

Rip Currents: Forecasting

Below is an overview of the activities [Rip Currents: Forecasting](#) (University Corporation for Atmospheric Research, COMET modules) to incorporate information learned from Dr. Herrington's presentation and subsequent discussion.

Lesson Overview

Students learn how find real-time data on the multiple variables that effect the formation of rip currents, how the National Weather Service compiles to data to make rip current forecasts, and then how to create a forecast.

Lesson Rationale

Students first learn about the National Weather Service Rip Current Program as well as how and where the scientists collect information about variables that influence the formation of rip currents. After learning how the scientists make daily rip current forecasts for all beaches in the United States, the students will have the opportunity to create their own rip current forecasts from different Case Studies. There are multiple extensions to the exercise if students are interested in creating their own rip current forecast theme (p. 25).

In addition, if students are interested in exploring further the data used to compile the rip current forecasts the remainder of the activity is an online exploration of swells, winds, and other factors included in the forecasts. The students learn how the information is collected (through observations or models), how the models work, and some of the other additional factors that are incorporated into the rip current forecasts for certain geographic areas. Students understanding will be assessed throughout with small quizzes to check for comprehension and application of the knowledge they are gaining.

Key Concept

Students use different oceanographic information to forecast the potential of rip currents along different beaches.

Rip Currents: Forecasting

2012 Update

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Print Version

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Introduction

Welcome

This module describes the main elements to consider when forecasting rip currents and provides an example forecast technique. It also discusses some things you need to be aware of when using wave observations and wave model data to estimate rip current risk.

At the end of this module, you should be able to:

- Describe the important elements that determine rip current risk.
- Describe a process and resources that can be used to develop a local rip current forecast scheme.
- Given wave data, determine whether wave masking is occurring and what the appropriate swell or wave components are to assess rip current risk.
- Describe factors, other than swell and wind waves, that can alter rip current.

Pretest

Find out what you may already know about Rip Current Forecasting!

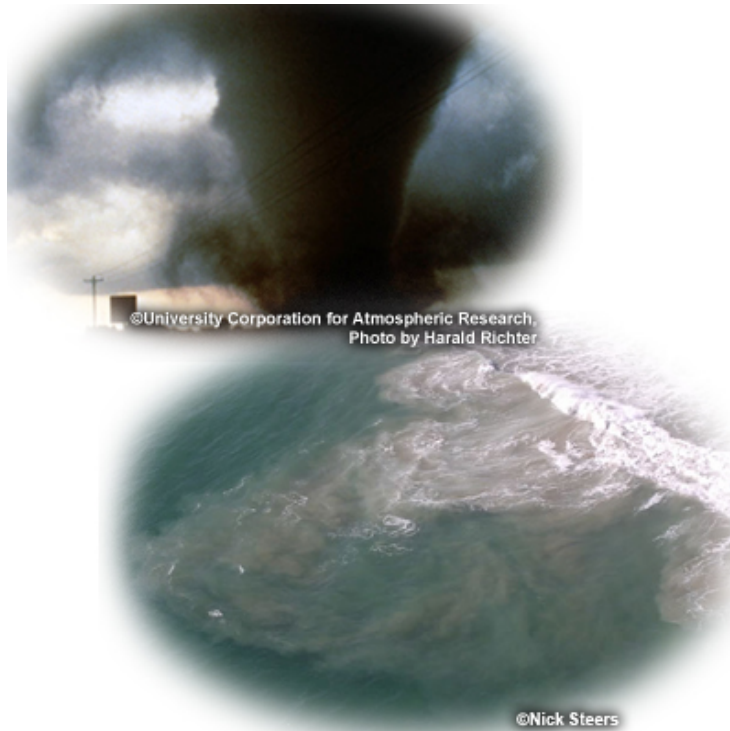
Before you begin, please complete the short, 15-item pre-assessment by clicking the link below. When you have completed the module, be sure to take the quiz at the end of the module to see how much you've learned.

Taking the pre-assessment will help you see where you need to focus your learning as you work through the module, and taking the module quiz at the end will help you gauge how much you've learned once you're done. This information will also help us see how well the module teaches the most important concepts of rip current forecasting.

Begin the Pre-Assessment » <http://daved.meted.ucar.edu/loginForm.php?urlPath=logonOption.php&quizID=192&fromModule=true>

Introduction

Rip Currents: An Indirect Weather Hazard



When people think of hazardous weather, phenomena such as tornadoes, hurricanes, and floods usually come to mind. However, weather events can have indirect effects that are just as dangerous as traditional hazardous weather. One such indirect effect is the development of rip currents. Rip currents are the result of wave energy that interacts with the nearshore environment. However, this wave energy often has been generated by winds associated with a distant weather system.

The United States Life Saving Association estimates about 100 drowning fatalities per year occur in the U.S. due to rip currents. Approximately 80 percent of all surf zone rescues in the U.S. are due to people getting caught in rip currents. Rip current fatalities are a problem in the Great Lakes as well with 26 fatalities related to rip currents occurring in southern Lake Michigan alone between 2002 and 2007.

Since rip current forecasting is relatively new in the National Weather Service, this module has been developed with two main objectives:

1. To describe a basic forecast process for analyzing waves, winds, and other factors important to rip current formation, and
2. To provide some information and resources that can help improve your rip current forecasts.

In the next section of the module, we will talk about the National Weather Service (NWS) Rip Current Program. The third section describes a basic rip current forecast process as well as an overview of

how to start developing your own local forecast process. Sections 4 and 5 focus on analyzing both the observed and modeled swell factors that determine rip current risk. A brief discussion of wind analysis and resources for remotely sensed wind data over water is given in section 6. Other factors that contribute to rip current risk are discussed in section 7. The last section of the module provides a few forecasting tips. The entire module will probably take you 2–3 hours to complete, so if you need to take it in shorter chunks, you might do sections 1, 2, and 3; then 4 and 5; and finally sections 6, 7, and 8.

While you're taking this module, we recommend that you make notes on things you may want to incorporate in your local forecast process or investigate in more detail.

NWS Rip Current Program

Because millions of people visit the shores each year, the NWS launched a national Rip Current Program to inform the public when rip currents will pose the greatest hazard to beachgoers. The daily rip current risk is typically communicated via the “Surf Zone Forecast” (or “SRF”), which also provides forecasts for other beach hazards, weather, and surf conditions.

This is an example of a Surf Zone Forecast produced by the Weather Forecast Office (WFO) in Tampa Bay. Note the highlighted portion that refers to rip currents.

Example of SRF from NWS Tampa WFO, September 2004

FZUS62 KTBW 010950
SRFTBW

WEST CENTRAL AND SOUTHWEST FLORIDA SURF ZONE FORECAST
NATIONAL WEATHER SERVICE TAMPA BAY AREA - RUSKIN FL
600 AM EDT WED SEP 1 2004

.DISCUSSION...HIGH PRESSURE OVER THE WESTERN ATLANTIC WILL CONTINUE TO RIDGE BACK OVER THE REGION INTO THE WEEKEND. HURRICANE FRANCES MAY IMPACT PORTIONS OF THE AREA ON SATURDAY AND SUNDAY WITH INCREASING WINDS AND SURF CAUSING A GREATER POTENTIAL FOR RIP CURRENTS. STAY ADVISED OF THE LATEST FORECASTS FROM THE NATIONAL HURRICANE CENTER FOR HURRICANE FRANCES.

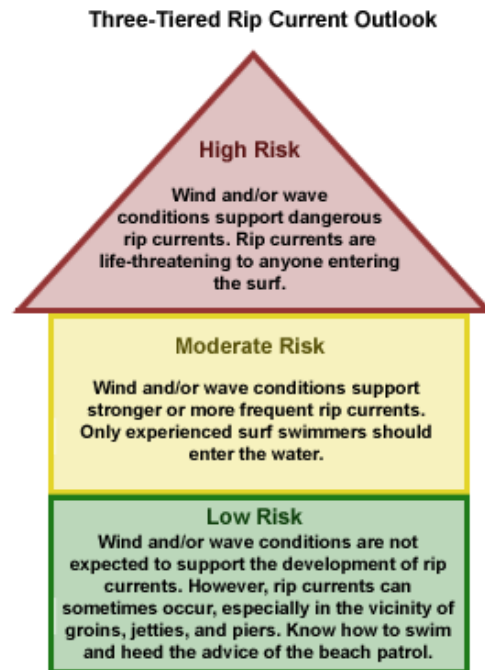
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FLZ062-065-012000-
CHARLOTTE-LEE-
INCLUDING THE BEACHES OF BOCA GRANDE...ENGLEWOOD...
FORT MYERS BEACH...SANIBEL ISLAND
600 AM EDT WED SEP 1 2004

.TODAY...
SKY/WEATHER..... PARTLY CLOUDY (CLOUD COVERAGE 50-60 PERCENT).
SCATTERED THUNDERSTORMS. CHANCE OF..... THUNDERSTORMS 50 PERCENT.
MAX TEMPERATURE..... AROUND 90.
BEACH WINDS..... EAST WINDS 5 TO 10 MPH BECOMING ONSHORE IN
THE AFTERNOON.
SURF..... 1 TO 2 FEET.
WATER CONDITION.... A LIGHT CHOP.
WATER TEMPERATURE... 89.
UVI INDEX..... VERY HIGH.
RIP CURRENT RISK.... LOW...HOWEVER...STRONG CURRENTS CAN OCCUR
..... NEAR PIERS AND JETTIES.

NOAA/NWS

NWS Rip Current Program
The Rip Current Outlook



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Within the SRF, a qualitative rip current outlook is provided using one of three tiers in a Low–Moderate–High scheme:

- **Low Risk:** Wind and/or wave conditions are not expected to support the development of rip currents. However, rip currents can sometimes occur, especially in the vicinity of groins, jetties, and piers. Know how to swim and heed the advice of the beach patrol.
- **Moderate Risk:** Wind and/or wave conditions support stronger or more frequent rip currents. Only experienced surf swimmers should enter the water.
- **High Risk:** Wind and/or wave conditions support dangerous rip currents. Rip currents are life-threatening to anyone entering the surf.

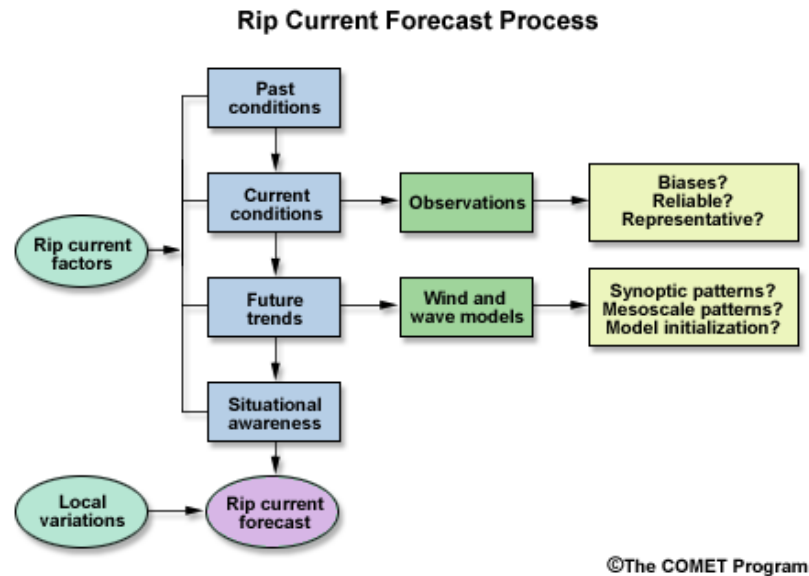
Rip currents designated Moderate or High Risk should be headlined in the SRF and included in the Day 1 portion of the NWS Hazardous Weather Outlook product.

To address episodes when numerous rescues or fatalities are reported, and especially for forecast offices that do not issue the SRF, the NWS Coastal Hazard Message is a short-fused product that may be used to reach surf zone users.



Local beachfront safety organizations may issue individual rip current alerts, which should be included in NOAA Weather Radio programming and local NWS forecasts. WFOs and their Warning Coordination Meteorologists are encouraged to work closely with local beachfront safety officials, as they can help relay NWS rip current information to the public. In addition, partnerships with these officials can provide observations of breaking wave height and rip currents to the WFO. These real-time, human observations are critical since little or no instrumentation exists in the surf zone to monitor these parameters.

Rip Current Forecast Process



Although you may be less familiar with forecasting rip currents, the process is similar to predicting other hazards in that you need to understand past conditions and evaluate current and future trends. You will review various data, assess their utility, and analyze the factors important to rip current development and severity. Of course, different locations will have variations in the process and tools used, as well as different forecast criteria, so throughout this module you should think about how your specific circumstances may alter your approach.

For a rip current forecast, you will likely begin by analyzing the latest set of wave and swell observations to identify components that could have a significant impact on rip current development. You should also become familiar with any observational biases in your local data and develop a sense of reasonable values so that you can determine whether the data are reliable and representative.

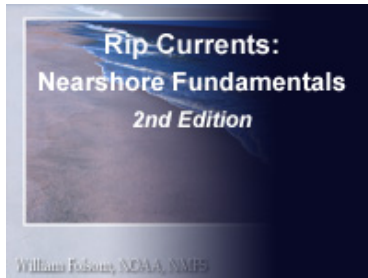
Once you have a handle on the current situation, the next step is to look at the future atmospheric conditions that will affect local wind wave growth or swell generated outside the region. Features that may produce swell directed toward the coast (such as hurricanes, coastal storms, or squall lines in the Great Lakes) are important considerations. Synoptic-scale features with large pressure gradients that may direct wind-generated waves toward shore are also important.

Wave models and wind models will be the primary tools for determining swell and wind wave trends. As with any model, you should check the output against in situ and remotely sensed observations to determine how well the model initialized.

The last step in your forecast process will be to consider any other relevant information (such as time of year or whether it's a holiday weekend) to fine-tune your forecast.

Rip Current Forecast Process

Rip Current Factors



[\(http://meted.ucar.edu/marine/ripcurrents/NSF/\)](http://meted.ucar.edu/marine/ripcurrents/NSF/)

The structure of the nearshore environment and how it produces rip currents was covered in COMET's module, "Rip Currents: Nearshore Fundamentals (<http://meted.ucar.edu/marine/ripcurrents/NSF/>)" (<http://www.meted.ucar.edu/marine/ripcurrents/NSF/>). If you have not taken this module already, we recommend that you do so before continuing.

As mentioned in that module, rip current potential is a function of a number of factors:

- Bathymetry and coastline orientation that make certain locations vulnerable to rip currents
- Waves or swell that impact the beach at an angle near normal
- Wind waves resulting from persistent onshore flow
- Tidal fluctuation of water level
- Forcing mechanisms such as wave set-up, coastal man-made structures, sandbars, and coral reefs

Many WFOs have developed rip current forecast schemes or flowcharts that consider each of these factors for their area of responsibility. We'll discuss how you can create one for your office, but first let's look at an example.

Rip Current Forecast Process

Example Worksheet

This figure is a modification of a worksheet used at the Wilmington, NC WFO to analyze rip current potential at two different beaches. Points are assigned to each factor in the forecast, and the rip current risk is determined from the total points. The factors and amount of weight for each will be different for your location, so this worksheet is meant only as an example of a forecast process.

Let's look more closely at the main features of this particular forecast process.

Example Rip Current Forecast Worksheet

Pender-New Hanover Beaches (East Facing)					Brunswick Beaches (South Facing)					
Is the prevailing wind (no sea breeze) between 60 and 150 ² ?					Is the prevailing wind (no sea breeze) between 150 and 220 ² ?					
No Enter 0 for the Factor 1					No Enter 0 for the Factor 1					
Yes Select wind speed factor below					Yes Select wind speed factor below					
<10 kt	0.0	15-20 kt	2.5		<10 kt	0.0	15-20 kt	2.5		
10 kt	1	20 kt	3		10 kt	1	20 kt	3		
10-15 kt	1.5	20-25 kt	4		10-15 kt	1.5	20-25 kt	4		
15 kt	2	25 kt	5		15 kt	2	25 kt	5		
Factor 1					Factor 1					
<input type="text"/>					<input type="text"/>					
Has the synoptic flow been between 60 and 150 ² 80% or more of the time over the last 48 hrs?					Has the synoptic flow been between 150 and 220 ² 80% or more of the time over the last 48 hrs?					
Enter 0 for Factor 2 if the answer is no; if yes, then add 1					Enter 0 for Factor 2 if the answer is no; if yes, then add 1					
Factor 2					Factor 2					
<input type="text"/>					<input type="text"/>					
The swell direction must be from the SE, E, or NE.					The swell direction must be from the SE and S.					
	7 Sec	8 Sec	9 Sec	10 Sec	11 Sec	12 Sec	13 Sec	14 Sec	15 Sec	16 Sec
1 ft	-	-	1	1	1	1.5	1.5	1.5	1.5	2
2 ft	-	-	1.5	1.5	2	2.5	2.5	2.5	2.5	3
3 ft	1	1.5	2.5	3	3	3.5	4	4	4	4.5
4 ft	2.5	3	4	4	4.5	4.5	5	5	5.5	5.5
5 ft	3.5	4	4.5	5	5.5	5.5	5.5	6	6	6
6 ft	4	5	5	5.5	5.5	6	6	6.5	7	7
7 ft	5	6	6	6.5	6.5	6.5	7	7	7	7
8 ft	6	6	6	6.5	7	7	7	7.5	7.5	7.5
Factor 3					Factor 3					
<input type="text"/>					<input type="text"/>					
1) Is the forecast period within 3 days either side of a full or new moon? 2) Is the low tide less than or equal to -0.5 MLLW and does it occur between 3 AM and 9 PM? (at Springmaid Pier...refer to ILM Tides book)					1) Is the forecast period within 3 days either side of a full or new moon? 2) Is the low tide less than or equal to -0.5 MLLW and does it occur between 3 AM and 9 PM? (at Springmaid Pier...refer to ILM Tides book)					
Enter 0 for the factor if the answer is no to 1) and 2) If there is a full moon enter 0.5 If yes for 2) then enter 1.0 (do not add to the 0.5 from part 1)					Enter 0 for the factor if the answer is no to 1) and 2) If there is a full moon enter 0.5 If yes for 2) then enter 1.0 (do not add to the 0.5 from part 1)					
Factor 4					Factor 4					
<input type="text"/>					<input type="text"/>					
Pender-New Hanover (East Facing) Total					Brunswick (South Facing) Total					
<input type="text"/>					<input type="text"/>					
< 4.0 Low Risk			4.0 - 5.5 Moderate Risk			> 5.5 High Risk				

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Factors 1, 2, and 3 address whether wind waves and/or swell will impact rip current activity, while Factor 4 deals with tidal effects.

In this worksheet, locally generated wind waves are dealt with in the first two sections. The forecaster first determines if the prevailing wind is from an onshore direction relative to the beach's orientation. If it is, the wind speed factor (Factor 1) is assessed. Stronger onshore speeds are weighted higher because they create larger local wind waves. If the flow is offshore, the forecaster skips to Factor 3.

If there is onshore flow, Factor 2 is evaluated. This factor addresses the persistence of the synoptic flow, which affects whether wind waves will be consistent enough to affect the rip current potential. Studies suggest that the daily sea breeze does not last long enough to do this. Consequently, the larger-scale synoptic pattern determines the wind contribution to rip current formation.

Factor 3 analyzes the swell components—the direction, height, and period for those waves that have traveled away from their generation area. Note that in the Wilmington case, the swell direction must be from the southeast, east, or northeast for the east-facing beach. For the south-facing beach, the swell must be from either the southeast or south. To determine which angles are important for your beaches, the important thing to remember is that rip currents are frequently generated when the incoming wave direction is nearly perpendicular to the shoreline, although the presence of shoreline structures may modify the optimum wave angle.

Note in the worksheet that larger swell heights and longer wave periods increase the rip current potential. Larger heights can increase the horizontal pressure gradient between areas of high and low wave setup.

The tricky part in assessing the swell is that it can be masked in both observational and model data. This requires some analysis by the forecaster, and we'll address this issue in the next section of the module. In addition, this forecast scheme is only designed for one swell, so forecasters are advised to use the dominant swell if more than one swell group is expected. So in cases when the scheme is close to an elevated rip current risk and there are two swell waves of near equal power, it may be best to lean toward the elevated risk and coordinate closer with local lifeguards.

Factor 4 addresses the influence of tides and water levels. As pointed out in the Nearshore Fundamentals module, rip currents are modulated by tides due to changes in the position of the breaker zone and the size of the surf zone. We'll discuss this further in the section on "Other Factors," along with additional considerations that might influence your forecast.

