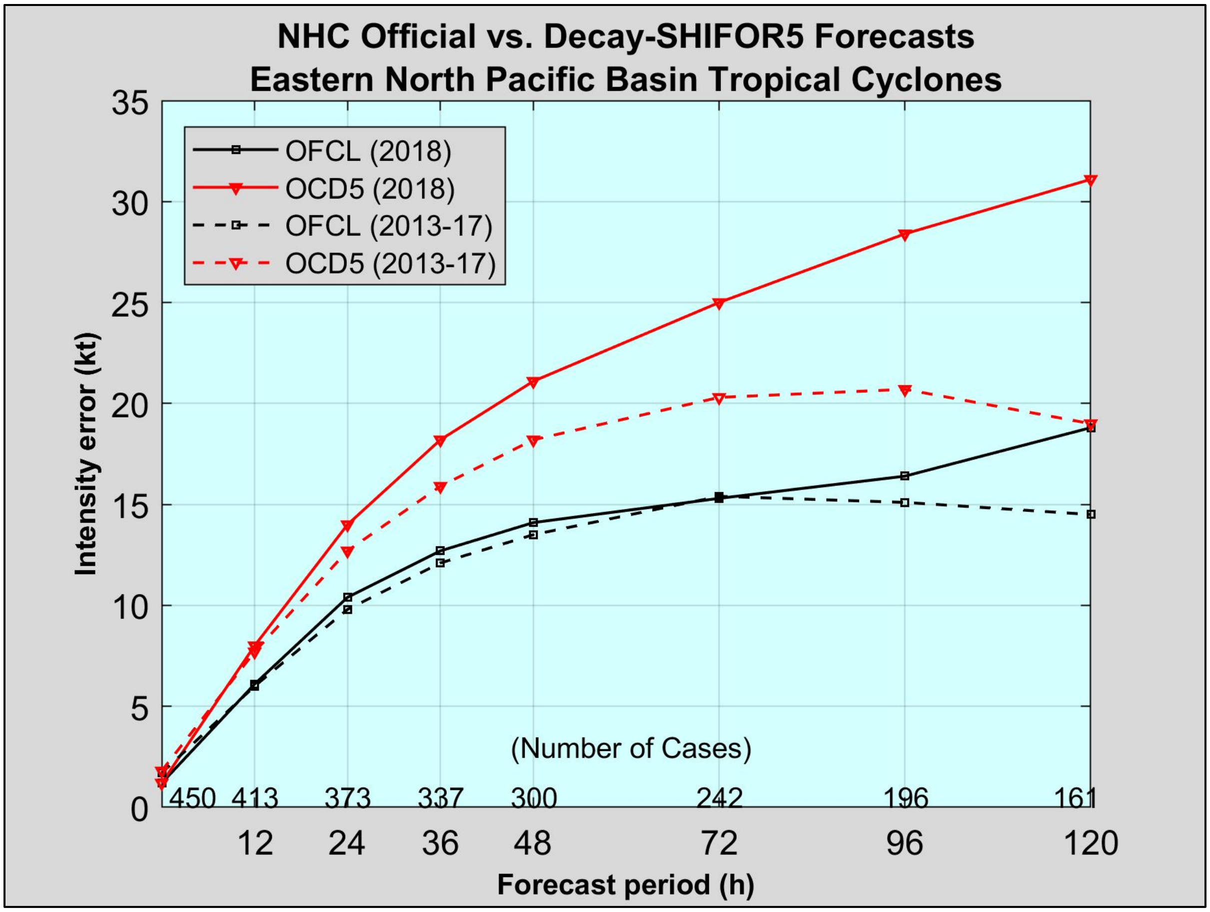
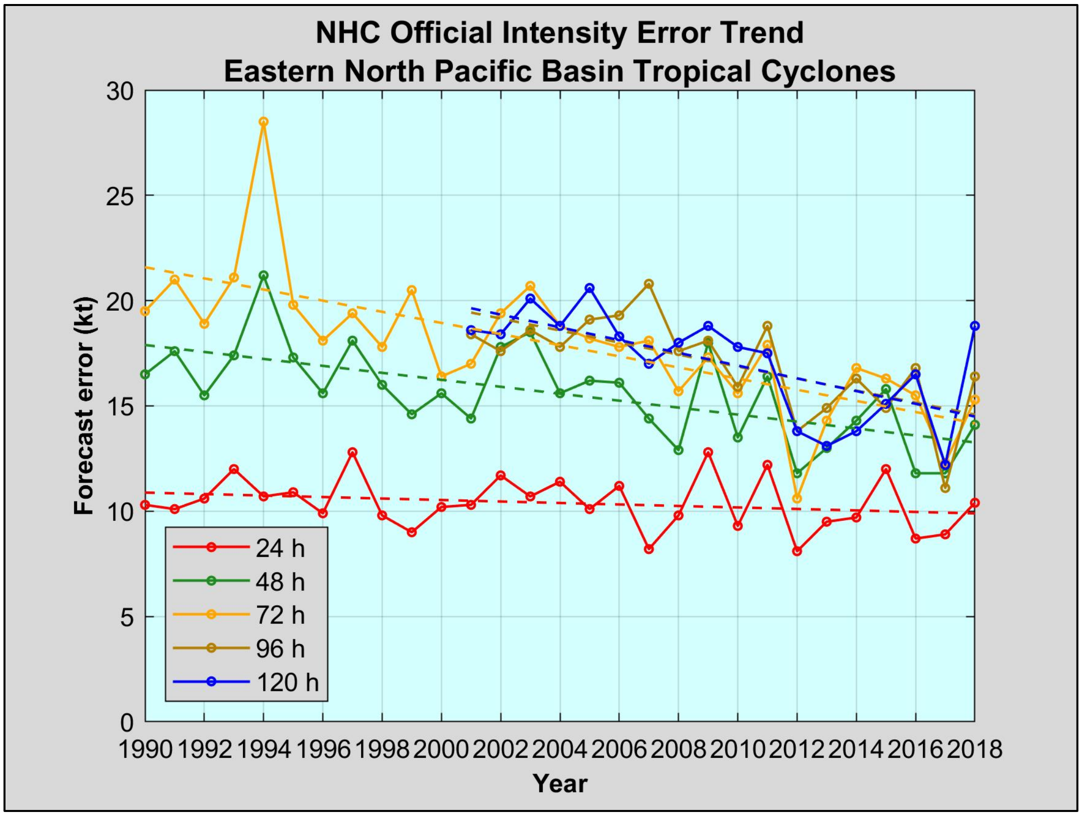


