9C.7 ASSESSMENT OF THE IMPACT OF INCREASED LEAD TIME FOR TROPICAL CYCLONE WATCHES/WARNINGS IN THE NORTH CENTRAL PACIFIC

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1. INTRODUCTION

The lead times for watches and warnings for tropical storms and hurricanes were increased to 48 and 36 hours, respectively, for the central North Pacific in 2009. This extra lead time was implemented to provide additional preparation time for emergency managers, media, and the public, especially in the main Hawaiian Islands, if tropical storm or hurricane winds were forecast to impact any land areas in the area of responsibility (AOR) of the Central Pacific Hurricane Center (CPHC).

Hurricanes Felicia and Neki, which occurred in the central North Pacific during 2009, required the issuance of TC watches. Neki also required a hurricane warning before it impacted some of the small islands which are part of the Papahānaumokuākea Marine National Monument (PMNP), northwest of the main Hawaiian Islands (Fig. 1). In addition to actual watches and warnings, CPHC considered the potential impact these new lead times could have in other scenarios, by applying them to historical North Central Pacific tropical cyclones (TCs). These hypothetical exercises demonstrate the unique challenges with issuing TC watches and warnings for relatively small and isolated geographic locations comprising most of the land areas in the CPHC AOR. Operational TC wind speed probabilities, provided in tabular and graphical product formats with each full CPHC advisory package, were instrumental in the decision making process for the issuance, or simulated issuance, of these watches and warnings.

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This work is part of a broader effort in the National Weather Service (NWS) to develop objective guidance for the issuance of TC watches and warnings that are based on the TC wind speed probabilities. It is also hoped that the result of these assessments will be useful to other TC forecast centers around the world, especially in areas with small, isolated islands for which they have warning responsibility.

This presentation will summarize the impacts of the new tropical cyclone watch and warning lead times on CPHC operations during 2009. Also, we will show a few examples of some significant historical central North Pacific hurricanes (e.g., Iwa of 1982, Iniki of 1992, Emilia of 1994, Daniel of 2000, Ioke of 2006, and Flossie of 2007) might have been handled if they occurred with the longer lead times and the benefit of the wind speed probability products.

2. TC WIND SPEED PROBABILITIES

Starting in the 2006 hurricane season, after an experimental period in 2005, a TC wind speed probability program was implemented for the Atlantic and eastern, central, and western North Pacific basins that takes into account the uncertainties in track, intensity, and wind structure forecasts out to 5 days (DeMaria et al. 2009). This program uses a Monte Carlo technique to estimate the probability of winds of at least 34, 50, and 64 kt at individual marine, coastal, and inland locations throughout each basin, from 6 to 120 hours, based on official forecast error statistics from the previous 5 years. DeMaria et al. (2009) described the Monte Carlo probability (MCP) model. The MCP model utilizes the error distributions from the official track and intensity forecasts. The National Hurricane Center (NHC) has forecast responsibility for all tropical cyclones in the North Atlantic and the eastern North Pacific out to 140^{O}W,

CPHC has that responsibility in the central North Pacific from 140°W to the International Date Line, and JTWC forecasts TCs in the western North Pacific. The three versions of the MCP model that were developed were for 1) the Atlantic, 2) the combined eastern and central North Pacific, and 3) the western North Pacific. The eastern and central North Pacific TCs were combined because the sample size is very small in the central North Pacific, and the 140°W partition has no physical significance.

Preliminary results of a study by Mainelli et al. (2008) based on the 2004-2006 hurricane seasons at NHC indicated the mean 64 kt wind speed probabilities were around 10% at the end points of a hurricane watch or warning at first issuance. This study did not include tropical storm watches or warnings. An application for automating NWS Weather Forecast Office products during tropical cyclone landfalls, based in part on the MCP model, is currently under development [e.g., see Santos et al. (2009)].

3. HURRICANES FELICIA AND NEKI

The first TCs which required the issuance of TC watches / warnings by CPHC based on the new longer lead times occurred in August (Hurricane Felicia) and October (Hurricane Neki) of 2009. Although Felicia ultimately weakened to a dissipating tropical depression prior to reaching the Hawaiian Islands, it is an example of other similar hurricanes that have required TC watches / warnings as they approached the Big Island of Hawaii during the previous decade (others include Daniel of 2000, Jimena of 2003 and Flossie of 2007).

3.1 *Hurricane Felicia*

According to Kimberlain et al. (2010), the CPHC issued its first advisory on Hurricane Felicia at 2100 UTC on 8 Aug. 2009 after it crossed 140°W with maximum sustained 1-min wind speeds of 75 kt (see Fig. 1). Early on 9 Aug., aircraft reconnaissance data and microwave imagery indicated the flight-level center of Felicia was no longer collocated with the surface center. This marked the beginning of a weakening trend, as Felicia encountered increasing westerly vertical wind shear produced by a broad upper-level trough over and north of the Hawaiian Islands.