Rip Current Forecast Process

Exercises

Please either download and print the [worksheet \(worksheet.pdf\)](http://meted.ucar.edu/marine/ripcurrents/forecasting/worksheet.pdf) (PDF) at <http://meted.ucar.edu/marine/ripcurrents/forecasting/worksheet.pdf> for the next three exercises or use the image of the worksheet from the previous page, *Example Rip Current Forecast Worksheet*.

*Note: The rip current forecast worksheet provided is specifically geared for WFO Wilmington's beaches. It is very likely that parameters will vary in your location.

Rip Current Forecast Process » Exercises

Case 1

Assess the rip current risk in the three cases below using the worksheet.

You are on a midnight shift and are analyzing the rip current risk for the current day. The NOAA WAVEWATCH III (NWW3) model output for the buoys in your area has initialized very well, and the model indicates a wind wave around 3 ft at 5 s and a swell from the southeast around 5 ft at 9 s. During the day, the NWW3 decreases the swell height to around 4 ft at 9 s. The marine forecast has south winds around 15 kt, and these winds are not associated with a sea breeze, but rather are from large-scale high pressure positioned east of the area.

Earlier the wind was variable as the area of high pressure moved by. This resulted in onshore winds for only about 20% of the time. It is about 5 days to new moon, and the astronomical low tide is only 0.2 ft Mean Lower Low Water (MLLW) at the tide gauge at 11 AM local time. Based on this information, what is the rip current risk for your area's east- and south-facing beaches?

East-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

The correct answer is b.

Factors	Remarks
Wind: 0	The wind is not directly onshore for the east-facing beaches.
Persistent Onshore Wind: 0	The wind has not been directed onshore (between 60 and 150 degrees for 80% of the time or more).
Swell: 4	Since NWW3 initialized very well, and unless there were other circumstances that would say otherwise, the lowering trend in the swell height can be used with confidence. As a result, the 4 ft/9 s swell translates to a factor of 4. In addition, the swell direction fits the domain for east-facing beaches.
Moon/Tide: 0	The new moon is 5 days away and the astronomical tide-level prediction is not significant enough to become a factor.
Totals: 4	Moderate Risk

South-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

Done

The correct answer is c.

Factors	Remarks
Wind: 2	The wind direction fits the requirements of 150 to 220 degrees and is not associated with a sea breeze.
Persistent Onshore Wind: 0	The wind has not been directed onshore for 80% of the time or more.
Swell: 4	Since NWW3 initialized very well, and unless there were other circumstances that would say otherwise, the lowering trend in the swell height can be used with confidence. As a result, the 4 ft/9 s swell results in a factor of 4. In addition, the swell direction fits the domain for south-facing beaches.
Moon/Tide: 0	The new moon is 5 days away and the astronomical tide level prediction is not significant enough to become a factor.
Totals: 6	High Risk

Summary:

The south-facing beaches are at a higher risk on this day because of the combined wind effects (and the resulting onshore wind waves) and the large swell directed onshore close to normal. The swell by itself is also a large enough contributor to rip current development along the east-facing beaches.

Rip Current Forecast Process » Exercises

Case 2

You are on the midnight shift and are analyzing the rip current risk for the day. NWW3 output for the buoys in your area has not properly initialized an observed east-northeast swell at 3 ft every 13 s. Instead, the model only indicates a weak 2 ft/8 s east swell projected to continue through the day along with other wind wave components. In addition, the buoy observations indicate that there has been a 1–2 ft/4 s wind wave. The marine forecast is calling for variable winds around 10 kt or less becoming southeast (140 degrees on average) at about the same speed in the afternoon. High pressure is directly overhead, and it is assumed that the afternoon winds are expected to be mainly associated with the sea breeze.

During the previous 48 hours, the wind has been between 60 and 150 degrees 60% of the time and between 150 and 220 degrees 20% of the time. The full moon is one day away, and the astronomical low tide is –0.6 ft MLLW at the tide gauge at 9 AM local time. Based on this information, what is the rip current risk for your area's east- and south-facing beaches?

East-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

Done

The correct answer is b.

Factors	Remarks
Wind: 0	Although the expected wind is from the right direction for the east-facing beaches, it is associated with the sea breeze.
Persistent Onshore Wind: 0	The wind has not been directed onshore for 80% of the time or more.
Swell: 4	Since NWW3 did not initialize well, use the buoy observations as a starting point. In this case the 3 ft/13 s wave data is initially used to calculate this factor. The day-shift marine forecaster needs to be aware of the assumption that this observed swell will continue and needs to verify its occurrence or amend the rip current forecast using a more appropriate swell value.
Moon/Tide: 1	It is one day from full moon (0.5); however, the tide levels are projected to be -0.6 ft MLLW. This predicted level exceeds the defined threshold; thus a factor of 1 is used for this section. In addition, this low tide will be at 9 AM local time, which meets the requirements.
Totals: 5	Moderate Risk

South-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

The correct answer is a.

Factors	Remarks
Wind: 0	The wind is associated with a sea breeze, and it does not fit the directional requirements of 150 to 220 degrees.
Persistent Onshore Wind: 0	The wind has not been directed onshore for 80% of the time or more.
Swell: 0	The observed swell is from the ENE, which does not directly affect the south-facing beaches.
Moon/Tide: 1	It is one day from full moon (0.5); however, the tide levels are projected to be -0.6 ft MLLW. This predicted level exceeds the defined threshold; thus a factor of 1 is used for this section. In addition, this low tide will be at 9 AM local time, which meets the requirements.
Totals: 1	Low Risk

Summary:

The primary impact on this day was the ENE swell that was large enough in height and long enough in period to support rip current development on the east-facing beaches. It is important to begin with an analysis of the wave components observed by the buoys. This will allow you to gauge if the wave model has initialized well enough to be considered useful. It is also important to remember the effects of the tidal cycle, especially when there is a full or new moon causing spring tides. It should be noted that tidal ranges can vary greatly from location to location and from coast to coast.

Rip Current Forecast Process » Exercises

Case 3

You are on the evening shift and are analyzing the rip current risk for the next day. Presently, the buoy in your area is showing a 5 ft/6 s wind wave from the south and a 2 ft/12 s swell from the southeast. NWW3 appears to have initialized reasonably well with the swell and the dominant wind wave. The output for the next day continues to show the 5 ft/6 s wind wave and a slightly different swell at 2 ft/11 s also from the southeast. Tomorrow's marine forecast is for a south wind (190 degrees) at 15 to 20 kt that is not associated with the sea breeze.

High pressure has been anchored in place to the east, with southerly flow prevailing over the waters for the last few days. In fact, the wind has been between 150 and 220 degrees about 90% of the time over the last 48 hours.

It is 2 days from the new moon, and the astronomical low tide is +0.2 ft MLLW at the tide gauge at 1130 AM local time. Based on this information, what is the rip current risk for your area's east- and south-facing beaches?

East-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

The correct answer is a.

Factors	Remarks
Wind: 0	The wind does not meet the directional requirement for the east-facing beaches.
Persistent Onshore Wind: 0	The wind has not been directed onshore for 80% of the time or more.
Swell: 2.0	Note that the rip forecast scheme for swell does not consider wave periods under 7 s. The lower period wind waves are handled indirectly in the wind section of the scheme. As a result, the 2 ft/11 s southeast swell should be used to compute the factor in this section.
Moon/Tide: 0.5	It is 2 days from new moon, and the tide levels are projected to only be +0.2 ft MLLW. Although this tide meets the time requirement, the predicted level does not exceed the defined threshold. Thus, only a factor of 0.5 is used in this section.
Totals: 2.5	Low Risk

South-Facing Beaches Rip Current Risk

Choose one:

- a) Low risk
-
- b) Moderate risk
-
- c) High risk
-

The correct answer is c.

Factors	Remarks
Wind: 2.5	The wind is not associated with a sea breeze and is expected to occur within 150 to 220 degrees.
Persistent Onshore Wind: 1	The wind has been blowing within the 150-220 degree range > 80% of the time. As a result, the persistent onshore wind has likely created a wave setup along the surf that supports rip current formation.
Swell: 2.0	The swell direction does affect the south-facing beaches. As a result, the 2 ft/11 s swell was used to compute the swell factor.
Moon/Tide: 0.5	It is 2 days from new moon, and the tide levels are projected to only be +0.2 ft MLLW. Although the occurrence of this tide meets the time requirement, the predicted level does not exceed the defined threshold. Thus, only a factor of 0.5 is used in this section.
Totals: 6.0	High Risk

Summary:

This example shows how the rip current risk can vary greatly as a result of the orientation of beaches. It is also a typical case for south-facing beaches along the east coast of the United States that can experience days of onshore flow when a strong Bermuda High is anchored in place.

Rip Current Forecast Process

Creating Your Own Rip Current Forecast Scheme

If your office doesn't have a rip current forecast process or worksheet, here are some ideas on how to go about creating one:

1. Find out if other WFOs with similar coasts (perhaps a neighboring WFO) have schemes that you can start with. An existing scheme will provide a good foundation and only minimal, local adjustments may be required.
2. Conduct case studies and develop climatologies for synoptic situations during past rip current episodes. Review the wind, wave, and tide conditions to determine thresholds for rip current activity. Possible resources for researching past rip current events are county coroner information, local law enforcement reports, and lifeguard logs or notes.
3. Develop a relationship with local lifeguard agencies, the beach patrol, and coastal engineers or specialists. There are many great resources at NOAA Sea Grant offices and universities. An ongoing partnership with these people will help you define the geographic elements that affect rip current formation in your area, as well as other important factors.
4. Establish a rip current verification program to refine and enhance your forecast process. This is where a strong relationship with lifeguards or local beach services is important. Maintain a daily log at the WFO with input from lifeguards about any rescues, fatalities, or noticeable rip current activity. Try to obtain at least two daily reports from each verification area.
5. Remain current with new research and the latest publications. Over the next several years, Sea Grant research will try to bridge the gap between rip current processes and forecasting. Researchers are working on operational, dynamic rip current models, but in the meantime, there may be new studies that can improve your local empirical scheme.

Whether you already have a forecast system or are just beginning to develop one, plan to fine-tune it through verification and data analysis over the years. This should be done in collaboration with the agencies and coastal specialists that helped you develop it.

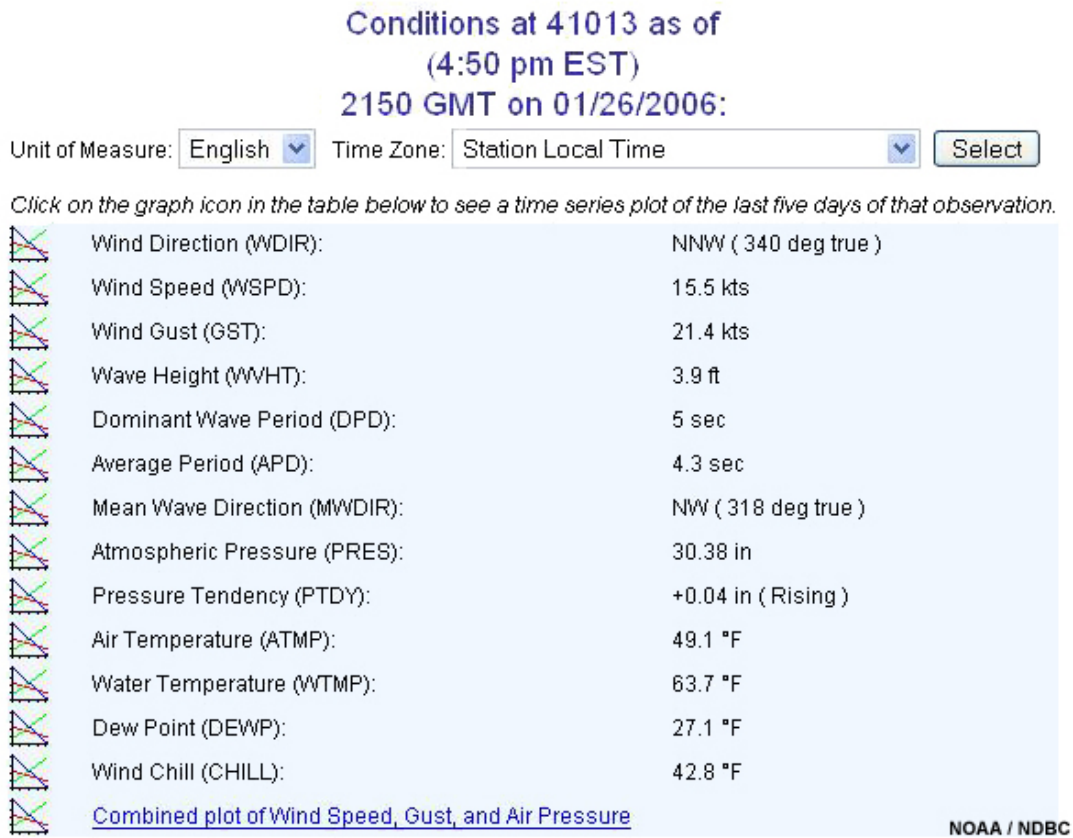
Analyzing Swell: Observations



Most rip current forecast schemes, like the Wilmington one, will require information about swell direction, height, and period. To get this information, you will use a mix of observational data (which could include lifeguard observations) and model data. We'll start by talking about the National Data Buoy Center (<http://www.ndbc.noaa.gov/>) (NDBC) standard hourly observation of wave height and period. However, this standard hourly report does not provide information on the entire wave spectrum, which is important for getting the complete picture of the rip current risk. Both the hourly report and the detailed information on the entire wave spectrum help you assess the current and past ocean state. In addition, you can use buoy observations to determine if a wave model has initialized correctly.

Analyzing Swell: Observations

NDBC Current Conditions Table



Buoy information is available both on AWIPS and on the Internet and can include data from a variety of sources other than NDBC buoys, such as those maintained by research institutions. If you look at a buoy report (like this one) on the NDBC Website, the first table on the page shows the current conditions. Note that this table gives wave height and dominant wave period. Mean wave direction is also included if the buoy has a direction sensor, but this is relatively uncommon.

These wave characteristics, however, are probably not appropriate for use in a rip current forecasting scheme. For example, the wave height reported in this table is the "significant wave height" that is, the average wave height of the highest one-third of all waves. When forecasting rip currents, the individual height of the dominant swell propagating toward the beach of concern is a more relevant parameter.

The dominant wave period and mean wave direction given in the table are associated with the wave or swell possessing the maximum energy. However, the data in this table does not tell you how much of the energy is due to swell and how much is due to wind waves. This is important since wind waves will likely be considered separately from swell when assessing the rip current potential, as was done in the Wilmington worksheet. Remember too that most buoys do not provide wave direction. Without wave direction information, you will not have any idea whether the dominant wave period relates to swell that will impact the beach of interest.

Finally, it might be good to know whether there are any other wave groups that are moving onshore (regardless of the direction of the dominant group), which might influence you to increase the rip current potential. It is important to remember that there can be significant energy in both the wind wave and swell portion of the wave spectrum. Consider an example in which there is a wind wave of 10 ft at 6 s and a swell of 5 ft at 20 s. Most of the energy is wind wave; therefore, the buoy returns the dominant wave period of 6 s, and the information for the swell at 20 seconds is essentially "hidden" from you.

To get a clearer picture of all wave groups that might affect rip current development, you will probably need to look at other data products. In the next few pages, we'll talk about additional information that is available.

Analyzing Swell: Observations










Detailed Wave Summary

Detailed Wave Summary for 41013 as of (5:00 pm EST) 2200 GMT on 11/04/2005:

These wave data are displayed in [rounded times](#).

Unit of Measure: Time Zone:

Click on the [graph icon](#) in the table below to see a time series plot of the last five days of that observation.

	Significant Wave Height (H0):	3.3 ft
	Swell Height (SwH):	3.3 ft
	Swell Period (SwP):	8.3 sec
	Swell Direction (SwD):	ESE
	Wind Wave Height (WWH):	1.0 ft
	Wind Wave Period (WWP):	3.7 sec
	Wind Wave Direction (WWD):	SE
	Wave Steepness (STEEPNESS):	SWELL
	Average Wave Period (AVP):	6.3 sec

MM DD	TIME (EST)	Previous observations									
		H0 ft	SwH ft	SwP sec	SwD	WWH ft	WWP sec	WWD	STEEPNESS	AVP sec	
11 04	4:00 pm	3.3	3.3	7.7	ESE	1.0	3.3	SSE	AVERAGE	6.0	
11 04	3:00 pm	3.3	3.0	7.7	ESE	0.7	3.4	E	AVERAGE	6.2	
11 04	2:00 pm	3.3	3.3	8.3	ESE	0.7	3.8	ESE	SWELL	6.2	
11 04	1:00 pm	3.0	3.0	7.7	ESE	0.7	3.8	ESE	AVERAGE	6.1	
11 04	12:00 pm	3.3	3.3	8.3	ESE	0.7	4.0	ESE	SWELL	6.3	
11 04	11:00 am	3.3	3.3	7.7	ESE	0.7	3.8	SE	AVERAGE	6.7	

NOAA / NDBC

If you scroll down farther on an NDBC buoy report, you will come to the Detailed Wave Summary section. This summary breaks the observations into the swell and wind wave groups. In this example, all three components of height, period, and direction are provided. If direction isn't listed, you will need to determine which waves are important from:

1. Your own knowledge about past and present wind events that are likely to have produced swell
2. A model analysis and forecast to examine the wave group movement

While this table provides more detail than the previous one, it can be misleading because it doesn't provide information about the entire wave spectrum, which could be important for rip current

formation.

Analyzing Swell: Observations

Wave Spectrum Plots

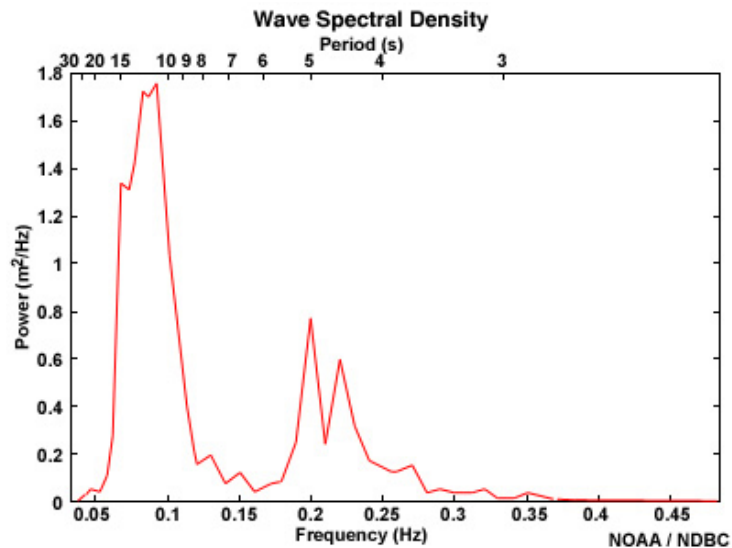
Portion of a Detailed Wave Summary Report

MM	DD	TIME (EST)	HO ft	SwH ft	SwP sec	Previous observations		WWH ft	WWP sec	WWD	STEEPNESS	AVP sec
						SwD	WWD					
11	09	2:00 pm	2.3	2.0	7.7	N/A	0.7	3.7	N/A	N/A		6.3
11	09	1:00 pm	2.3	2.0	7.7	N/A	0.7	3.1	N/A	N/A		6.2
11	09	11:00 am	2.3	2.3	7.1	N/A	0.7	4.0	N/A	N/A		6.2
11	09	10:00 am	2.3	2.3	7.7	N/A	0.7	2.8	N/A	N/A		6.3
11	09	9:00 am	2.3	2.3	7.7	N/A	0.7	3.1	N/A	N/A		6.1
11	09	8:00 am	2.0	2.0	7.7	N/A	0.7	3.6	N/A	N/A		6.0
11	09	7:00 am	2.3	2.3	7.1	N/A	0.7	3.0	N/A	N/A		6.1
11	09	6:00 am	2.3	-	-	N/A	-	-	N/A	N/A		6.2
11	09	5:00 am	2.3	2.3	7.1	N/A	0.7	3.6	N/A	N/A		5.9
11	09	4:00 am	2.3	2.3	7.7	N/A	0.7	3.7	N/A	N/A		5.9
11	09	3:00 am	2.3	2.3	6.7	N/A	0.7	3.3	N/A	N/A		5.8
11	09	2:00 am	2.3	2.3	7.1	N/A	0.7	3.1	N/A	N/A		5.8
11	09	1:00 am	2.6	2.3	7.7	N/A	1.0	3.6	N/A	N/A		5.7
11	09	12:00 am	2.6	2.6	7.1	N/A	1.0	3.3	N/A	AVERAGE		5.6
11	08	11:00 pm	3.0	2.6	6.2	N/A	1.0	3.4	N/A	STEEP		5.5
11	08	10:00 pm	3.0	3.0	6.7	N/A	1.0	3.4	N/A	AVERAGE		5.7
11	08	9:00 pm	3.3	3.0	6.7	N/A	1.0	3.7	N/A	AVERAGE		5.6
11	08	8:00 pm	3.0	2.6	6.2	N/A	1.0	3.2	N/A	STEEP		5.6
11	08	6:00 pm	3.0	3.0	5.9	N/A	1.0	3.6	N/A	STEEP		5.7
11	08	5:00 pm	3.0	2.6	7.7	N/A	1.0	3.7	N/A	AVERAGE		5.6
11	08	4:00 pm	3.0	3.0	7.1	N/A	1.0	3.4	N/A	AVERAGE		5.6