Figure 20. NHC official and Decay-SHIFOR5 (OCD5) eastern North Pacific basin average intensity errors for 2018 (solid lines) and 2013-2017 (dashed lines).



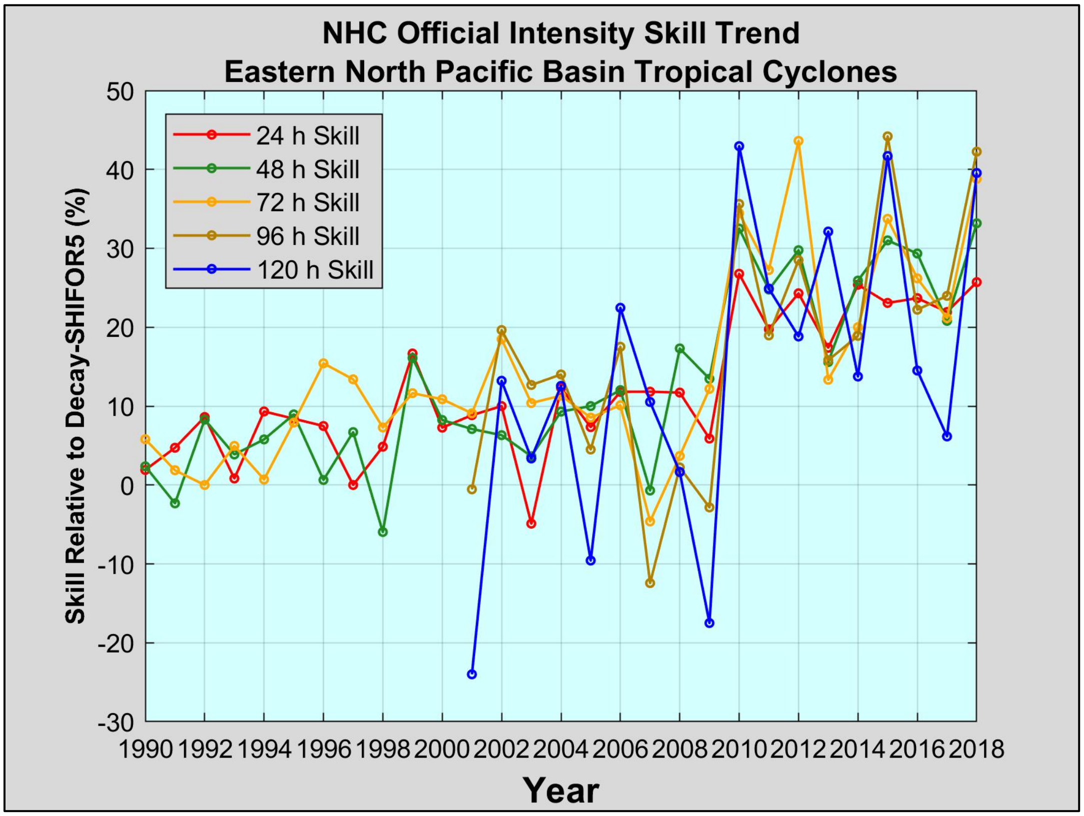