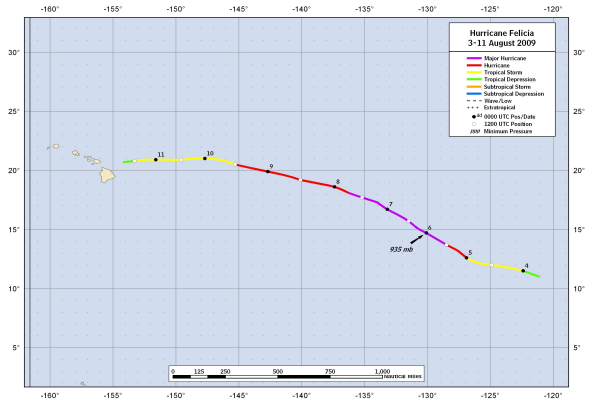

Figure 1. *Best track for Hurricane Felicia.*

Table I shows the watches required for Hurricane Felicia, with the initial tropical storm watch issued at 0300 UTC on 9 Aug. The TC Discussion issued at that time indicated:

"GIVEN THE UNCERTAINTIES WITH INTENSITY FORECASTING...IT IS IMPORTANT TO POINT OUT THE INTENSITY PROBABILITIES ACCOMPANYING THIS ADVISORY PACKAGE. THAT PRODUCT INDICATES THAT THERE IS ABOUT A 60 PERCENT CHANCE OF FELICIA BEING A TROPICAL STORM IN 48 HOURS WHEN IT IS VERY NEAR THE HAWAIIAN ISLANDS...WITH ABOUT A 25 PERCENT CHANCE OF IT BEING A TROPICAL DEPRESSION...AND A 10 PERCENT CHANCE OF IT BEING A HURRICANE.

THE NEW FORECAST NECESSITATES THE ISSUANCE OF A TROPICAL STORM WATCH FOR PORTIONS OF THE HAWAIIAN ISLANDS...SINCE THE LEAD TIME FOR WATCHES IN THE CENTRAL PACIFIC BASIN IS 48 HOURS. FORECAST POSITIONS AND MAX WINDS"

Table I: *T.C. watches issued for Felicia*

0300 UTC 9 Aug.	T.S. Watch issued for the islands of Hawaii, Maui, Molokai, Lanai and Kahoolawe
0300 UTC 10 Aug.	T.S. Watch expanded to include island of Oahu

Felicia weakened to a tropical storm by 1200 UTC 9 Aug. while centered about 550 n mi east of Hilo, Hawaii. By 0000 UTC 10 Aug., the increasing vertical wind shear had

caused Felicia to weaken significantly, as the exposed low-level circulation center became displaced from the deep convection. The maximum sustained winds had diminished to 45 kt, down from 75 kt just 24 hours earlier.

Felicia weakened to a tropical depression by 1200 UTC 11 Aug. while centered 120 n mi northeast of Hilo, and became a remnant low around 1800 UTC. Shortly thereafter, the low-level circulation center became ill-defined as it interacted with the high terrain of the Big Island of Hawaii, and the circulation dissipated. Therefore, no TC warnings were ever issued for Felicia.

3.2 *Hurricane Neki*

Neki was the final TC and only Saffir-Simpson Scale category three hurricane in the north Central Pacific in 2009 according to Wroe and Knabb (2010). After developing south of the main Hawaiian Islands (see Fig. 2), Neki moved northwestward toward Johnston Island for the first few days. The hurricane turned toward the north well before it reached Johnston Island and then toward the north northeast. Neki arrived in the PMNP as a hurricane, but slowed its forward speed considerably by the time it reached these islands. As it passed through the PMNP, it weakened to a tropical storm that impacted French Frigate Shoals and Necker Island (see Fig. 3). After leaving the PMNP, Neki degenerated into a remnant low over the open waters of the Central Pacific.

Table II shows the TC watches and warnings that were issued for Neki. Note that even though the TC never directly affected Johnston Island, the 48 hour lead time for TC watches, resulted in the issuance of a hurricane watch for that island at 0900 UTC 20 Oct. Once it was clear that Neki's hurricane winds would not affect that small island, the hurricane watch was changed to a tropical storm watch (this watch was also cancelled a short time later).