[Plot of wave energy versus frequency \(and period\)](#)

NOAA / NDBC

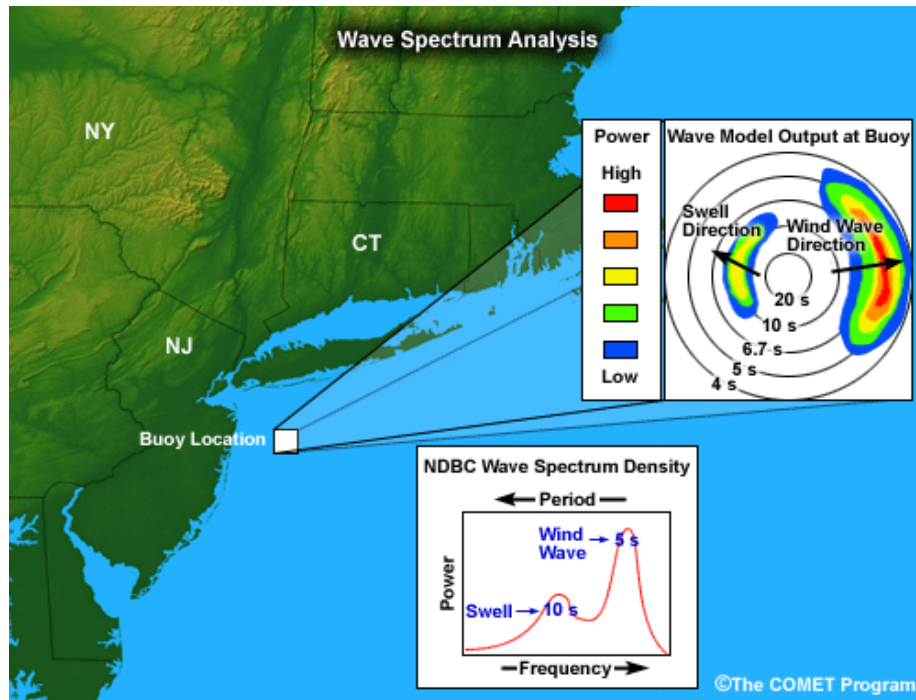
Because the Detailed Wave Summary only reports the dominant swell, it can "mask" other swell groups approaching the shore. As a result, the rip current potential may appear low when, in reality, it is moderate or even high. This is particularly true when the reported swell is moving offshore, but other groups are moving onshore.



Analyzing the wave spectrum can help you accurately determine if wave or swell groups will impact your beach of interest. Another important use of this analysis is to check the initialization of numerical wave models. We'll discuss this more in the next section.

To examine the wave spectrum, the NDBC Website provides plots of wave energy (or power) versus frequency. Frequency is the inverse of the period. These products are called wave spectral density plots and are available on the Internet (but not on AWIPS). A link to the latest hourly plot can be found at the bottom of the Detailed Wave Summary section.

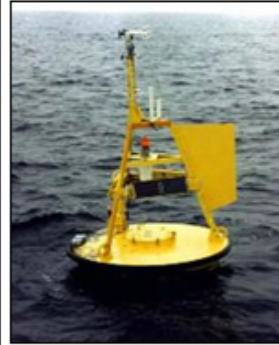
These spectral density plots show the peaks in wave power over the entire frequency range and make it easier to identify the total number of wave groups passing that location. To sort out which peaks are swell and which are wind waves, you will need to compare them with the wave period observations in the Detailed Wave Summary table. Note that the plot does not indicate the direction of propagation—you will need to look at model data or possibly scatterometry data to determine which, if any, of the wave groups will impact your beach.



For example, in this graphic, the wave spectrum density data show that there are two main wave groups, but we can't tell which, if either, would impact a particular beach. However, the wave model data indicate that swell from the southeast is impacting New Jersey and Long Island, while westerly winds are creating eastward-moving wind waves. In this case, the swell waves are the potential contributors to rip currents along the New Jersey and Long Island beaches.

Analyzing Swell: Observations Wave Masking Example

Date	Time	Wind Dir.	Wind Speed	Gust	Sig. Wave Height	Dom. Period
07/06	5 am	SW	13.6	17.5	5.2	5
07/06	4 am	SW	15.5	17.5	4.9	5
07/06	3 am	SW	15.5	17.5	4.9	5
07/06	2 am	SW	15.5	17.5	4.6	5
07/06	1 am	SW	17.5	19.4	4.9	9
07/06	12 am	SW	17.5	19.4	4.6	5
07/05	11 pm	SW	19.4	21.4	4.6	5
07/05	10 pm	SSW	15.5	19.4	4.9	9
07/05	9 pm	SSW	17.5	19.4	4.9	9
07/05	8 pm	SSW	19.4	21.4	4.9	10
07/05	7 pm	SSW	17.5	19.4	4.9	9

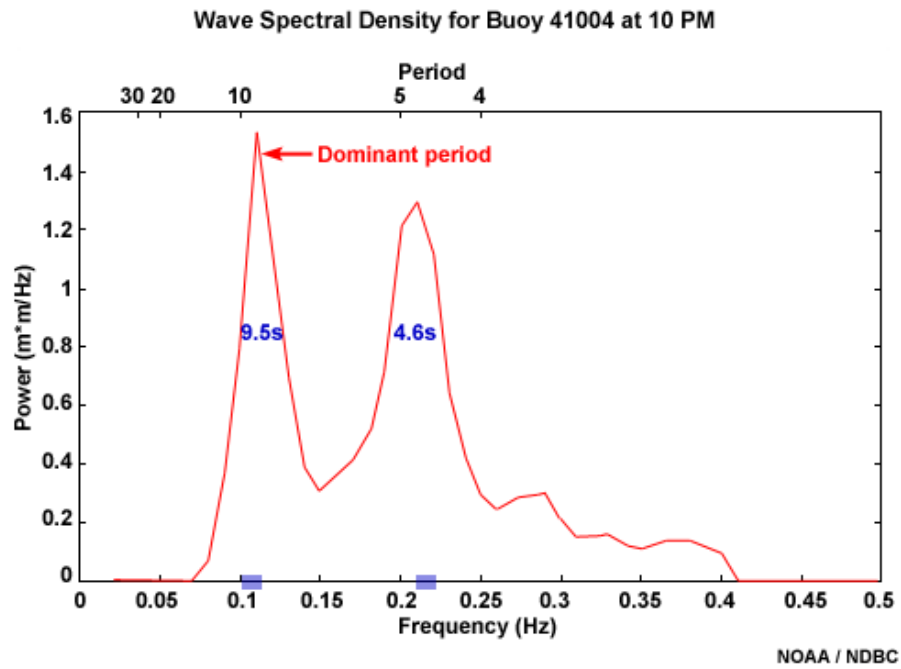


What happened at 11 pm to the 9 second swell reported earlier?

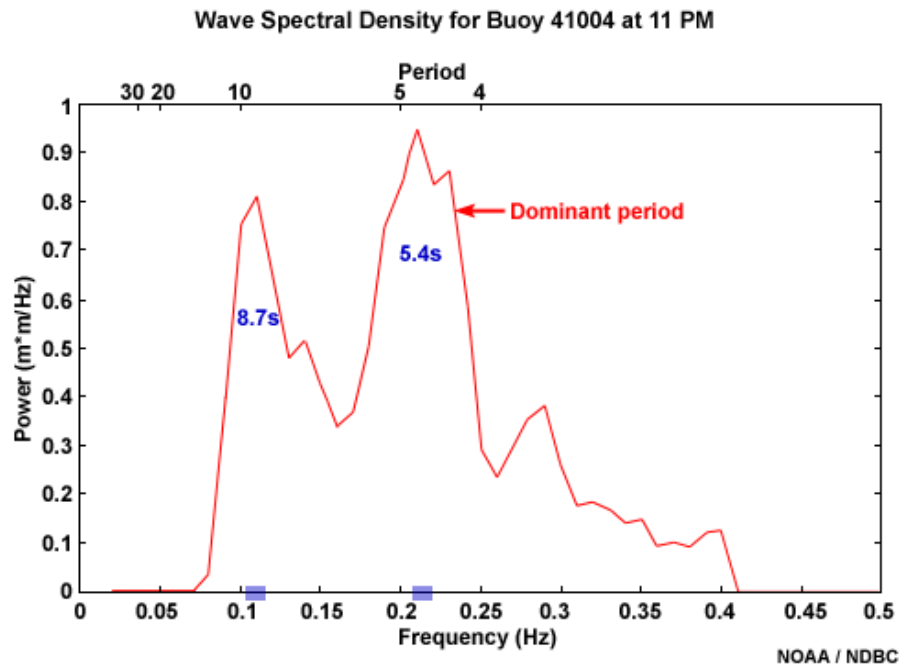
NOAA / NDBC

Let's look at an example of why forecasters should not rely solely on the dominant wave period reported by NDBC buoys when assessing rip current risk.

The data from this buoy shows a persistent wind from the southwest and little variation in wave height over 11 hours. However, the period changes from 9 s to 5 s at 11 PM. It appears that the 9 s wave group has passed by and no longer exists, or perhaps the slight wind change has caused a different wave group to develop. However, the buoy data is merely presenting the dominant period. It is important to remember that other wave groups with less energy may exist in the same location.



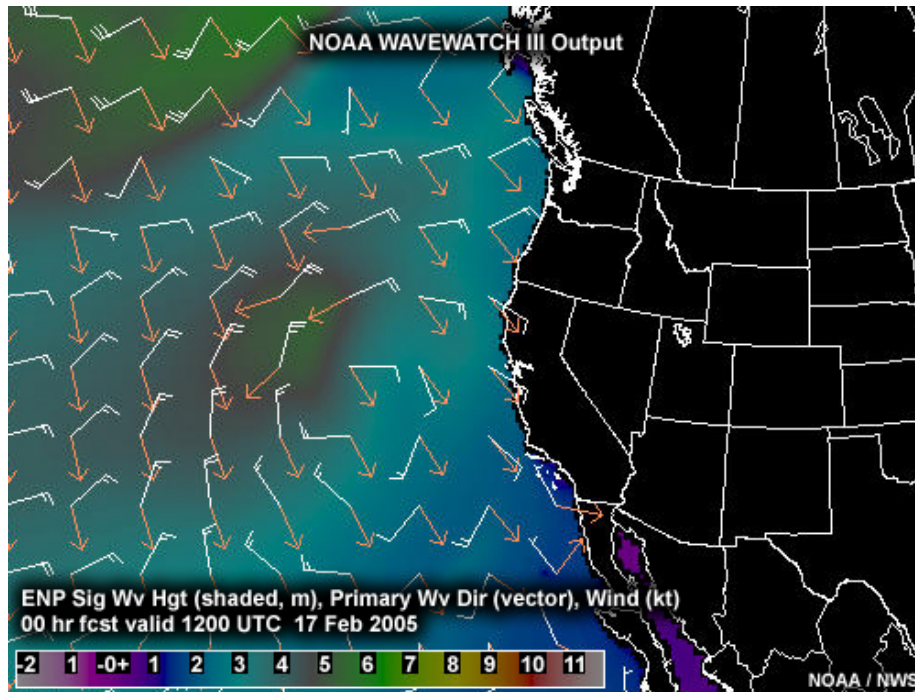
Let's look at the wave energy plots to see what happened to the 9 s wave group. Notice that at 10 PM, two distinct wave groups can be identified. The long-period wave group at 9.5 s has more energy than the 4.6 s wave group.



On the 11 PM plot, you can see that the two wave groups still exist, although the period of the second wave group has increased and now has more energy than the 9 s wave group. Therefore, the

5 s group has become the dominant wave group and is "masking" the 9 s group. However, it is important to realize that the 9 s wave group still exists and could be a contributor to rip current development.

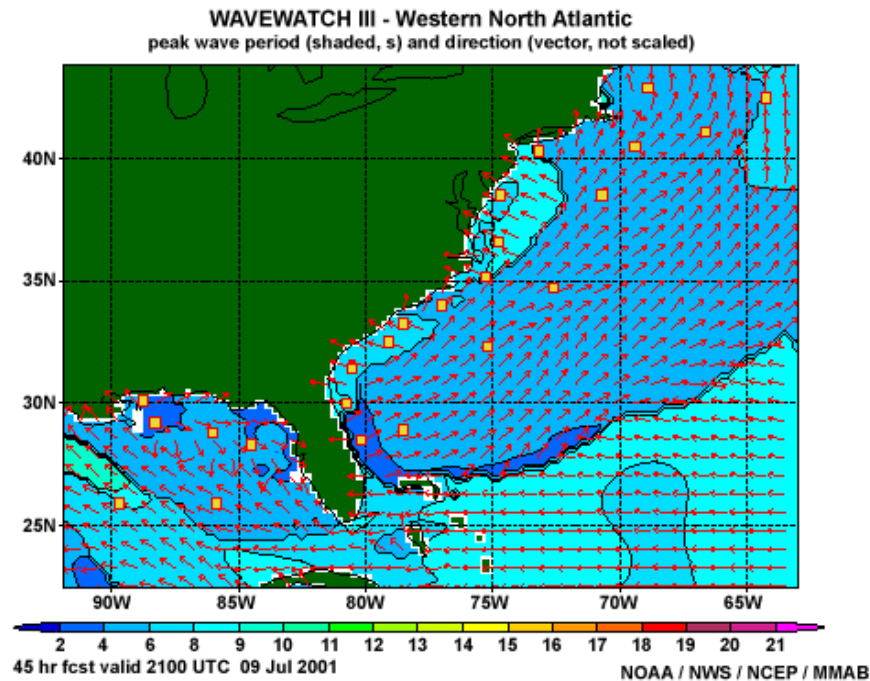
Analyzing Swell: Wave Model Data



Example of a 2-D NWW3 plot of significant wave height/direction and wind speed/direction in the eastern North Pacific (ENP)

Numerical wave models keep track of the location and propagation direction of newly generated waves and existing swell groups. They use this information, along with great circle tracks and wave physics (such as dispersion of wave energy), to forecast their movement. NOAA's WAVEWATCH III (NWW3) is the primary wave model used for ocean wave analysis in early 2006 when this module was published. The Great Lakes region uses the Great Lakes Coastal Forecasting System (GLCFS). It and other regional models are discussed later in this section.

Analyzing Swell: Wave Model Data
NOAA Wavewatch III Model



Example of a 2-D NWW3 plot of peak wave period and wave direction for the western North Atlantic

The NWW3 is a global model that produces a seven-day forecast four times a day. Wind fields used to drive the wave model come from the Global Forecast System (GFS) atmospheric model. In addition to the global domain, there are also several smaller domains that are run at a higher spatial resolution using the global output as boundary conditions (see the section titled "Regional Wave Models").

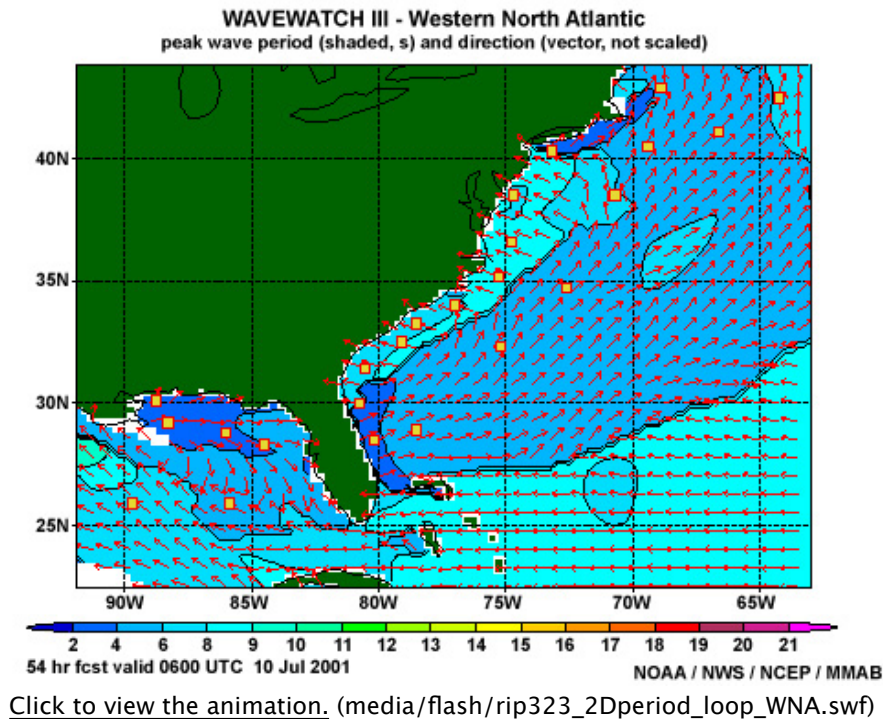
All NWW3 model data cannot be found on AWIPS. Some of the data we are going to look at in this section are only available from the Operational Products Website hosted by the NCEP Marine Modeling and Analysis Branch (<http://polar.ncep.noaa.gov/mmab/products.shtml>) (<http://polar.ncep.noaa.gov/mmab/products.shtml>).

For more information about using the NWW3 Web page and the model products, see the NWW3 primer at http://polar.ncep.noaa.gov/waves/pres/primer/primer_1.html (http://polar.ncep.noaa.gov/waves/pres/primer/primer_1.html).

For information on various marine models, see COMET's Marine Model Matrix at

http://www.meted.ucar.edu/nwp/pcu2/marine_matrix/ (http://www.meted.ucar.edu/nwp/pcu2/marine_matrix/)

Analyzing Swell: Wave Model Data NWW3 2-Dimensional Plots



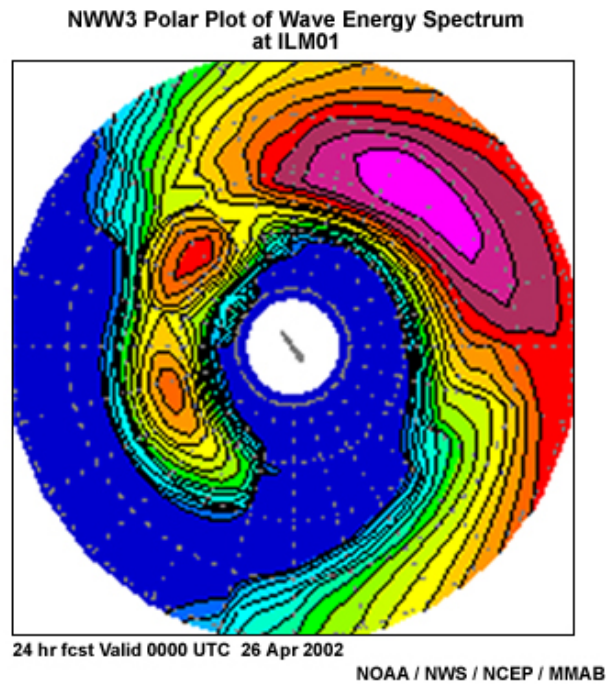
(media/flash/rip323_2Dperiod_loop_WNA.swf)

Forecast parameters from the NWW3 include significant wave height, dominant (or peak) period, and GFS wind speed and direction. The output is displayed in 2-D plots, which can be useful to see how features behave spatially (e.g., tracking a swell front in the wave period field).

This is a loop of peak period for the western North Atlantic domain. Other graphical displays are available for wave heights and wind speeds. Notice that the southeast U.S. coast is affected by weak onshore swell at the beginning of the loop. Eventually, shorter-period wind waves moving toward the northeast develop along the East Coast, and the onshore swell seems to disappear.

The usefulness of 2-D plots is often limited by the fact that they can only display the direction and period of the dominant wave. Similar to wave masking in the buoy observations, the 2-D plots must be used with caution because other wave or swell groups that could lead to rip current activity are sometimes masked, as is the case in this loop.