Figure 21. Recent trends in NHC official intensity forecast error (top) and skill (bottom) for the eastern North Pacific basin.

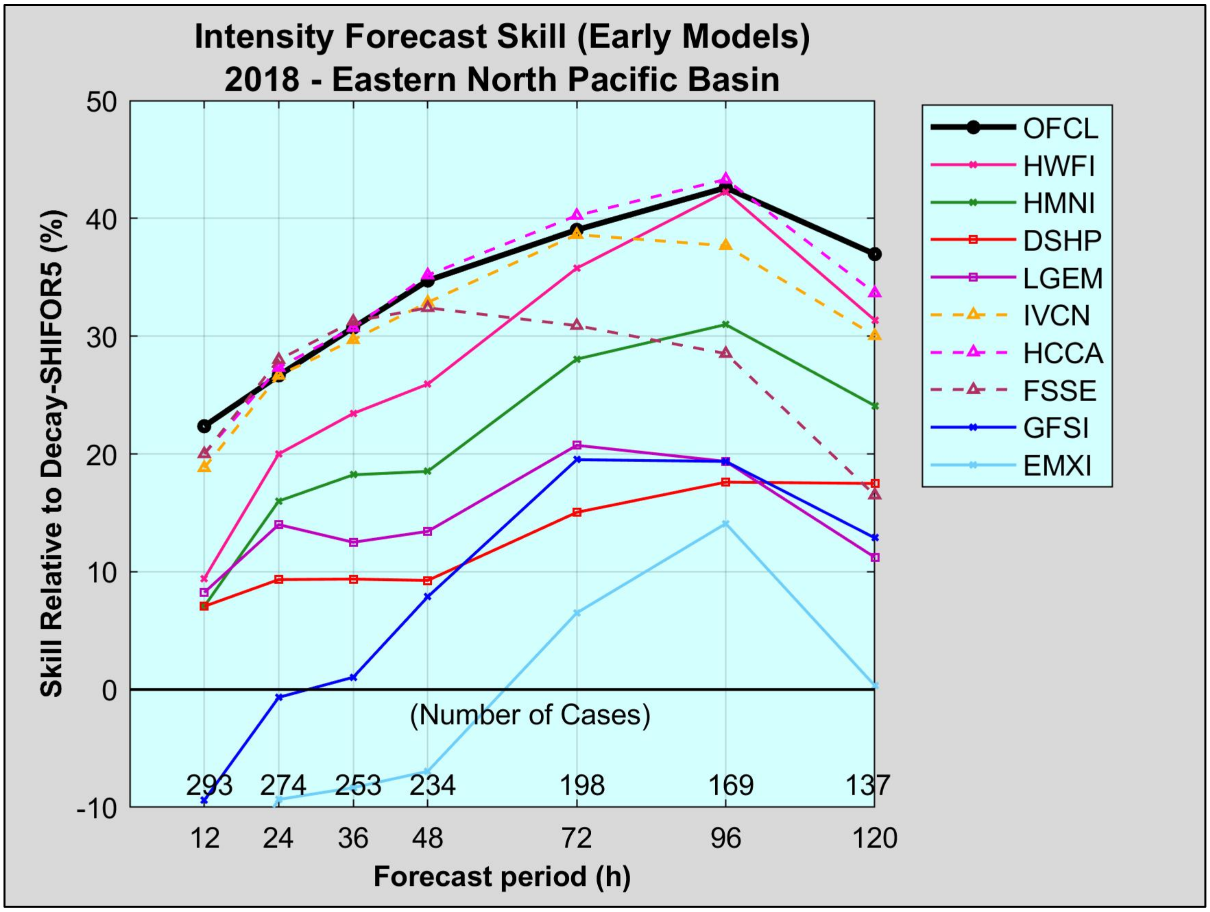


Figure 22. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2018.