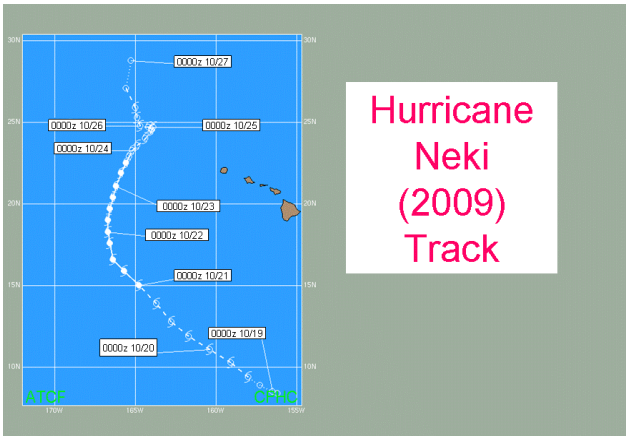

Figure 2. *Best track for Hurricane Neki with positions shown at 0000 UTC each day in Oct. 2009.*

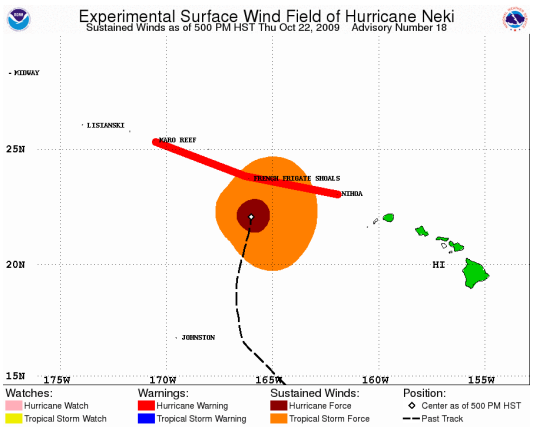

Figure 3. *Real-time plot of the Hurricane Neki wind field valid at 0300 UTC 23 Oct. 2009, with line segments showing the hurricane warnings for the islands in the PMNP.*

Table II: *Watches / warnings issued for Neki*

0900 UTC 20 Oct.	Hurricane watch issued for Johnston Island
0300 UTC 21 Oct.	T.S. watch for Johnston Island
0900 UTC 21 Oct	Hurricane watch for PMNP from French Frigate Shoals to Lisianski
1800 UTC 21 Oct	Hurricane watch expanded to include Nihoa Island to French Frigate Shoals
2100 UTC 21 Oct.	Hurricane warning from Nihoa island to Maro Reef
0300 UTC 22 Oct.	Hurricane watch from Maro Reef to Lisianski changed to a T.S. watch
1200 UTC 22 Oct.	T.S. watch cancelled from Maro Reef to Lisianski
1500 UTC 23 Oct.	Hurricane warning from Nihoa island to Maro Reef changed to T.S. Warning

Neki's intensification to a major hurricane and its shift to a more northward forward motion early on 21 Oct. proved to be problematic for forecasting the arrival of its outermost winds in the PMNP. Besides the strong winds and heavy rains associated with the TC, these low-lying islands are vulnerable to inundation by large waves and significant swells For example, Tern Island (Fig. 4) and Laysan Island provide vital habitats for Hawaiian monk seals and nesting sea turtles. As a result, a few Federal and State of Hawaii park managers, biologists, and operations specialists are often present on some of these very remote islands and atolls at any time of the year, including the official north Central Pacific hurricane season, which is from 1 June to 30 November.

Figure 4. *Tern Island is an example of one of the very small land areas in French Frigate Shoals, which is part of the PMNP.*

Neki's maximum sustained winds had increased to 75 kt by 0900 UTC 21 Oct. At the same time, the TC wind probability text product showed an 8% chance of 64 kt winds, and a 54% chance of 34 kt winds at French Frigate Shoals within the next 120 hours (see Table III). A hurricane watch was issued for the PMNP from French Frigate Shoals to Lisianski at that time according to Table II. By 1800 UTC 21 Oct., Neki's winds were near 100 kt and the intensifying hurricane was moving toward the north northwest at about 10 kt. The probability of 64 kt winds had previously increased to 11% at French Frigate Shoals 3 hours earlier (see Table III). Therefore, the hurricane watch was expanded to include the segment from Nihoa Island to French Frigate Shoals. A hurricane warning was issued from Nihoa Island to Maro Reef at 2100 UTC 21 Oct., when the cumulative probability of 64 kt winds had increased to 22% at French French Frigate Shoals.