Analyzing Swell: Wave Model Data NWW3 Spectral Plots

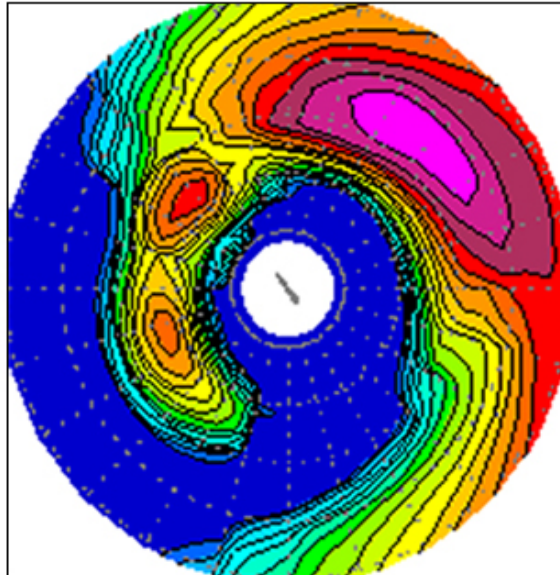


Model spectral data provides the forecaster with information on individual wave groups, including their propagation direction and period, which can be used in rip current forecasts. In addition, model output can be compared to buoy observations to determine how well the wave model initialized. We'll talk more about that use later.

Spectral plots of the wave energy and textual information on each wave group are provided by NWW3 at select locations. These output points are often collocated with NDBC observation points. The plots are available from any of the three interfaces (interactive, tabular, or text) on the NWW3 Website (<http://polar.ncep.noaa.gov/waves> (<http://polar.ncep.noaa.gov/waves>)).

Analyzing Swell: Wave Model Data
Interpreting NWW3 Spectral Plots

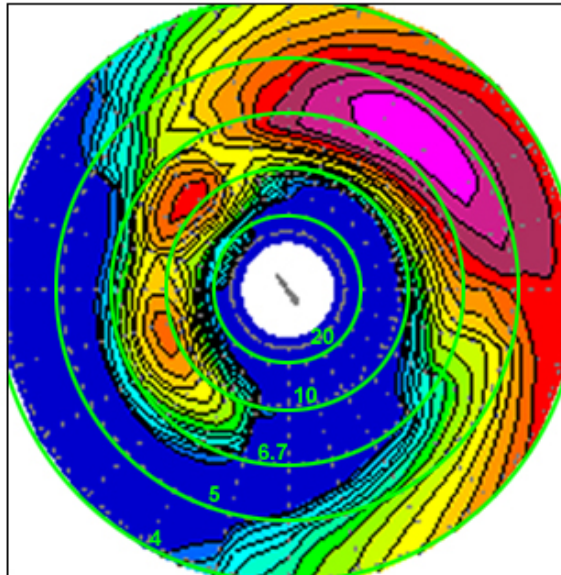
NWW3 Polar Plot of Wave Energy Spectrum
at ILM01



24 hr fcst Valid 0000 UTC 26 Apr 2002

NOAA / NWS / NCEP / MMAB

NWW3 Polar Plot of Wave Energy Spectrum
at ILM01



24 hr fcst Valid 0000 UTC 26 Apr 2002

NOAA / NWS / NCEP / MMAB

The gray rings on the NWW3 polar spectral plot correspond to frequency, which is inversely

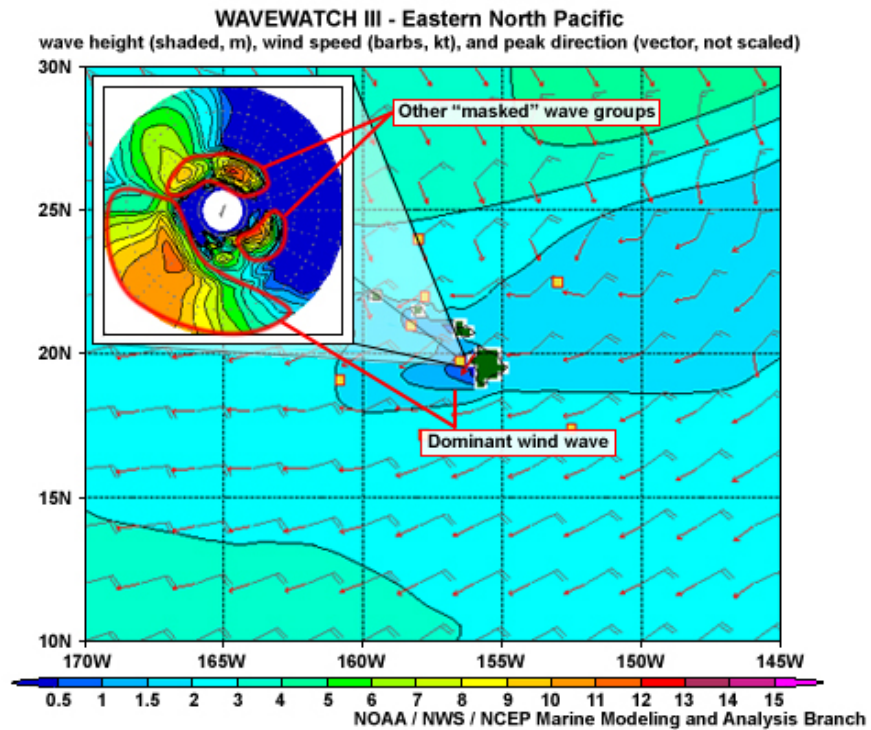
proportional to period. Consequently, the center green ring on the plot represents a frequency of 0.05 Hz or a wave period of 20 s, and the outermost ring represents a frequency of 0.25 Hz or a shorter-wave period of 4 s. Thus, the wave energy dispersed around the outer half of the plot is the higher-frequency (shorter-period) waves usually associated with locally generated wind waves. The wave energy in the inner half of the plot represents the lower-frequency (longer-period) swell waves.

Since wind typically varies in both speed and direction, the wave energy generated by local winds has a fairly large area of maximum energy that is spread over a range of frequencies and directions. In contrast, swell is characterized by wave energy that is typically focused around a narrow frequency range and a particular direction. The colors represent wave energy density, with dark blue indicating the absence of wave energy and light purple the local maximum. The figure shows that the wind wave group in the top right has the most energy, so its period would be the dominant period. To determine the actual height of the individual wave components, you would refer to the text bulletin output, which will be discussed later.

It is important to note that wave direction is shown on these plots in terms of moving away from the grid point, in other words **toward** the edge of the plot. This is the oceanographic convention, which is opposite the atmospheric wind direction convention.

Analyzing Swell: Wave Model Data

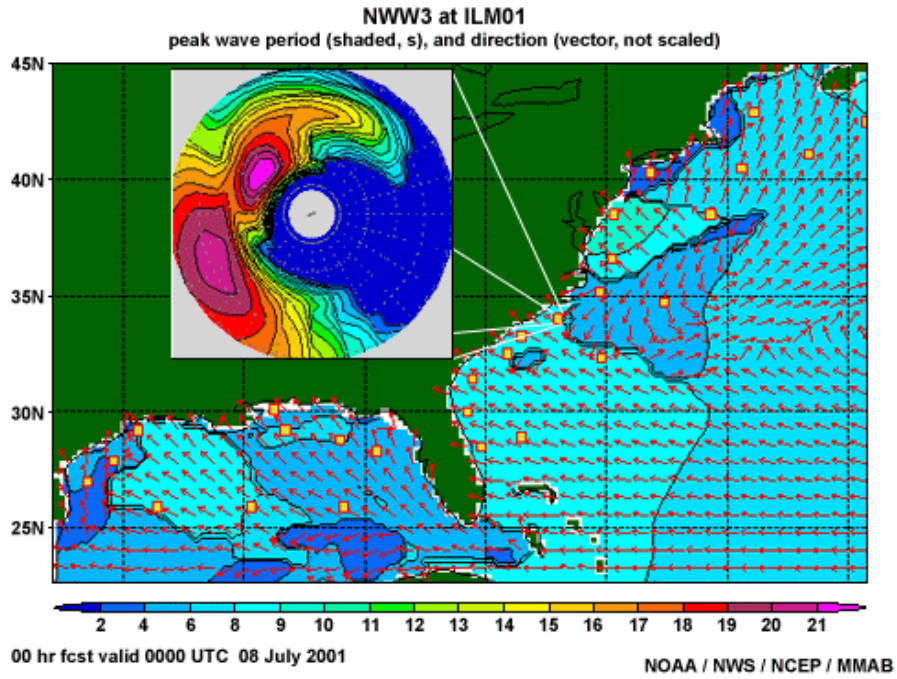
Wave Masking

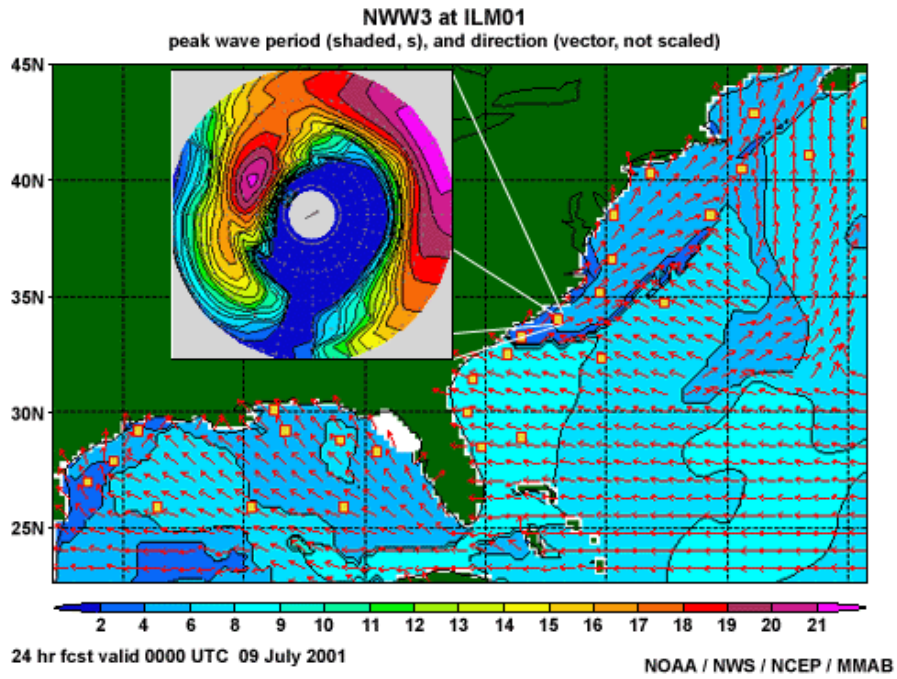
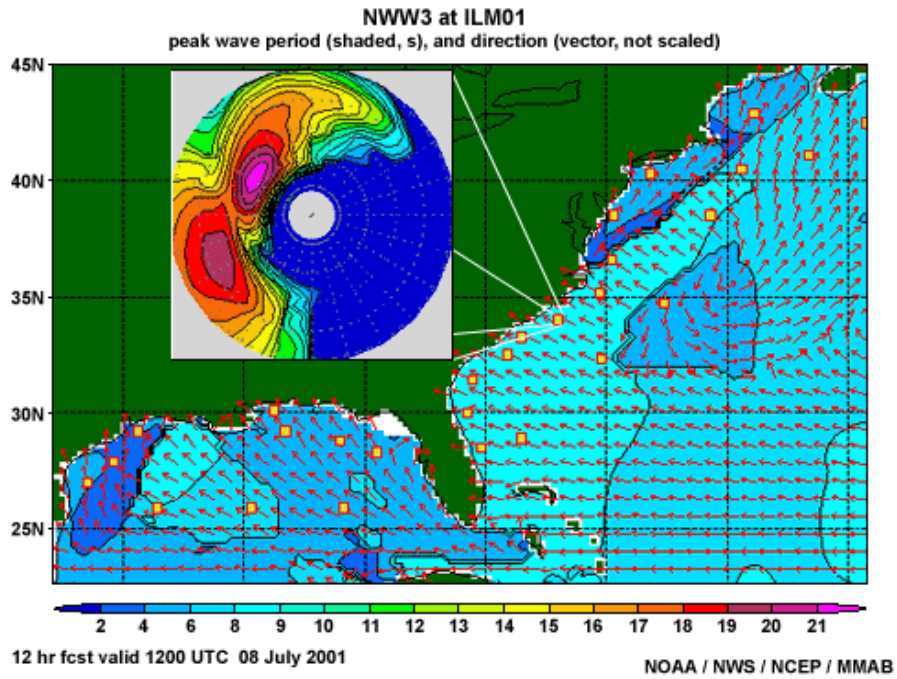


As shown in this example, wave masking is an issue in model data, just as it is in observations. The 2-D map indicates the dominant waves are moving to the southwest (red arrows), which would not affect rip current potential on the west coast of the island (depicted in green). However, looking at the spectral plot, you can see that it is the wind wave that is dominating the spectrum. The masked wave groups moving toward the southeast and northeast might affect the coast, depending on the orientation of the beaches. Forecasters can better identify those forecasted wave components that may become significant contributors to rip current development by using spectral wave analysis.

Analyzing Swell: Wave Model Data Using NWW3 Spectral Plots

These graphics combine the NWW3 model predictions of peak wave period and direction for the Western North Atlantic (2-D plot) with the model spectral energy density (polar plot) for the output point at ILM01 that is just off the coast of Wilmington, N.C. Review these products and then answer the following True or False questions.

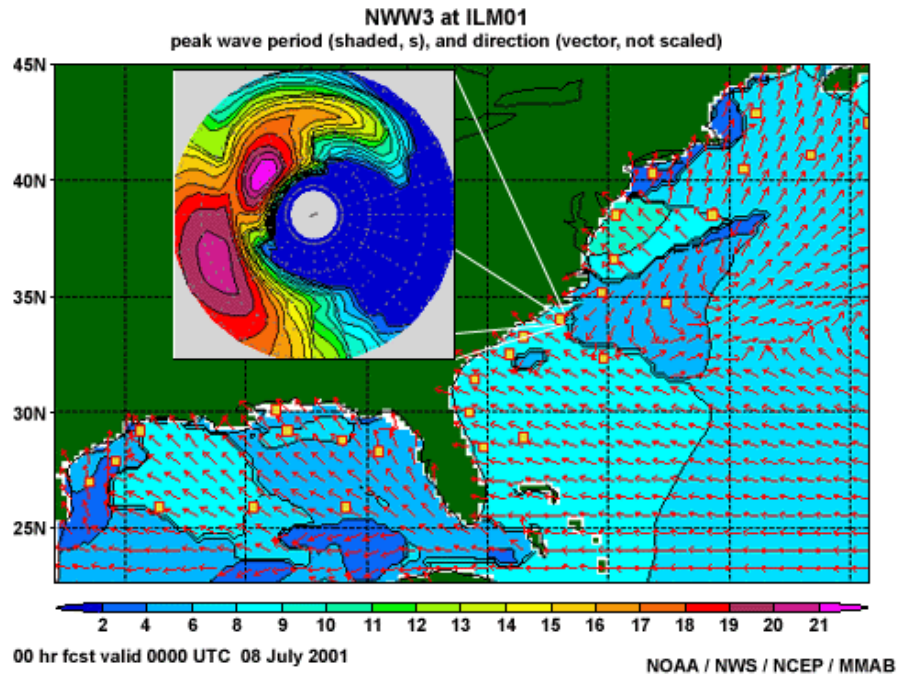




Analyzing Swell: Wave Model Data » Using NWW3 Models

Question 1

This graphic is the NWW3 forecast for 0000 UTC on 8 July 2001. Examine the figure and determine if the following statement is True or False.



Question 1a

[True/False] Wind waves at ILM01 are presently moving from the northeast toward the southwest.

- a) True
- b) False

Done

The correct answer is True.

There are two groups of high wave energy. One is in the southwest part of the plot with the maximum centered near the 5 s (or 0.20 Hz) radius. The other is in the northwest quadrant of the plot, with the maximum centered near the 9 s (or 0.11 Hz) radius. The 5 s group has energy spread over approximately a 160-degree range of direction. Its low period and large direction range are typical of a wind wave field,

and it is moving toward the southwest. The 9 s group is more focused and has slightly more energy. This indicates that it is swell that has traveled from a distant location. The wave energy that is northwest–northeast of the 9 s swell is a wave group that is probably young swell associated with southeast winds. Those winds have now turned northeasterly where they are presently generating the more energetic wind waves moving toward the southwest.

Question 1 b

[True/False] Onshore swell has more energy than the wind waves at point ILM01.

a) True

b) False

Done

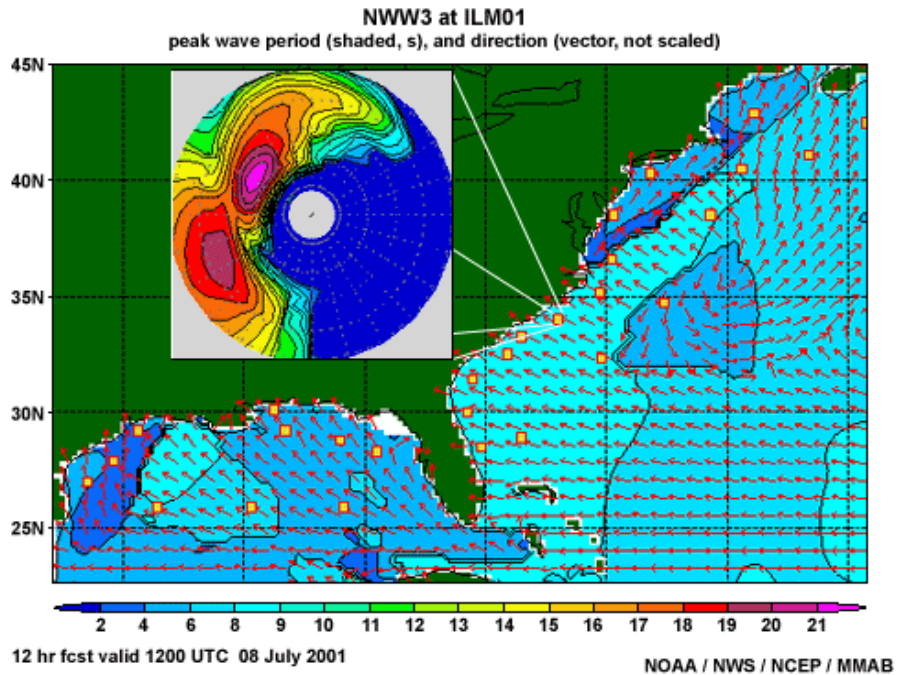
The correct answer is True.

This is a bit difficult to tell from the 2–D plot because the buoy is on the edge of the transition between the waves moving southwest and those moving northwest. However, it appears that the buoy is still in the area corresponding to waves moving toward the northwest, which would mean the swell waves are more dominant here. Comparing the color contours of wave energy density for the wind waves and the swell on the spectral plot, you can see that the swell group has one more contour in the center (the light purple area), which corresponds to more energy.

Analyzing Swell: Wave Model Data » Using NWW3 Models

Question 2

Compare the 12-hour forecast (valid 1200 UTC) with the earlier 00-hour forecast (valid 0000 UTC) and determine if the following statement is true or false.



[True/False] On 8 July, the 12-hour forecast valid at 1200 UTC is for onshore swell to persist and wind wave energy to decrease at point ILM01.

- a) True
- b) False

Done

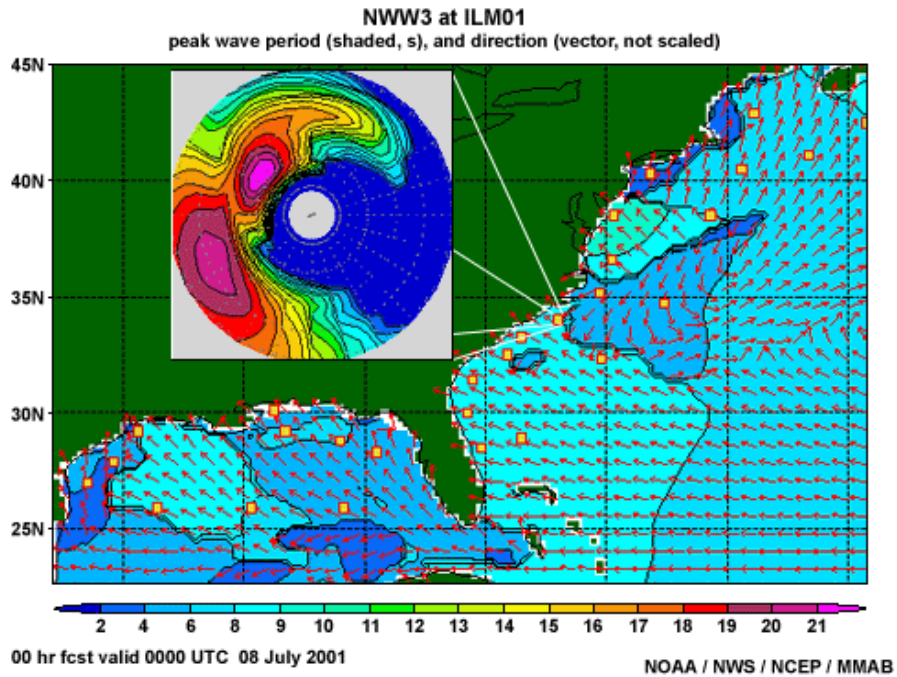
The correct answer is True.