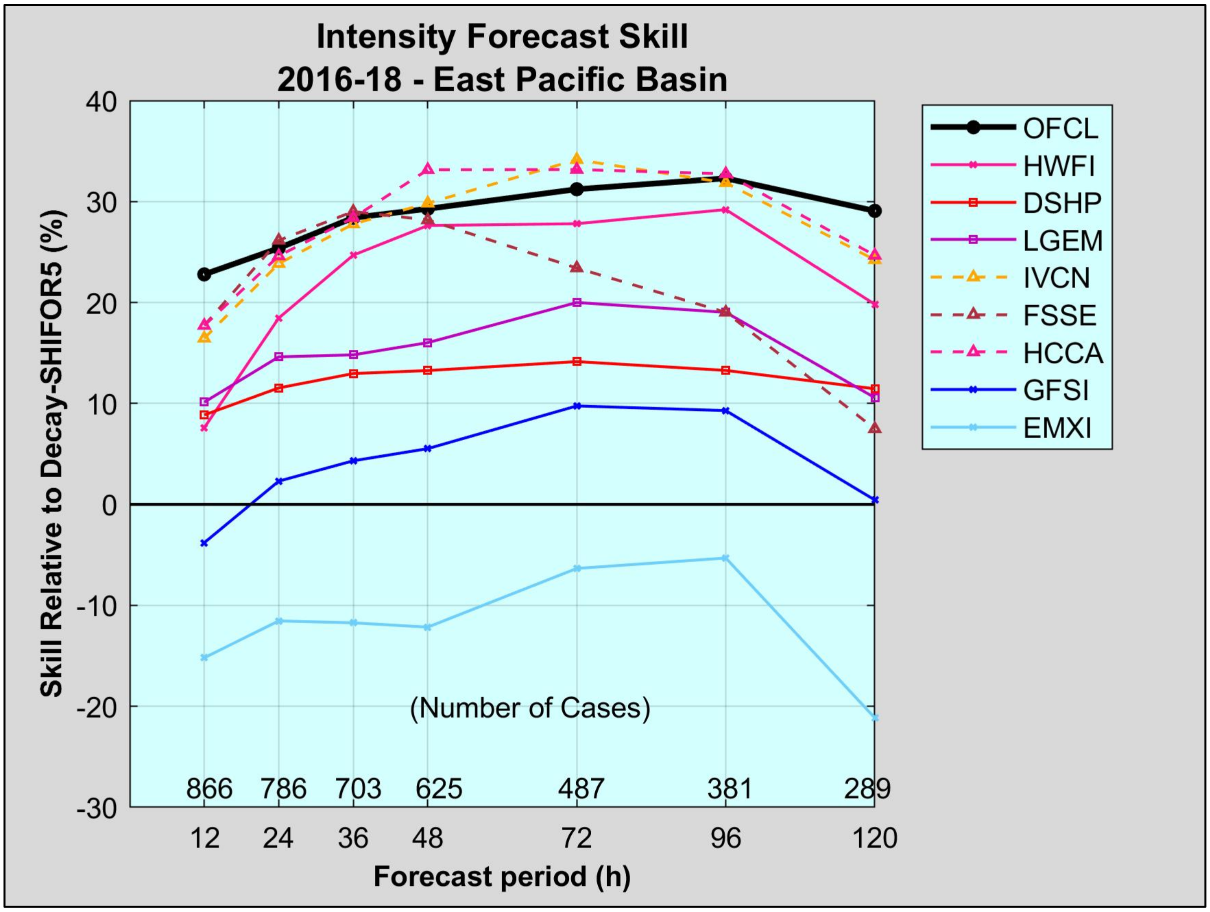
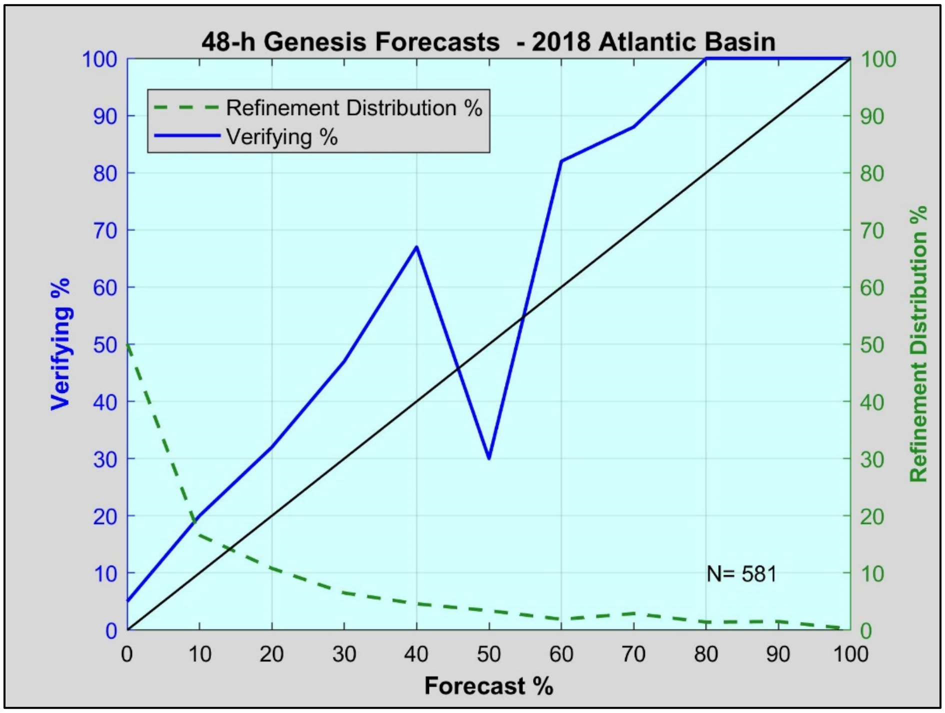