Table III: *Real-time TC wind probabilities for French Frigate Shoals during Hurricane Neki. Prob34 and Prob64 are the 120 hour cumulative probabilities of occurrence of 34 kt and 64 kt winds, respectively, at that location.*

Date	Hr(UTC)	Prob34 (%)	Prob64 (%)
18	2100	0	0
19	300	0	0
19	900	3	0
19	1500	0	0
19	2100	9	0
20	300	14	1
20	900	18	2
20	1500	17	2
20	2100	34	5
21	300	34	4
21	900	54	8
21	1500	65	11
21	2100	82	22
22	300	89	33
22	900	87	30
22	1500	69	8
22	2100	89	28
23	300	94	26
23	900	91	22
23	1500	99	0

According to Wroe (2010), there were no reports of property damage or casualties associated with Neki. However, due to the isolated and extreme vulnerability of the low-lying islands and atolls within the PMNM, emergency evacuations were required for personnel at two island locations shortly before Neki's outer bands of sustained 34 kt winds arrived. With enough lead time (although less than the goal of 36 hours in this case), ten people were evacuated from the path of the hurricane at Tern Island (see Fig. 4.) by a United States Coast Guard C-130 which made a successful, but precarious landing and departure in deteriorating weather conditions at approximately 2230 UTC 21 Oct.. Also, seven individuals were safely removed from Laysan Island (located northwest of French

Frigate Shoals) by the NOAA R/V *Oscar Elton Sette* at approximately 0130 UTC 22 Oct.. A PMNP Press Release (2009) indicated "Round Island may now be smaller, and, true to its name, Disappearing Island has disappeared" as a result of Neki's passage.

4. PROBABILITIES FOR HISTORIC CPHC HURRICANES

Starting in 2002, the CPHC has conducted annual training workshops for its hurricane forecasters at the beginning of each hurricane season. During the early years of this training, much time was devoted to basic training about forecasting track and intensity for TCs, especially as these parameters related to the Automated Tropical Cyclone Forecasting (ATCF) application used at CPHC, NHC and JTWC. However, only general guidelines were provided in the portion of the training related to the issuance of TC watches or warnings in these workshops. After the implementation of the new 48 hour TC watch and 36 hour TC warning criteria for hurricanes in the CPHC AOR in 2009, increased emphasis was placed on this type of training at the workshops. The primary guidance available for this type of decision making in 2009 was based on the TC wind speed probability products, which were still relatively new to the CPHC forecasters, since there had been only a few TCs in the north Central Pacific after these products became available. It was decided that one way to begin familiarizing the forecasters with this guidance was to examine some historical hurricanes that had actually approached or directly impacted land areas in the north Central Pacific. Using these historic hurricanes, the forecasters were able to simulate the decision making process using "WARn Games" prior to the start of the active portion of the 2009 season.

These "WARn Games" were first conducted during the annual training workshops at CPHC in June and July of 2009 using reconstructed forecasts for central North Pacific Hurricanes Iniki (1992), Emilia (1994), Jimena (2003) and Ioke (2006). The CPHC hurricane forecasters were divided into groups of two or three for these exercises. Each group was given a series of "mock forecast packages" simulating successive 6 hour forecasts for each of their assigned storms. The forecasts packages included the TC wind probabilities as text and graphical products, as well as the public advisory and the forecast/advisory [note: obviously these simulated text products were generic and contained no headlines with watches or warnings] The forecasters were also given the corresponding forecast track for each TC, which included the forecast intensity and wind radii through 120 hours. Each forecast group was provided a "sufficient", but limited amount of time to consider each advisory package. This also simulated the limited amount of time the forecasters might actually have to consider the issuance of a TC watch and/or warning in real-time before coordination calls were made to brief outside agencies (e.g., emergency management officials), and to issue the routine advisory package by the deadline at Tau-3 (i.e., 3 hours after synoptic time). The participants were asked to write down what type of watch or warning they would issue, if one was required? The forecasters were also allowed to include non-meteorological factors in their consideration of whether to issue a TC watch or warning (e.g., if the watch/warning is issued at 1100 pm Local Time, it might be less effective than earlier in the evening when many people are still awake)? After going through this process for several advisory packages, the entire class met and briefed the rest of the members with the results of their decisions about when to issue any types of watches or warnings?

The main result so far of these "WARn Games" has been increased familiarization of the CPHC forecasters to the potential benefits of these wind speed probability products in their decision making process for the issuance of TC watches and warnings. This is especially important with the increased lead times for the TC watches / warnings. Additional work needs to be done to better define thresholds of these probabilities for small islands, (e.g., Kauai, Oahu, Johnston Island, etc.). One way to do this is to look at additional historic north Central Pacific hurricanes. Another possibility is to look at these wind speed probabilities for historic hurricanes affecting

small islands in other basins (e.g. historic hurricanes affecting some of the small islands in the Caribbean Sea, as well as Bermuda in the North Atlantic). This work is ongoing, so expect additional results to be provided in the future.

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