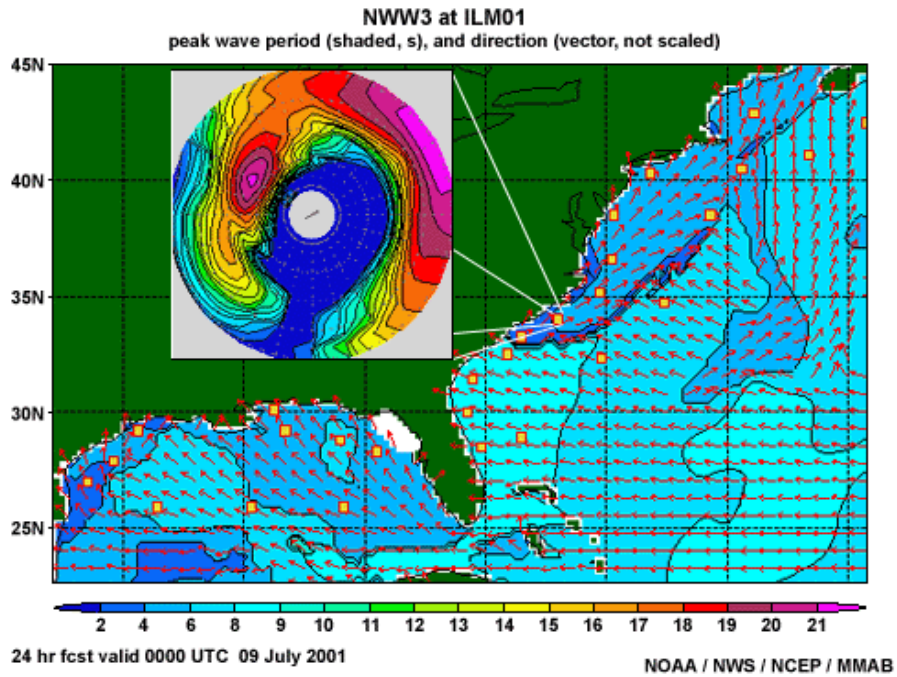
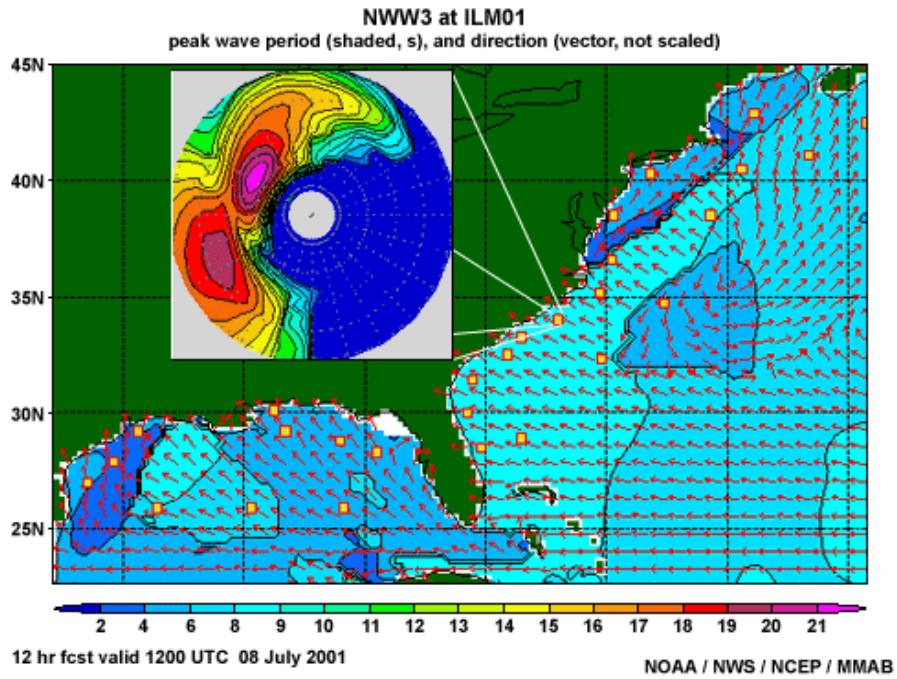
Again, comparing the color contours on the spectral plots, you can see that the forecast swell at 1200 UTC heading northwest has the same number of contours as earlier at 0000 UTC while the area corresponding to wind waves heading southwest no longer has the light purple contours. This indicates that the forecast wind energy decreased from 0000 UTC to 1200 UTC.

Analyzing Swell: Wave Model Data » Using NWW3 Models

Question 3

These graphics combine the NOAA WAVEWATCH III model predictions of peak wave period and direction for the Western North Atlantic (2-D plot) with the model spectral energy density (polar plot overlaid on the U.S. land area) from the output point ILM01 (see telescoping lines) that is just off the coast of Wilmington, N.C. The 00-, 12-, and 24-hour forecasts of these products from the 0000 UTC 8 July, 2001 model run are provided. Determine if the following statements are true or false for this model forecast.





Question 3a

[True/False] By 0000 UTC on 9 July (24-hr forecast), the winds are expected to decrease and a larger swell group moving toward the northeast will have appeared.

a) True

b) False

Done

This statement is False.

The high frequency energy moving toward the northeast is a new wind wave group that forms when the winds change direction. Remember that the majority of the energy from wind waves is on the outer part of the polar plot because they have been generated recently and therefore have low wave periods. In addition, wind wave energy is spread over a larger range of directions than swell due to the variability of the wind direction.

Question 3b

[True/False] The wind waves at 0000 UTC on 9 July have more energy than that of the onshore long-period swell.

a) True

b) False

Done

This statement is True.

According to the color contours on the spectral plot, the energy of the wind waves and the swell is approximately the same. However, the 2-D plot indicates that the dominant waves have relatively short periods (4–6 s), so the wind waves have more energy.

Question 3c

[True/False] The swell moving onshore (toward the northwest) at ILM01 has persisted through the change in wind direction and is masked by the wind wave energy by 0000 UTC on 9 July (24-hour forecast).

a) True

b) False

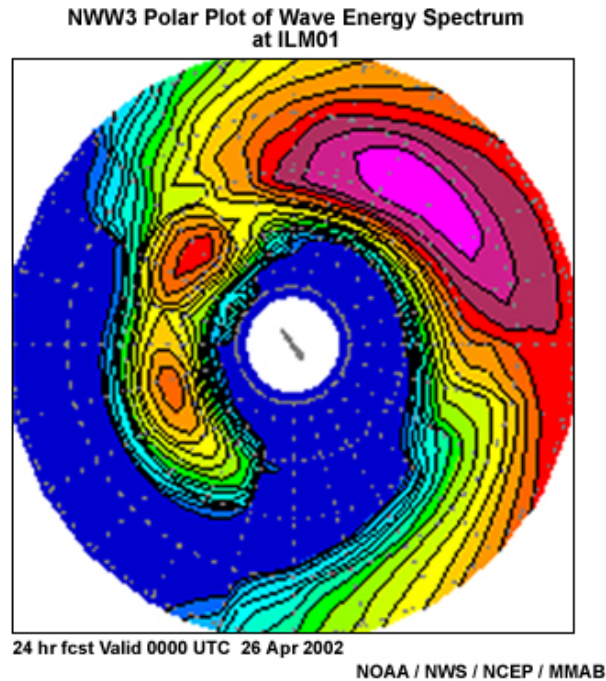
Done

This statement is True.

If you looked at only the 2-D plot, you would conclude that the waves were not going to impact the shore. The wind waves moving to the northeast are masking the swell moving to the northwest.

Analyzing Swell: Wave Model Data Using NWW3 Spectral Text Bulletins

Spectral plots can be used to quickly identify the individual wave components over the life of the model run. However, you will need to examine the model text output to determine the wave height and exact wave period associated with the energy maxima seen on the spectral plots. Some forecasters just go directly to the text bulletin to find the wave groups of importance. Others first use the spectral plot to help identify where to look in the numerical output and to glance at trends for an individual point in the wave model.



This spectral plot displays three main groups of waves. Looking at the corresponding text bulletin, you can see that two of these are swell groups of 8.4 s and 8.5 s moving toward the northwest (311 degrees) and west-southwest (253 degrees), respectively. The third wave group has a period of 5.7 s and is generating a variety of waves with general movement toward the northeast (47 degrees). Heights are expressed in meters.

Textual Output from NWW3

```

Location : ILM01      (34.00N 77.00W)
Model    : Western North Atlantic 0.25deg
Cycle    : 20020421 t00z
-----
| day & | Hst  n x | Hs  Tp dir | Hs  Tp dir | Hs  Tp dir | Hs  Tp dir |
| hour | (m)  - - | (m) (s) (d) | (m) (s) (d) | (m) (s) (d) | (m) (s) (d) |
-----
126 00 | 1.3 3 | 0.2 8.4 311 | 0.2 8.5 253 | 1.2 5.7 47 |
    
```

Hst (m) = overall wave height
n = number of identified individual wave fields
Hs (m) = wave field height
Tp (s) = wave field period
dir (d) = wave field direction

NOAA / NWS / NCEP / MMB

The text output from NWW3 is also available on AWIPS. The data format is slightly different but wave height, period, and direction are all provided. When displayed in AWIPS, the wave height is in feet and the wave direction is "from," analogous to the meteorological wind direction convention. This is important to note since the text output from the Web version of NWW3 uses the oceanography convention. Also, the column headings are slightly different in the AWIPS display; "SS" stands for wave height and "HS" stands for significant wave height based on all wave groups.

AWIPS Format of WAVEWATCH III Bulletin

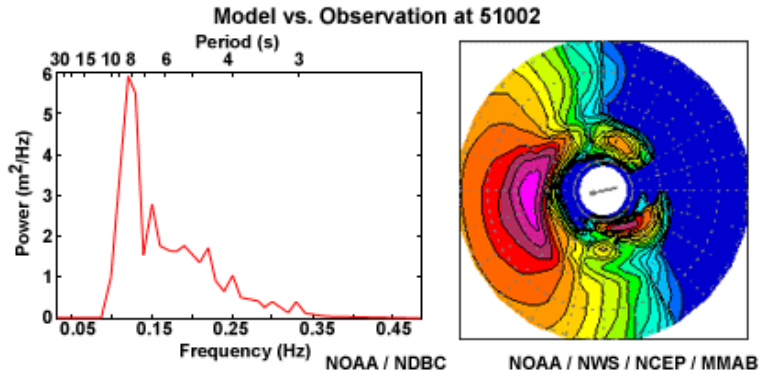
```

AGNT42 KWB 032250
OSBW09
LOCATION : ILM01      (34.00N 77.00W)
MODEL  : WESTERN NORTH ATLANTIC 0.25DEG
CYCLE  : 20031203 T18Z
-----
DDHH HS SS PP DDD SS PP DDD SS PP DDD SS PP DDD SS PP DDD
-----
0312 5 4 05 042 1 08 067 1 14 122
0313 5 5 05 044 1 08 064 1 14 120
0314 5 5 05 047 1 14 122
0315 5 5 05 047 1 14 120
0316 5 5 05 049 1 14 122
0317 5 5 06 049 1 14 120
0318 5 5 06 050 1 13 123
0319 5 3 07 064 1 13 120
0320 5 5 06 051 1 13 123
0321 5 5 05 051 1 13 120
0322 5 5 05 050 2 09 075 1 13 123
0323 5 5 05 048 1 13 120 2 08 067
0400 5 5 05 051 2 09 075 1 13 123
0401 5 4 05 050 1 13 120 2 08 067
0402 5 4 05 050 2 09 075 1 13 123 2 07 065
0403 5 4 05 052 1 13 120 3 07 066
0404 5 4 05 054 2 09 074 1 13 123 2 07 066
0405 5 4 05 056 1 13 120 2 07 066
0406 4 3 05 057 1 09 074 1 13 123 2 07 064
0407 4 1 13 120 4 07 061
0408 4 1 09 074 1 13 123 4 07 061
0409 4 3 05 060 1 13 120 3 07 063
0410 4 3 05 061 1 13 123 2 07 066
0411 4 3 05 062 1 13 120 2 07 063
0412 4 1 09 073 4 05 063 1 13 122 2 07 064
    
```

DD = day of month
HH = hour of day (UTC)
HS = total significant wave height (ft)
SS = significant wave height of separate wave field (ft)
PP = peak period of separate wave field (whole seconds)
DDD = mean direction of separate wave field (degrees / "from")

NOAA / NWS / NCEP / MMB

Analyzing Swell: Wave Model Data
 Model Initialization



Wave models are quite useful, and they are improving. However, as with any model, the analysis and forcing parameters in the model can be in error and should always be checked with real observations when possible. Spectral analysis of wave observations allows the forecaster to know not only what wave groups presently exist, but whether the marine model was initialized well.

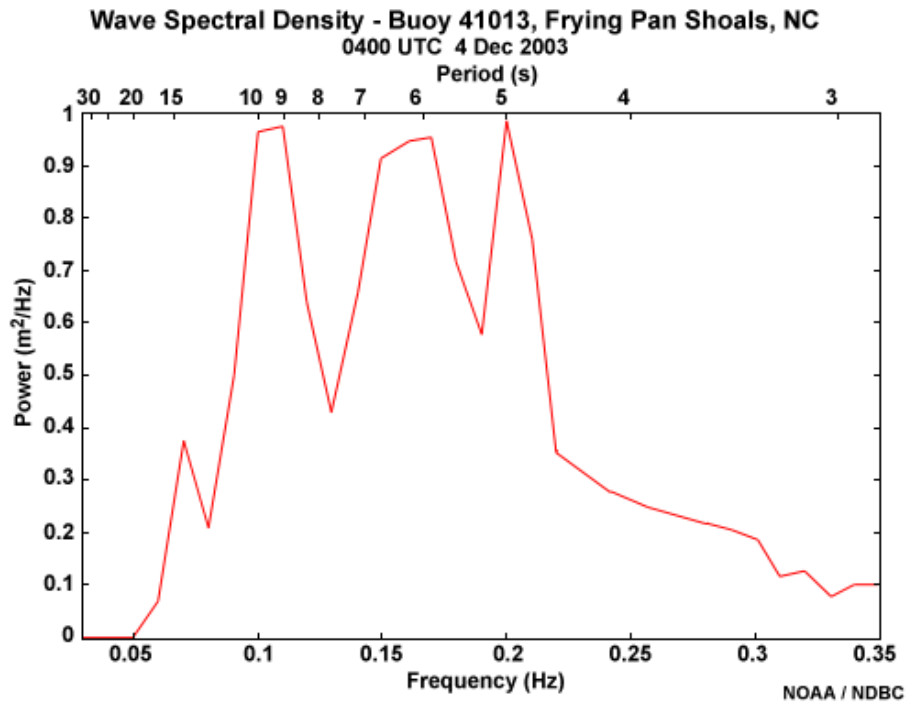
NWW3 Hourly Wave Groups Forecast
 3 Dec 2003

AGNT42 KMBJ 032250
 OSBW09
 LOCATION : ILM01 (34.00N 77.00W)
 MODEL : WESTERN NORTH ATLANTIC 0.25DEG
 CYCLE : 20031203 T18Z

DDHH	HS	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD
0312	5	4	05	042	1	08	067	1	14	122									
0313	5	5	05	044	1	08	064	1	14	120									
0314	5	5	05	047					1	14	122								
0315	5	5	05	047					1	14	120								
0316	5	5	05	049					1	14	122								
0317	5	5	06	049					1	14	120								
0318	5	5	06	050					1	13	123								
0319	5	3	07	064					1	13	120								
0320	5	5	06	051					1	13	123								
0321	5	5	05	051					1	13	120								
0322	5	5	05	050	2	09	075	1	13	123									
0323	5	5	05	048					1	13	120	2	08	067					
0400	5	5	05	051	2	09	075	1	13	123									
0401	5	4	05	050					1	13	120	2	08	067					
0402	5	4	05	050	2	09	075	1	13	123	2	07	065						
0403	5	4	05	052					1	13	120	3	07	066					
0404	5	4	05	054	2	09	074	1	13	123	2	07	066						
0405	5	4	05	056					1	13	120	2	07	066					
0406	4	3	05	057	1	09	074	1	13	123	2	07	064						
0407	4								1	13	120	4	07	061					
0408	4	1	09	074					1	13	123	4	07	061					
0409	4				3	05	060	1	13	120	3	07	063						
0410	4				3	05	061	1	13	123	2	07	066						
0411	4				3	05	062	1	13	120	2	07	063						
0412	4	1	09	073	4	05	063	1	13	122	2	07	064						
0413	4				4	05	065	1	13	120	2	07	064						
0414	4	1	09	073	4	05	067	1	13	123	1	07	063						

DD = day of month
 HH = hour of day
 HS = total significant wave height (ft)
 SS = significant wave height of separate system (ft)
 PP = peak period of separate system (whole seconds)
 DDD = mean direction of separate system (degrees / "from")

NOAA / NWS / NCEP / MMAB



The text output from NWW3 provides an easy way for the forecaster to compare model predictions to wave observations. The wave groups in the model can be checked against the buoy's wave spectral energy distribution. For example, comparing the data from the Frying Pan Shoals buoy and the text output from a model point collocated with the buoy, you can see that the four wave periods indicated in the observational data match closely with the NWW3 prediction of four wave groups.

Analyzing Swell: Wave Model Data » Model Initialization

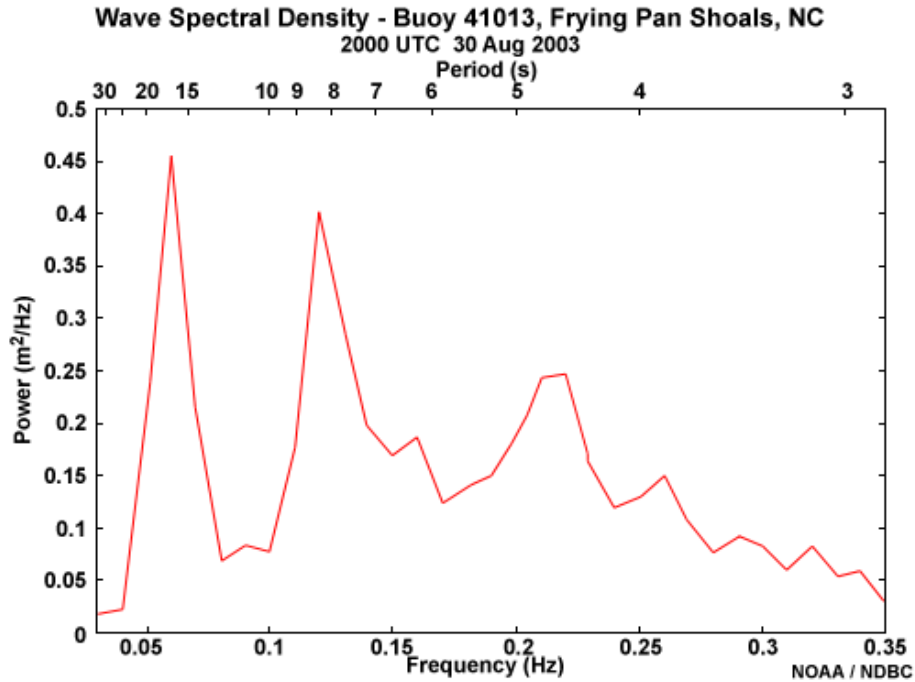
Model Errors

If the NWP forecast for winds is incorrect, then the NWW3 wave forecasts will also be in error. Therefore, the first and most critical consideration to make when using any wave model is whether or not the winds used to force the wave model are correct. Most errors in wave models result from incorrect initial winds because wave growth and dispersion are determined by the actions of wind in the model.

Also, if the timing of wave generation or swell propagation is incorrect, the forecast of rip current development will be in error. Since the longest period waves travel the fastest from the generation region, they are usually the first to arrive. Consequently, forerunner swell is very important to rip current forecasts. When the leading edge of a swell group (i.e., swell front) begins to reach the beach, the formation of rip currents becomes more likely, and correctly timing the swell event becomes critical. If the model is incorrect, whether in timing or swell height and period, observations will be the only source of reliable information.

Analyzing Swell: Wave Model Data » Model Initialization
 Exercise

Look at the data and then choose the correct answer.