Figure 23. Homogenous comparison for selected eastern North Pacific basin early intensity guidance models for 2016-2018.



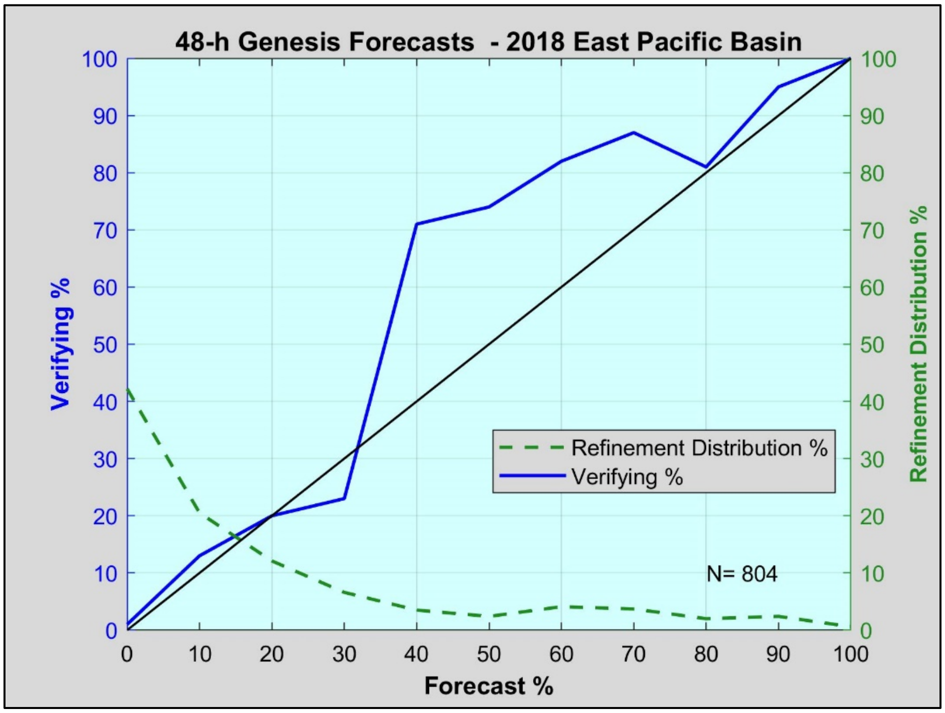
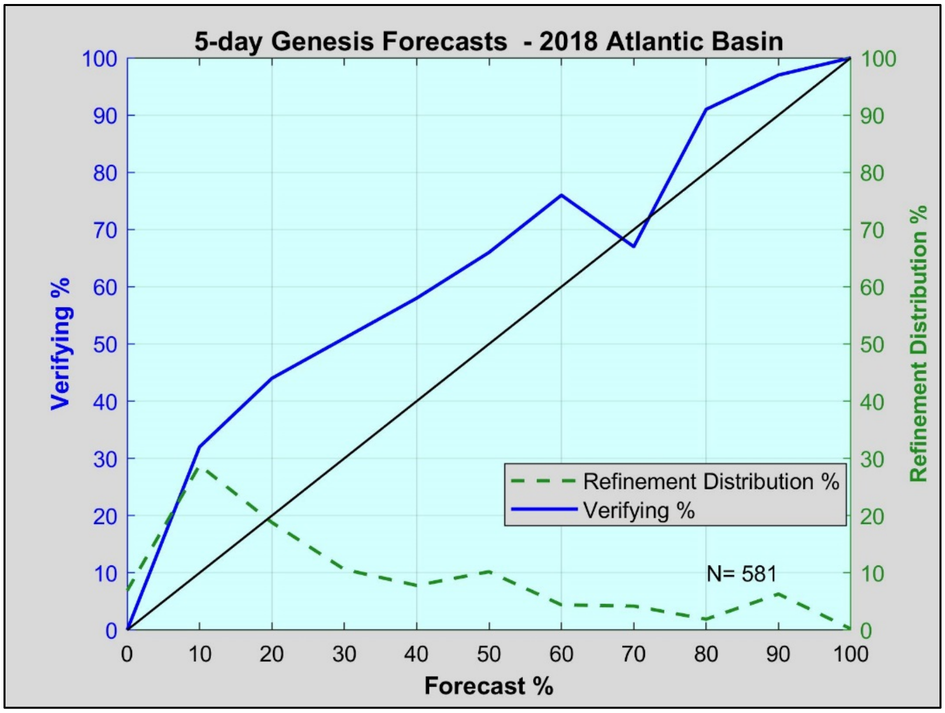