NWW3 Hourly Wave Groups Forecast
 30 Aug 2003

LOCATION : ILM01 (34.00N 77.00W)
 MODEL : NORTH ATLANTIC HURRICANE 0.25
 CYCLE : 20030830 T12Z

DDHH	HS	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD	SS	PP	DDD	SS	PP
3006	3	2	04	196	2	08	127								
3007	3	2	04	196	2	08	126								
3008	3	2	04	193	2	08	126								
3009	3	2	04	199	2	08	125	1	04	161					
3010	3	2	04	198	2	08	126	1	04	161					
3011	2	1	04	198	2	08	125	1	04	163					
3012	2	1	04	196	2	08	125	1	04	162					
3013	2	1	04	185	2	08	124								
3014	2	1	04	183	2	08	125								
3015	2	1	04	180	2	08	124								
3016	2	1	04	178	2	08	125								
3017	2	1	04	176	2	08	124								
3018	2	1	04	175	2	08	125								
3019	2	1	04	175	2	08	124								
3020	2	1	04	176	2	08	125								
3021	2	1	04	184	2	08	125								
3022	2	1	04	174	2	08	125								
3023	2	1	05	169	2	07	124	2	03	192					
3100	2	1	04	161	2	07	125	2	03	193					
3101	2	1	04	161	2	07	124	2	03	194					

DD = day of month
 HH = hour of day (UTC)
 HS = total significant wave height (ft)
 SS = significant wave height of separate wave field (ft)
 PP = peak period of separate wave field (whole seconds)
 DDD = mean direction of separate wave field (degrees / "from")

NOAA / NWS / NCEP / MMAB

[True/False] The model results and buoy observations agree well.

a) True

b) False

Done

The correct answer is False.

The observed wave spectrum indicated that three wave or swell groups were propagating by the buoy. The NWW3 output for that same time only showed the 8 and 4 s period wave groups and left out the 17 s period group. This other wave group could contribute to rip currents depending on its direction of propagation. Without model guidance for the wave direction, a forecaster would need to make some assumptions about the waves to try to determine their origin from a known storm that has recently occurred.

Analyzing Swell: Wave Model Data

Model Limitations

In addition to model initialization errors, problems can also arise from poor dynamic predictions or from resolution limitations that do not capture smaller-scale events. For example, if the model winds used as forcing in the wave model unrealistically strengthen the wind field, then large errors in wave height prediction can occur. Or in the case of a small, intense tropical cyclone, the winds are often underestimated because the model resolution is too coarse to adequately represent such a strong mesoscale feature.

Another example is that of warm air advection occurring over relatively cooler waters leading to unrealistically high wind speeds predicted by the model and subsequent high wave-growth predictions. Because the stable layer near the water surface is not well-resolved by global-type models in these cases, higher wind speeds in the lower atmosphere are falsely mixed down to the surface level by the model, causing an overestimate of the actual surface winds. This can be a problem early in the warm season when increases in water temperature tend to lag behind seasonal air temperature fluctuations by about a month. These problems can also occur during periods of cool, deep ocean water upwelling.

Another key limitation is that NWW3 does not currently include shallow water wave physics. This, along with its coarse resolution, limits the model's use to deep water offshore areas more than 15 km from the coast.

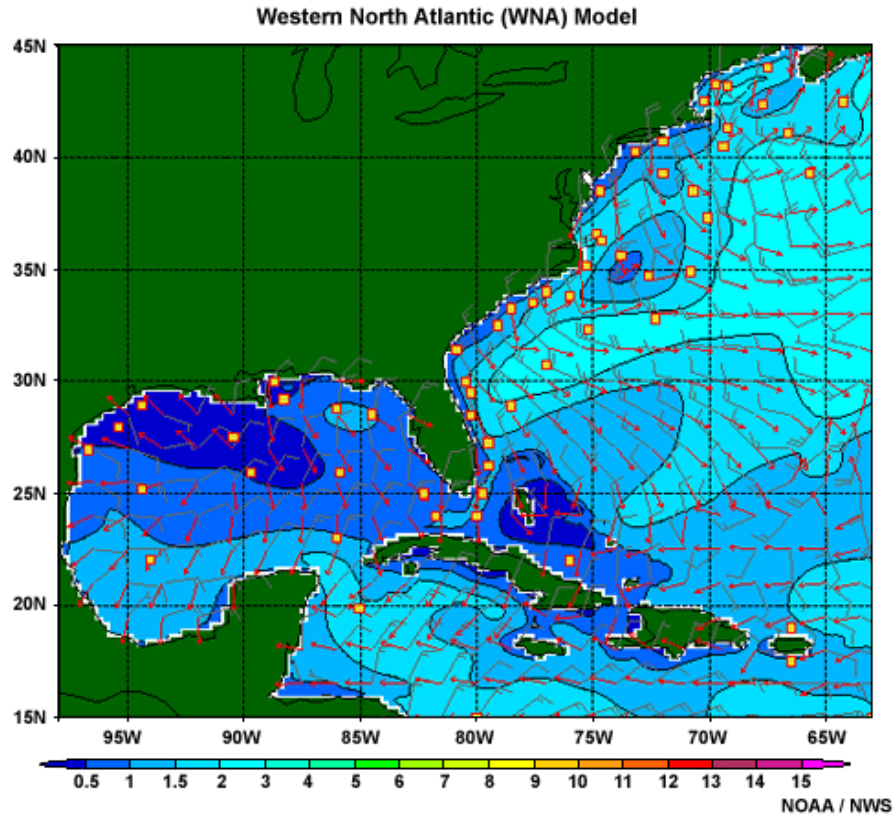
Analyzing Swell: Wave Model Data

Regional Wave Models

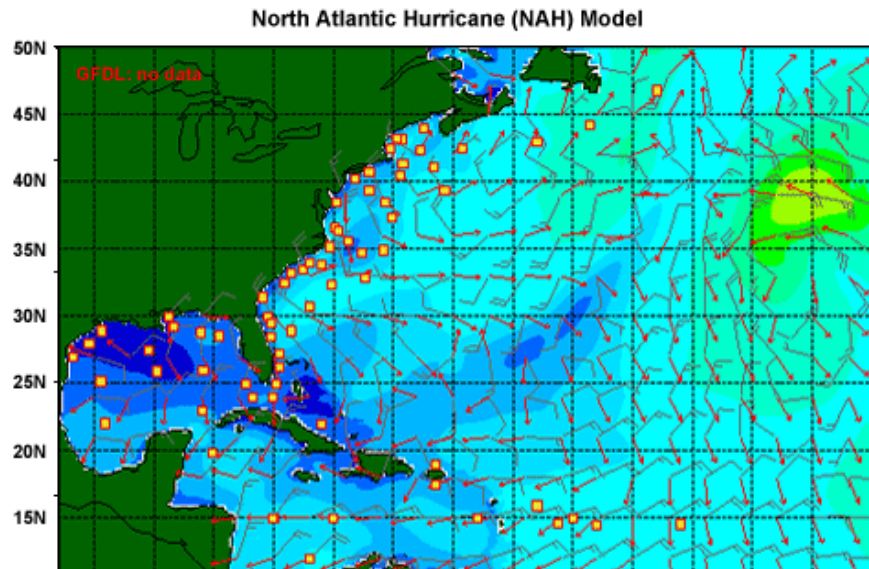
The need for regional wave models is analogous to the need for regional domains in atmospheric models. This section discusses regional NWW3 models, the SWAN model (which is more appropriate for shallow water wave processes than NWW3), and the modeling system used for forecasting waves in the Great Lakes.

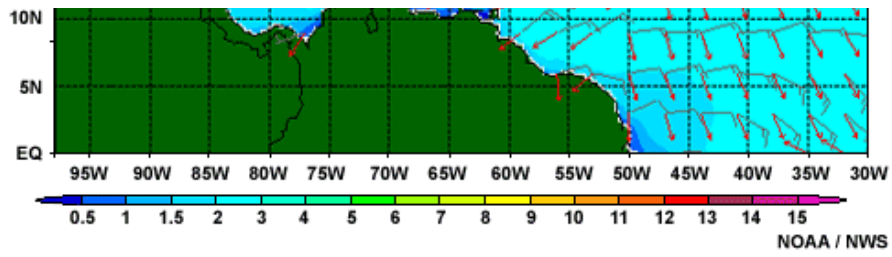
Analyzing Swell: Wave Model Data » Regional Wave Models
Regional NWW3 Models

In addition to the global NWW3 model, the operational NWW3 wave model suite consists of five regional models:



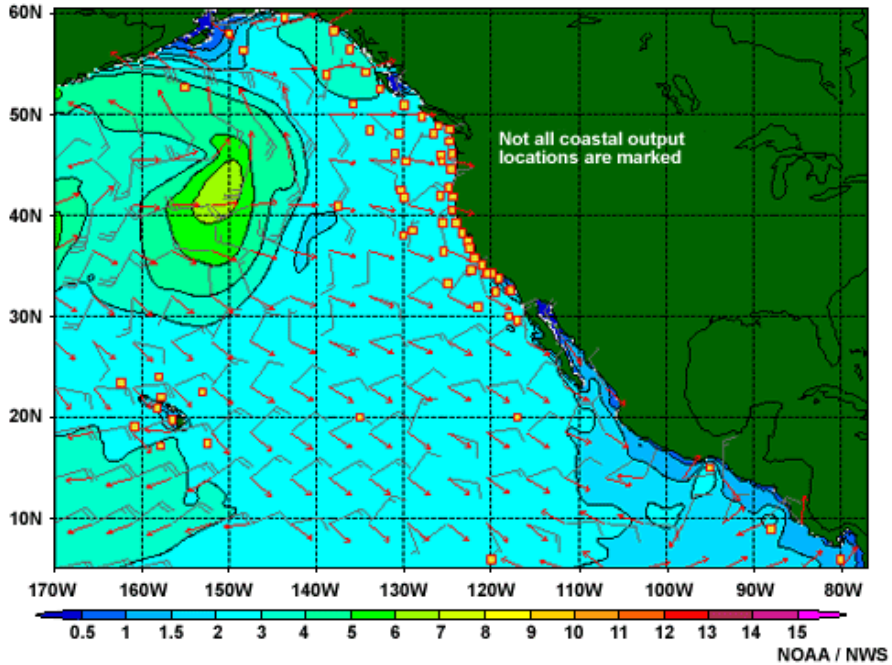
Western North Atlantic (WNA) model





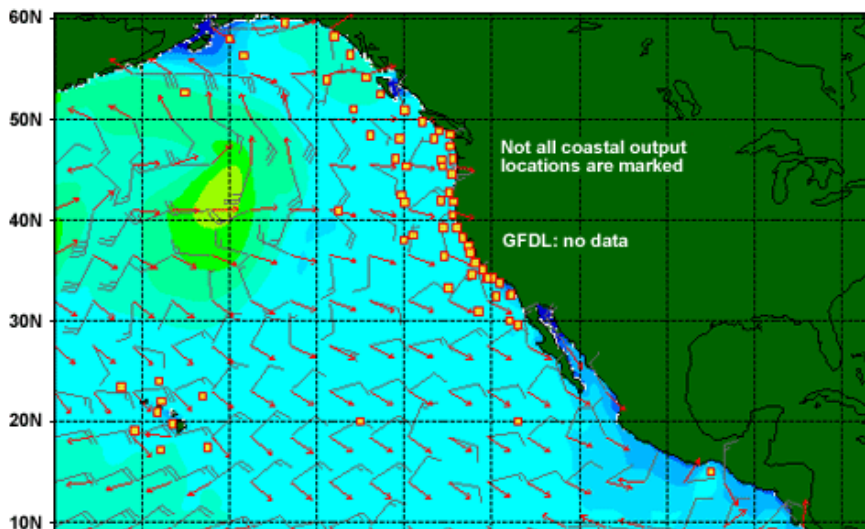
Western North Atlantic (WNA) model

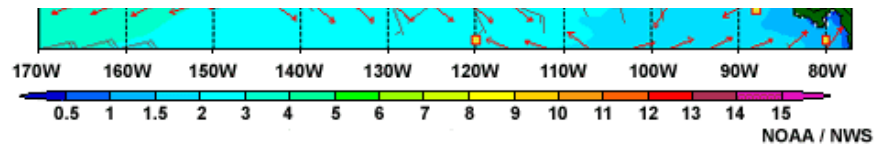
Eastern North Pacific (ENP) Model



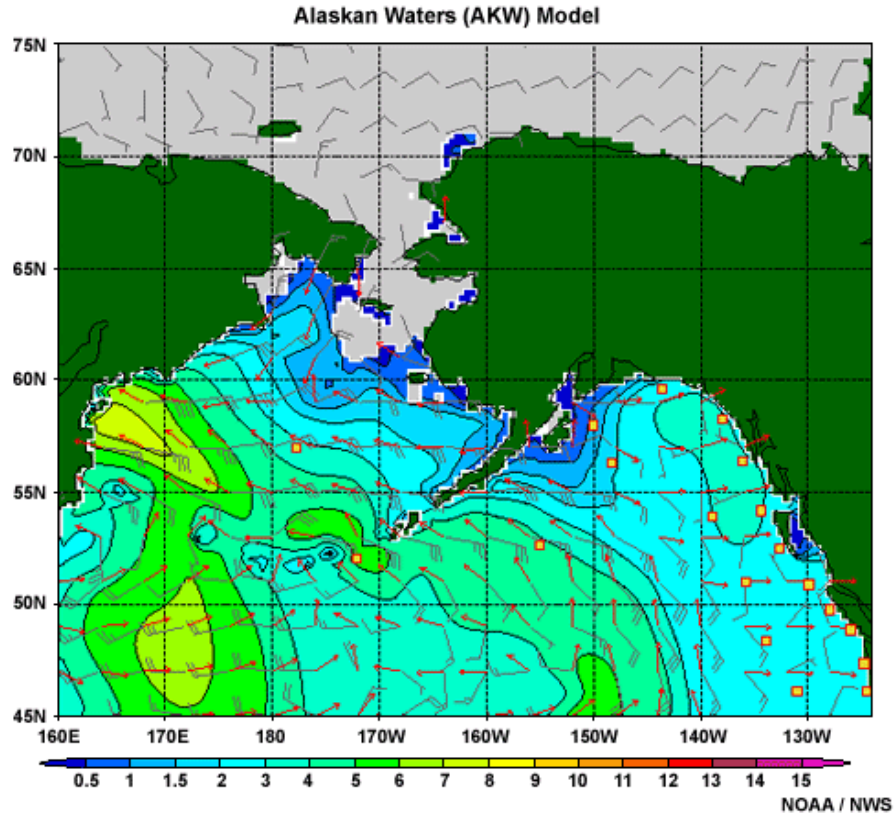
Eastern North Pacific (ENP) model

North Pacific Hurricane (NPH) Model





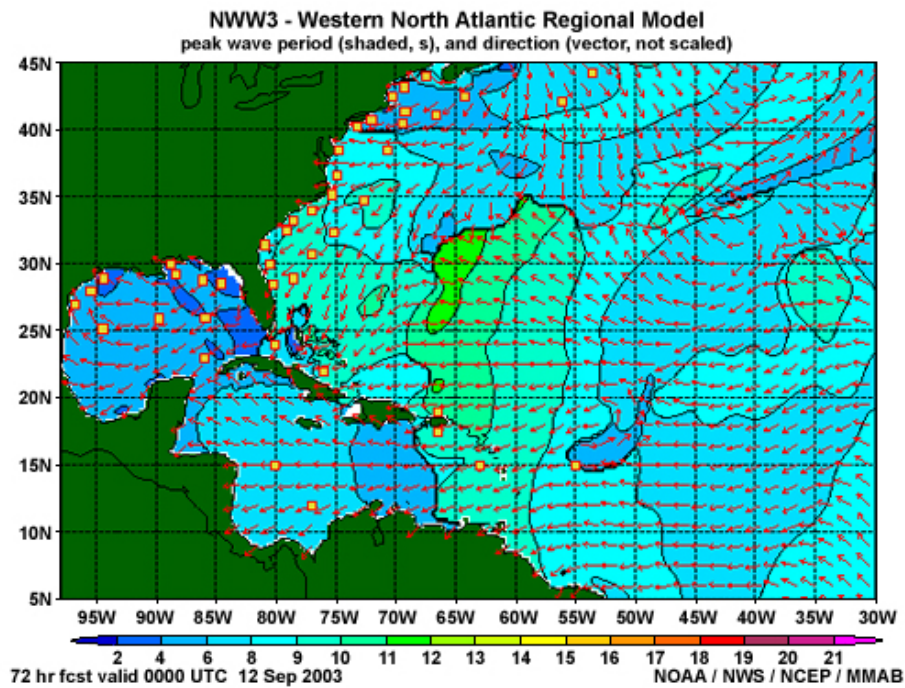
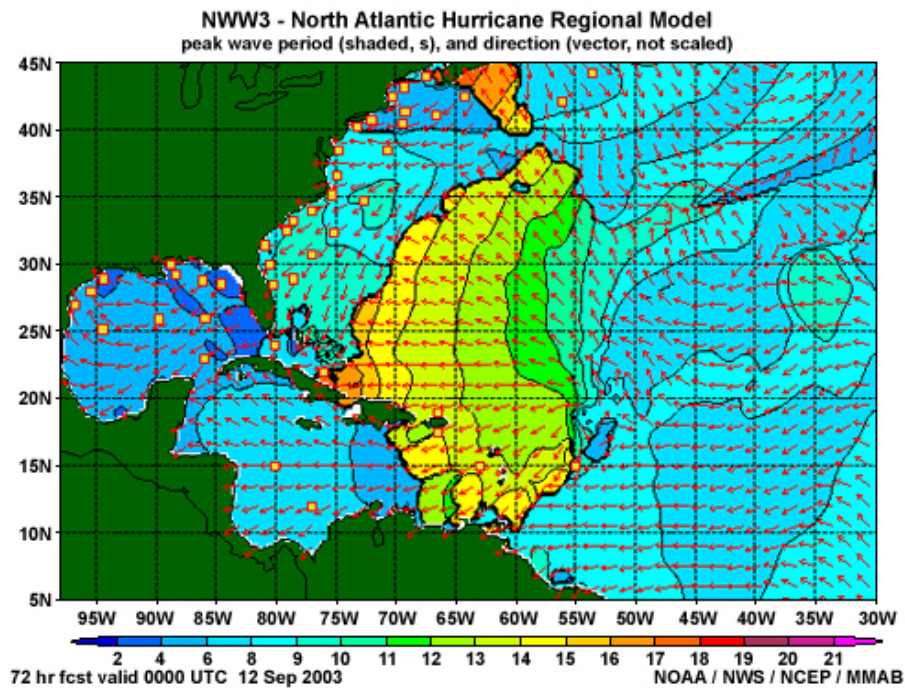
North Pacific Hurricane (NPH) model



Alaskan Waters (AKW) model

Winds for these models come from the GFS. However, the NAH and NPH models blend GFS winds with winds from the Geophysical Fluid Dynamics Laboratory (GFDL) model whenever possible.

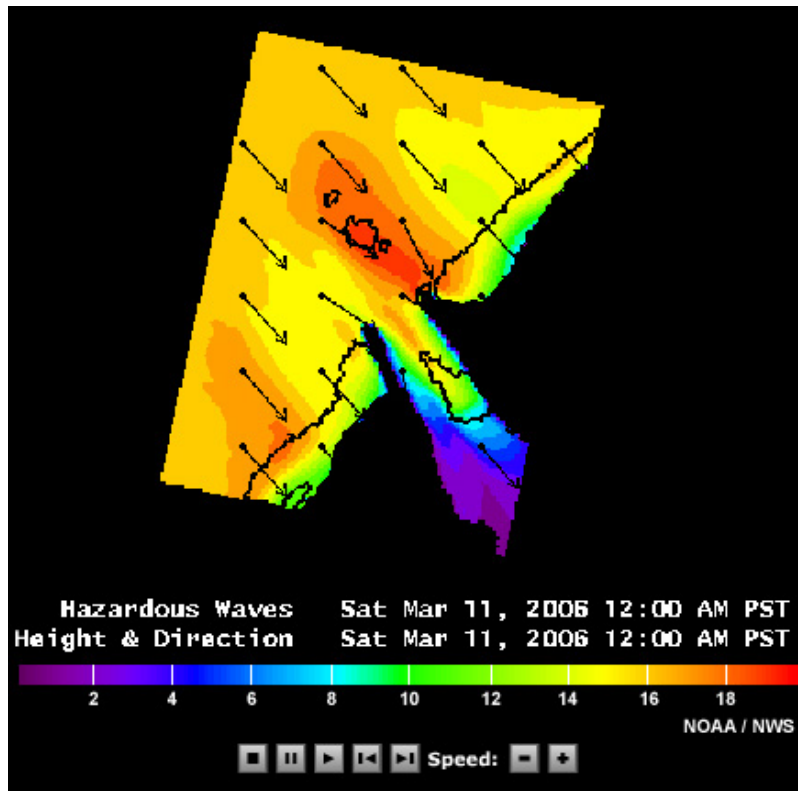
Forecasters need to know when to use the hurricane versions versus the regional models. When the GFDL is performing well, the wave field rendered by the NAH or NPH model is often the most reliable solution. In their products, the National Hurricane Center often discusses what they think of the GFDL and its intensity forecast.