Figure 24. Reliability diagram for Atlantic (top) and eastern North Pacific (bottom) probabilistic tropical cyclogenesis 48-h forecasts for 2018. The solid lines indicate the relationship between the forecasts and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the forecasts were distributed among the possible forecast values.



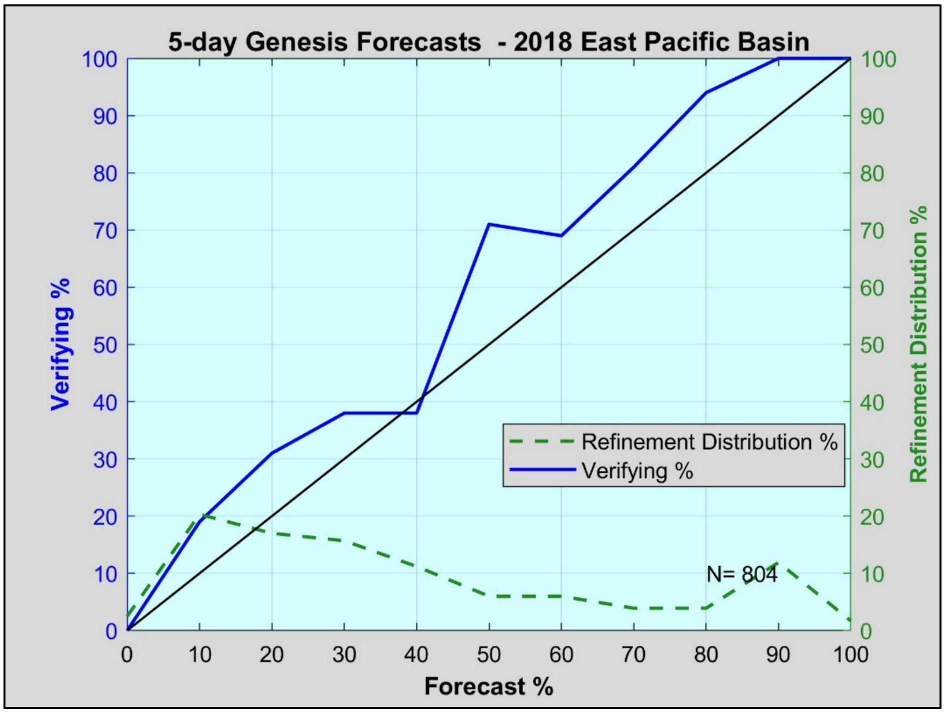


Figure 25. As described for Fig. 24, except for 120-h forecasts.