Hurricane Isabelle (2003) is a good example of the NAH outperforming the WNA. With the GFDL providing a more realistic wind field, the swell front is better defined in the NAH; a fact that was verified by observations. If the WNA had been the only model used, the forecaster would have incorrectly anticipated a shorter-period swell and predicted the event to impact the coast a day or two later than what was observed.

Analyzing Swell: Wave Model Data » Regional Wave Models

SWAN Model



[Click to view the animation. \(media/flash/swan_eur.swf\)](#)

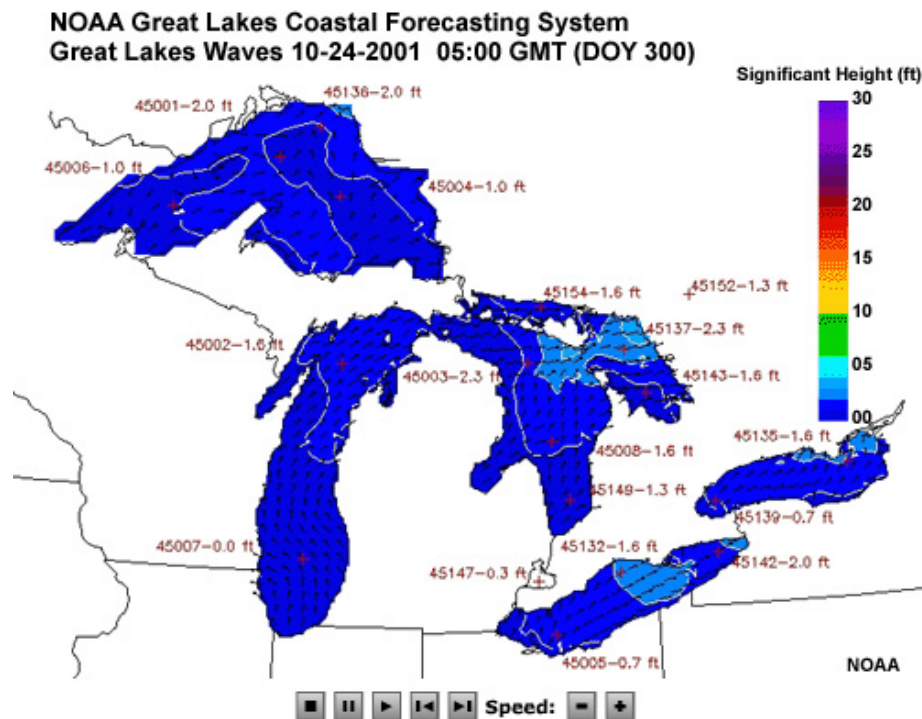
(media/flash/swan_eur.swf)

Similar to the evolution of atmospheric numerical modeling, marine models are also improving, with higher resolutions and various parameterization schemes used to forecast a variety of coastal and nearshore fields. Since 2000, the NWS Eureka, CA forecast office has been running a version of the Simulating Waves Nearshore (SWAN) model for the nearshore environment.

The SWAN model contains the physics associated with waves in shallow water and can account for the energy, wave breaking, and refraction (wave bending) as waves travel through the nearshore zone. The SWAN model is therefore used to propagate the deep-water wave field from the NWW3 through the shallow water of the nearshore zone and to the coastline. Other coastal forecast offices are also running the SWAN model locally on a workstation. Plans for a high resolution workstation version of NWW3 are also being made.

In addition, the wind wave height and period from the SWAN model are more accurate and detailed than those developed by human forecasts using sparse point data such as buoys. Of course, if the forecast winds used in the model are inaccurate, the SWAN model will surely be in error. Therefore, gridded wind fields that have been edited by forecasters are preferred for input, and this practice has already started at the Eureka WFO. Similarly, gridded winds prepared by forecasters are also being used in the Great Lakes forecast offices, where a local workstation runs a different shallow-water wave model.

Analyzing Swell: Wave Model Data » Regional Wave Models
GLCFS Model



[Click to view the animation.](#) (media/flash/lwv_ncast.swf)

(media/flash/lwv_ncast.swf)

The NOAA Great Lakes Environmental Research Laboratory (GLERL) has developed a system of numerical prediction models that collectively simulate and predict the currents, temperatures, water level fluctuations, wind waves, and sediments in the Great Lakes. This is known as the Great Lakes Coastal Forecasting System (GLCFS, <http://www.glerl.noaa.gov/res/glcfs/> (<http://www.glerl.noaa.gov/res/glcfs/>)). A workstation version of the GLCFS wave model is run locally at Great Lakes region WFOs to produce a wind wave field.

This wave model uses parameters modified by the forecaster with the Graphical Forecast Editor (GFE) including an edited, gridded wind field instead of the atmospheric model output of forecasted winds. Temperature forecast grids of 2-meter air temperature and the lake surface temperatures are input to calculate near-surface stability. In the Great Lakes and other inland bodies of water, instability effects can be more important than pressure gradient forces in determining wind speed since water temperature variations can exceed those found over oceans. If the air is colder than the water, heat and moisture fluxes from water to air will destabilize the layer of air just above the lake surface. The instability lends itself to convective motions and hence turbulent mixing of stronger winds in the marine boundary layer to the water surface.

After the various initial and forecast grids have been saved in the GFE, the GLCFS wave model can be run to produce forecasted wave height, period, and direction. Because swell in the Great Lakes are generally short-lived, this wave model only computes wind waves. The buoy data and other marine observations should be used to monitor for any discrepancies so that adjustments can be made and

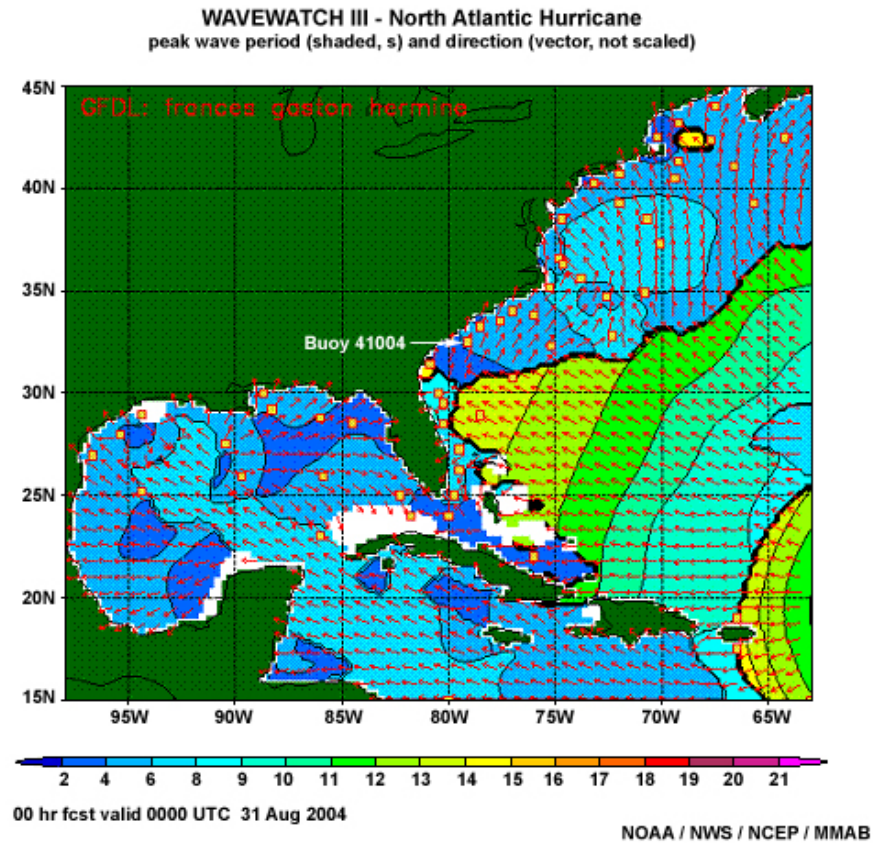
the model re-run as needed, which takes only a few minutes.

For more information about rip currents in the Great Lakes, check out these links to two case studies written by Dave Guenther at the forecast office in Marquette, MI (you will need [Adobe \(http://get.adobe.com/reader\)](http://get.adobe.com/reader)[®] Reader (<http://get.adobe.com/reader>)[®] to view the papers):

[Rip Current Case Study 1: 10 July 2002 \(Case Study_071002.pdf\)](#)

[Rip Current Case Study 2: 04 July 2003 \(Case Study_070403.pdf\)](#)

Analyzing Swell: Wave Model Data
Wave Masking Exercise 1

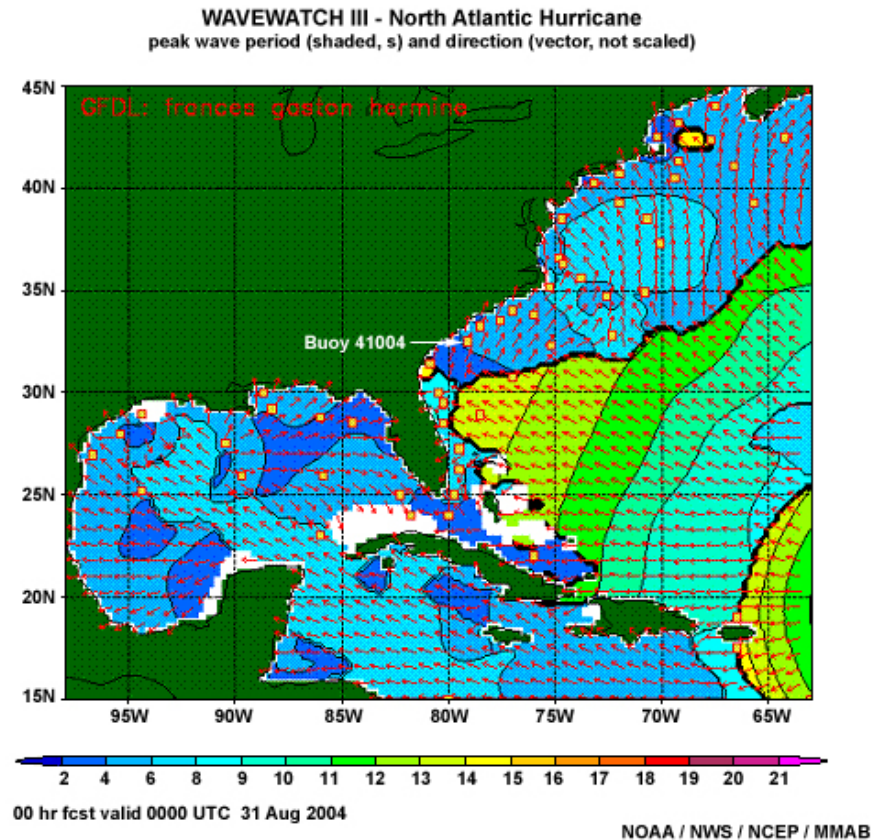


During the evening of 30 August 2004, you are tasked with issuing the Surf Zone Forecast for the Charleston, SC beaches (close to buoy 41004) valid for the next day. A main concern for this forecast is the swell expected from Hurricane Frances, which is presently located just north of the Lesser Antilles. In addition, there is a persistent southwesterly wind across Charleston's adjacent Atlantic waters due to a synoptic high pressure area in the Western Atlantic.

Analyzing Swell: Wave Model Data » Wave Masking Exercise 1

Question 1

This graphic is the 2-D plot of peak wave period and direction for the NWW3 North Atlantic Hurricane wave model 00 hour forecast valid for 0000 UTC on 31 August 2004.



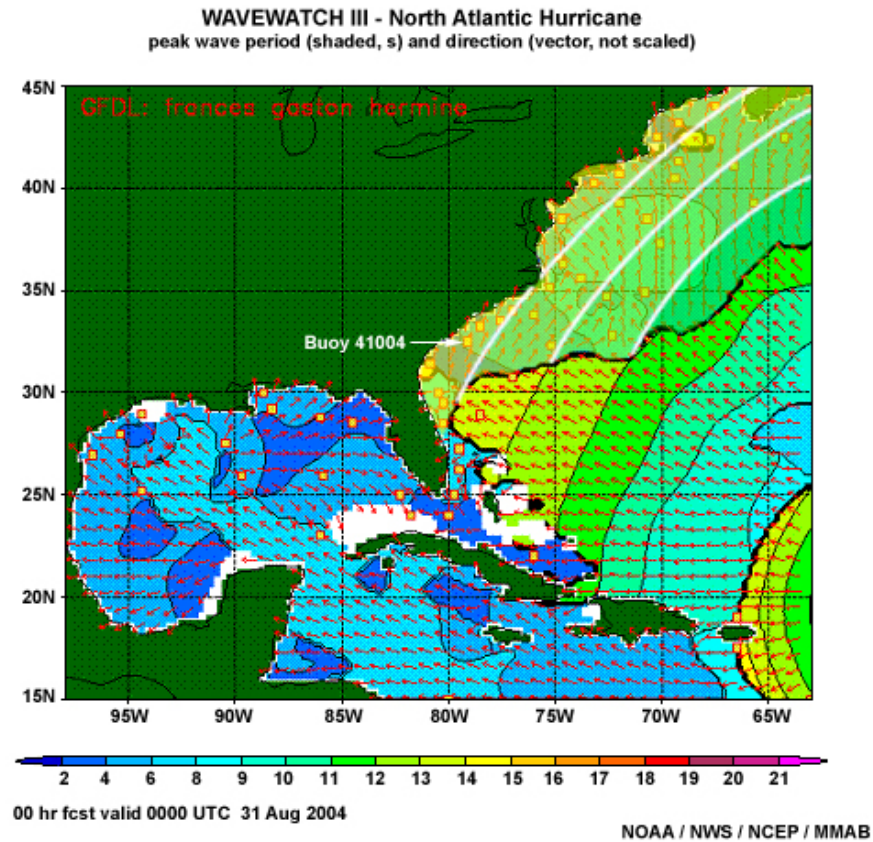
[Yes/No] Assume that the model initialized well. Using this 00 hour model forecast 2-D product, would you use a swell period of 4 s and a direction from the southwest when calculating the rip current risk at a beach near buoy 41004 for the valid time given on the product? This might be something you would do to verify that the rip current risk presently in the public Surf Zone Forecast product is appropriate or to determine that the forecast needs to be amended.

- a) Yes
- b) No

Done

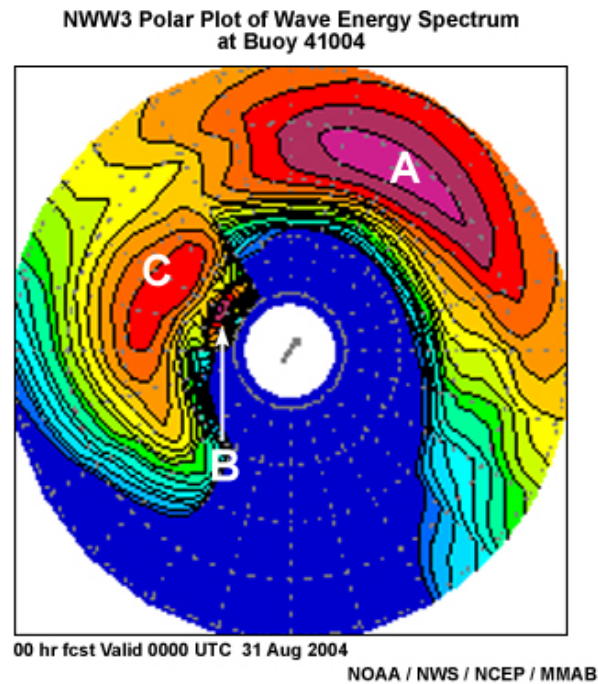
The correct answer is No.

The 2-D plot does indicate 4 s waves from the southwest near the buoy, but the short period indicates that these are wind waves, not swell. Also, there is a hint in the plot that 14 s swell from the south-southeast might already be at the buoy, and that those long-period swells are being masked by the more energetic 4 s wind waves from the southwest. The clues are the small areas of yellow corresponding to 14 s swell near the Georgia coast and offshore of Massachusetts (circles) in addition to the more obvious random discontinuity line between the swell group and the low period waves that exist off the East Coast. If we were to draw the masked swell contours, it might look something like this modified graphic.



Analyzing Swell: Wave Model Data » Wave Masking Exercise 1

Question 2



To confirm whether wave masking is occurring, or to see if other model swell groups are passing by this point, let's look at the model's polar plot of wave energy spectrum for the buoy location.

Which statement most correctly describes the points labeled on the model's polar plot?
(Choose the best answer.)

- a) A and C are wind waves; B is anomalous noise.
- b) A is wind waves; B and C denote swell from the hurricane.
- c) A is swell from the hurricane; B and C denote wind waves associated with the southwesterly wind.
- d) A is wind waves; C is swell from the southeast but not associated with the hurricane; B is swell from the hurricane.

Done

The correct answer is d.

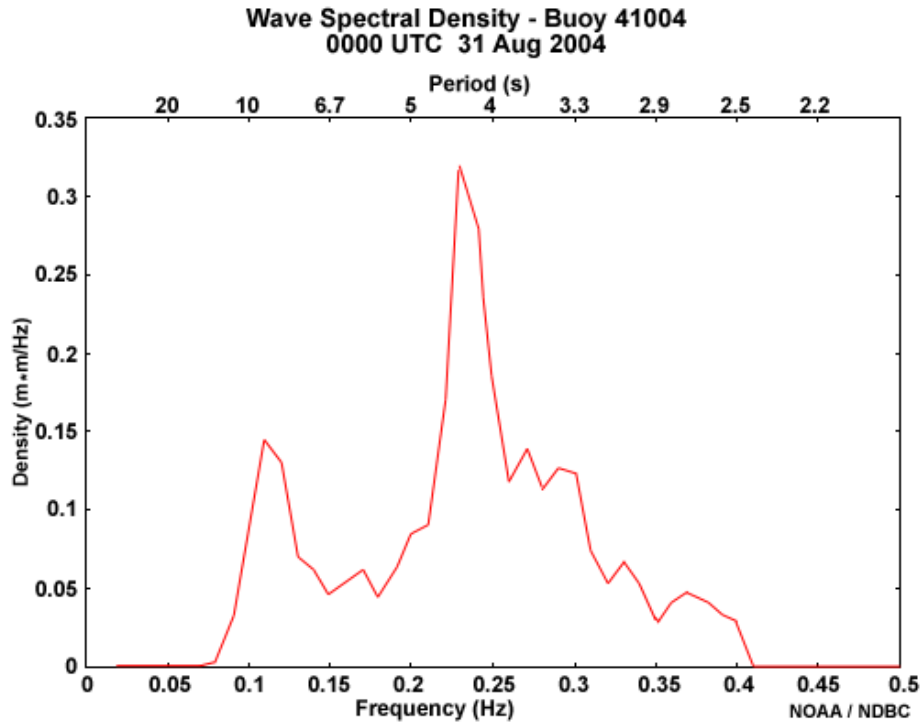
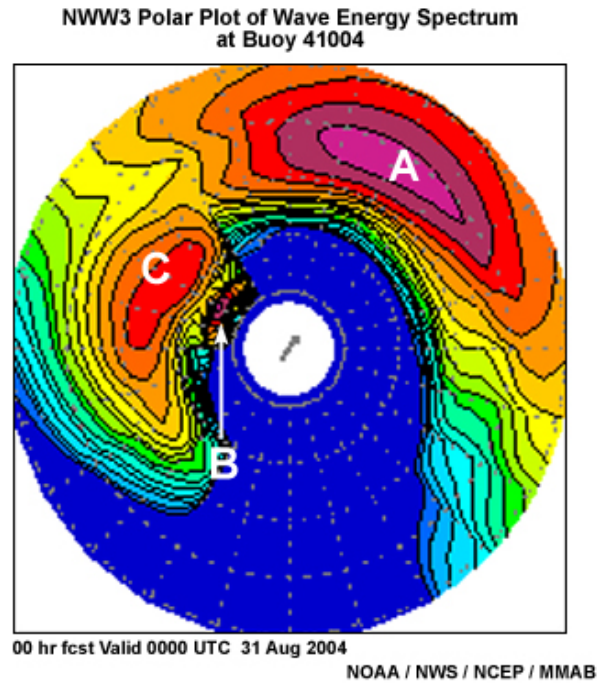
Point A refers to the 5 s waves generated by the southwest winds. These are the most energetic waves in the spectrum, and consequently dominate the 2-D plot at

buoy 41004, masking the other two wave groups indicated in the polar plot. Points B and C have the longer periods typical of swell. These cannot both be from the hurricane because long-period swell travels faster than short-period swell and over time, the range of periods within a swell group will become stratified with longer ahead of shorter. It would be logical to assume that the 20 s swell is associated with the hurricane, while the 10 s swell is from another source, probably the easterly trade winds typical here in the summer.

In summary, the 2-D plot hinted at wave masking hiding swell with periods around 14–15 s at the buoy, which is essentially confirmed by this polar spectral plot. In addition, this spectral plot indicates that the dominant wind waves are also masking a 10 s swell. In order to determine which swell period to use in a rip current forecast (since both of them are in a direction that would likely impact Charleston beaches), the question now becomes, "Is the model right—has the swell from Hurricane Frances already reached buoy 41004?"

Analyzing Swell: Wave Model Data » Wave Masking Exercise 1

Question 3



The online NDBC Detailed Wave Summary (not shown here) for buoy 41004 reported a wind wave height of about 3 ft with a 4 s period and a swell of 2 ft at 10 s. Since the buoy does not have a direction sensor, one must use the NWW3 model products to determine the direction of movement of each of these groups. The polar spectral energy plot shows the wind wave moving toward the northeast and the 10 s swell moving toward the west-northwest. But what about the other swell group?

Let's look at the buoy spectral density graph to see how many wave groups are passing by this observation point.

[Yes/No] Does the spectral graph show that the 14+ s swell from Hurricane Frances has reached buoy 41004?

a) Yes

b) No

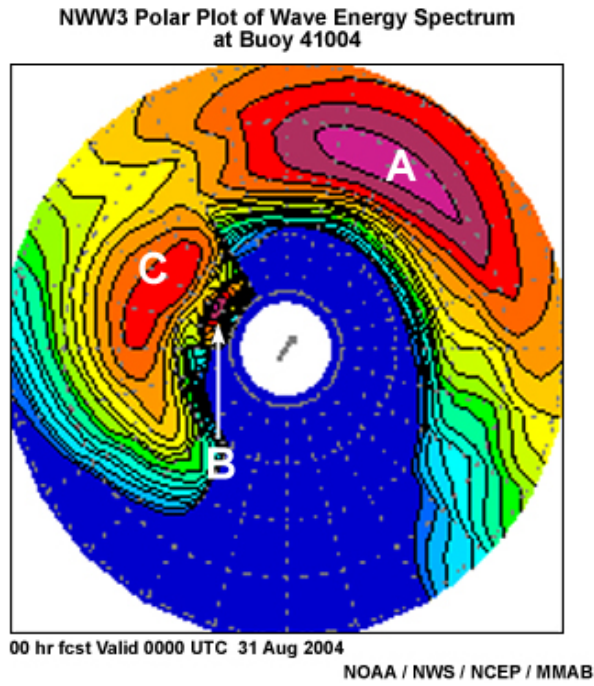
Done

The correct answer is No.

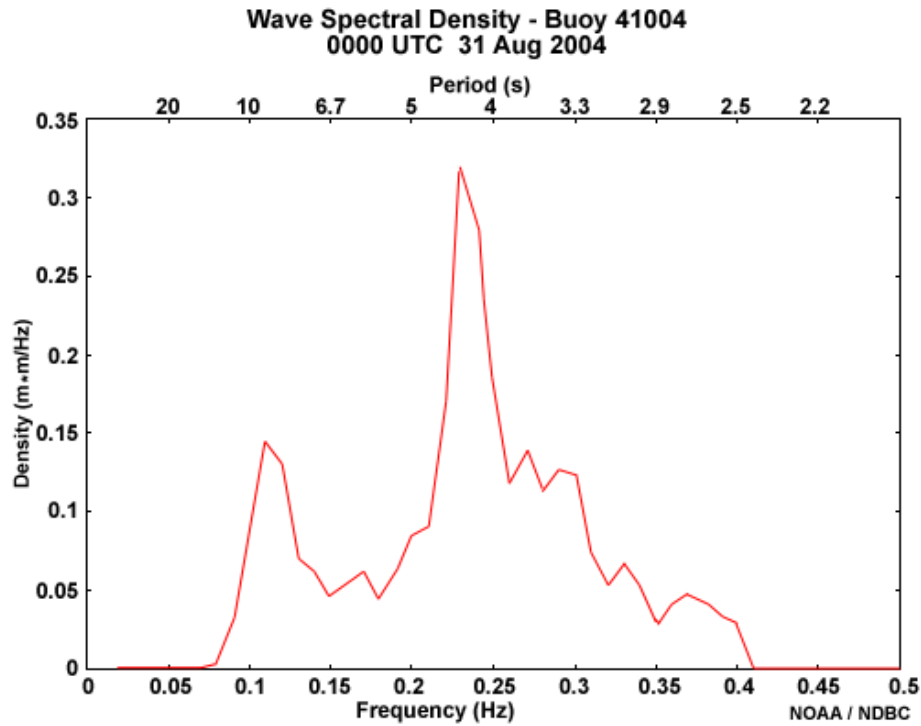
Recall that you take the inverse of frequency to get period. The 0000 UTC spectral graph confirms that the 4 s wind waves are dominant and that the 10 s swell is the only other energetic wave group passing by this point. No long-period swell of 14 s (or higher) is presently being observed by the buoy.

Analyzing Swell: Wave Model Data » Wave Masking Exercise 1

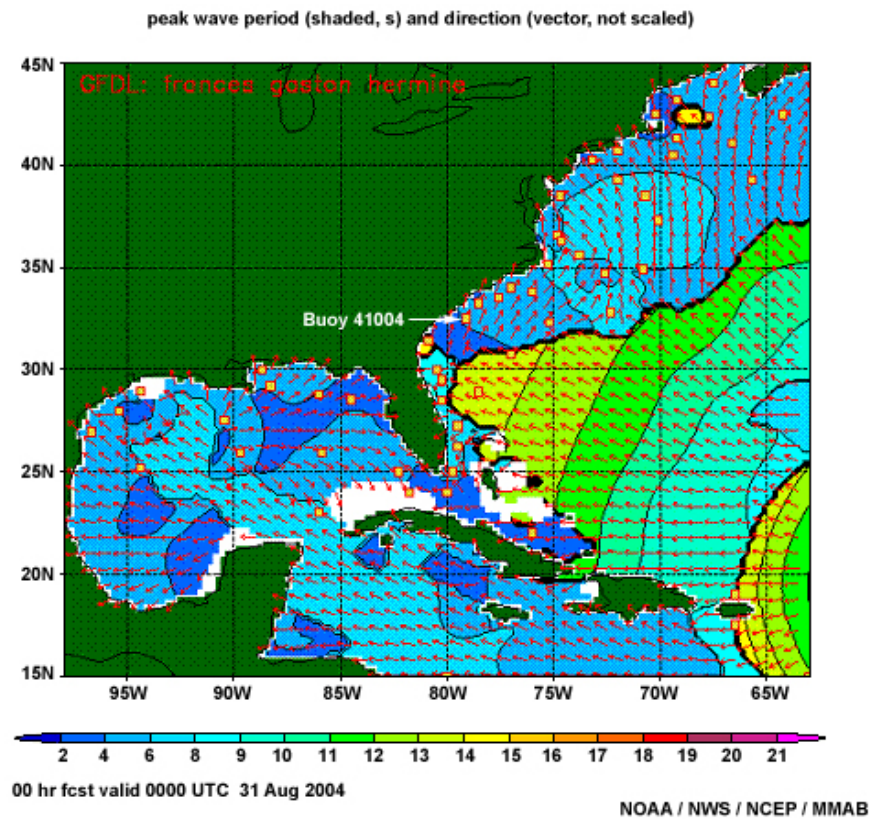
Question 4



(valid at 0000 UTC 31 August 2004 at buoy location 41004)



WAVEWATCH III - North Atlantic Hurricane



[Yes/No] Does the NWW3 NAH model seem to have initialized well compared to what Buoy 41004 observed at 0000 UTC?

a) Yes

b) No

Done

The correct answer is No.

Although the NWW3 NAH has captured the 4 s wind waves and the 10 s swell seen in the buoy spectral density graph, it has a third wave group at 14+ s that is not presently being observed by the buoy. In addition, this erroneous 14+ s swell group has more spectral power than the 10 s swell group. This allows the 14+ s swell to appear on the 2-D plot of peak period instead of the 10 s swell in areas where both are more dominant than the wind wave group.

The model may be in error for a couple of reasons. The first possibility is that the model has propagated the hurricane swell past this point too soon, and that the buoy will observe 14+ s swell at some later time. The second possibility is that the model winds associated with the hurricane were too strong and, therefore, generated swell with periods that are longer than what will actually be observed. Since the model seems to be accurately reflecting

the 4 s and 10 s wave groups observed at the buoy, the first possibility is the most likely. Determining why the error is occurring in the model will help with how to adjust the swell characteristics for the rip current worksheet to be used in the Surf Zone Forecast product for the following day. To do that, you will probably need to re-examine the model wind forecast and compare it to some additional over-water wind observations (i.e., buoy, scatterometry) in order to see where the wave forcing was in error. Then, using a wave nomogram or your past experience, determine how fast and how strong the swell will likely be.

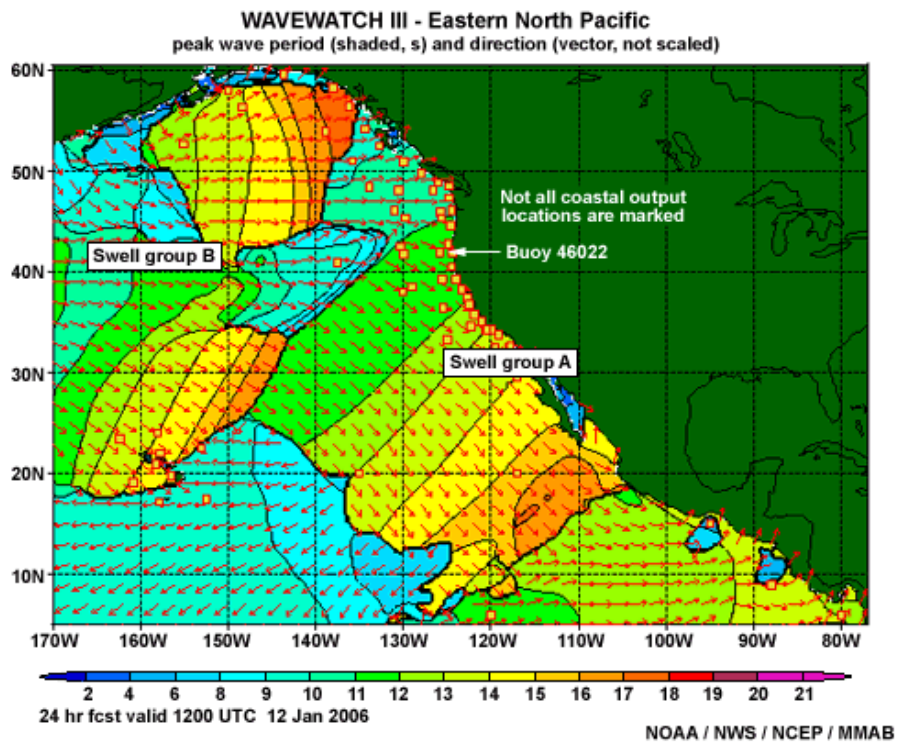
Analyzing Swell: Wave Model Data » Wave Masking Exercise 1

Summary

With respect to many of the various rip current forecast schemes, it is important to identify the main swell contributing to the scheme. As a rule, the standard 2-D plots are helpful in showing the progression of swell fronts. However, the wave period fields can be harder to partition when there are several swell components present in addition to the wind wave field. Thus, when there are multiple wave groups, it is important to review the detailed information in the buoy observations, spectral polar plots, and model text bulletin output.

In this case, it is likely that the NAH was too fast with introducing 14+ s swell, which would have led to a high risk rip current hazard forecast that day when, in fact, there were no strong rip currents reported in the Carolinas until 2 September, when the larger swell from Hurricane Frances finally did arrive.

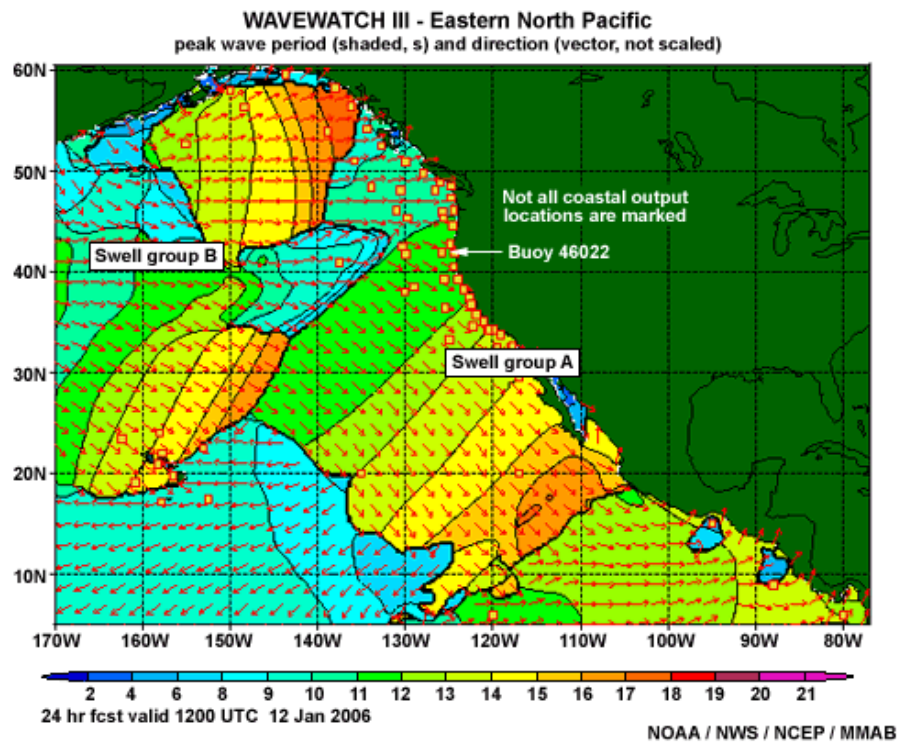
Analyzing Swell: Wave Model Data Wave Masking Exercise 2



This next case is not specifically relevant to rip current forecasts because of the season in which it occurs, but it provides more practice in using buoy and model data. This should be helpful in preparing Surf Zone Forecasts throughout the year and rip current forecasts seasonally when that hazard is more of an issue due to increased public beach usage.

Analyzing Swell: Wave Model Data » Wave Masking Exercise 2

Introduction



During the late afternoon of 11 January 2006, your shift duties include issuing the Surf Zone Forecast for the northern coast of California valid for the next day. Besides the large swell and high surf presently affecting the coast, you need to examine the potential for a new long-period swell generated by an Aleutian Low to move into your marine area the following day. For comparison to model forecasts, we will use observations from buoy 46022.

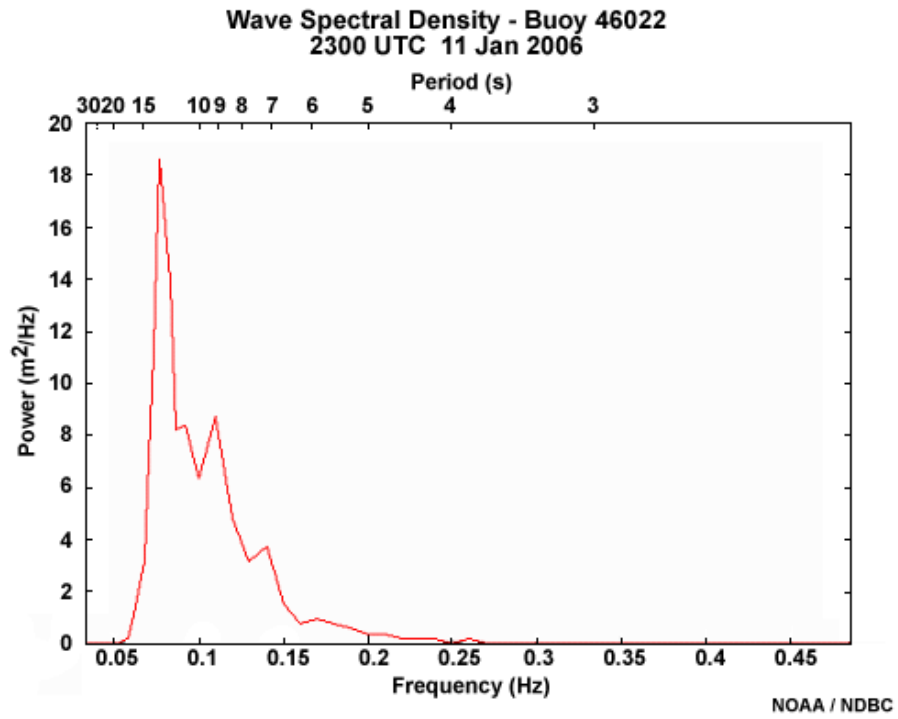
This graphic is the NWW3 Eastern North Pacific (ENP) 2-D plot of peak period and direction for the 24-hour forecast. The plot indicates two significant swell groups. The first swell group, labeled “A” in the plot, is an old swell group that was generated from the previous Aleutian storm several days earlier. The second swell group, labeled “B,” is a relatively new swell that has been generated by the next storm in the area of a synoptic Aleutian Low.

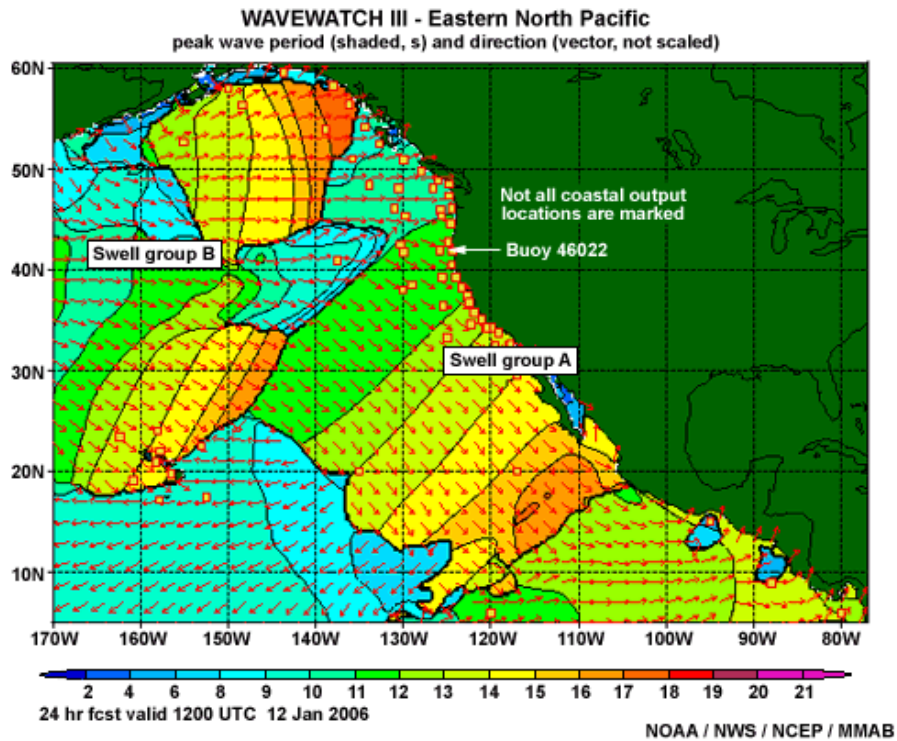
The NWW3 forecast plot indicates that buoy 46022 will be experiencing a period of 11 s in 24 hours. However, it appears to be very close to the end of one swell train (A) and the beginning of the next (B). So let’s see what the buoy is observing now.

The 2300 UTC (3 PM PST) 11 January 2006 observations from the online NDBC Detailed Wave Summary (not shown) indicate the wind wave has a height of about 1 ft with a period of 4 s and the most energetic swell is 11 ft at 13 s. Remember that the NDBC Detailed Wave Summary section only lists the observed wind wave group and the swell group with the most energy. Therefore, one still needs to check the observed wave spectrum graph for other swell groups passing by this point.

Analyzing Swell: Wave Model Data » Wave Masking Exercise 2

Question 1





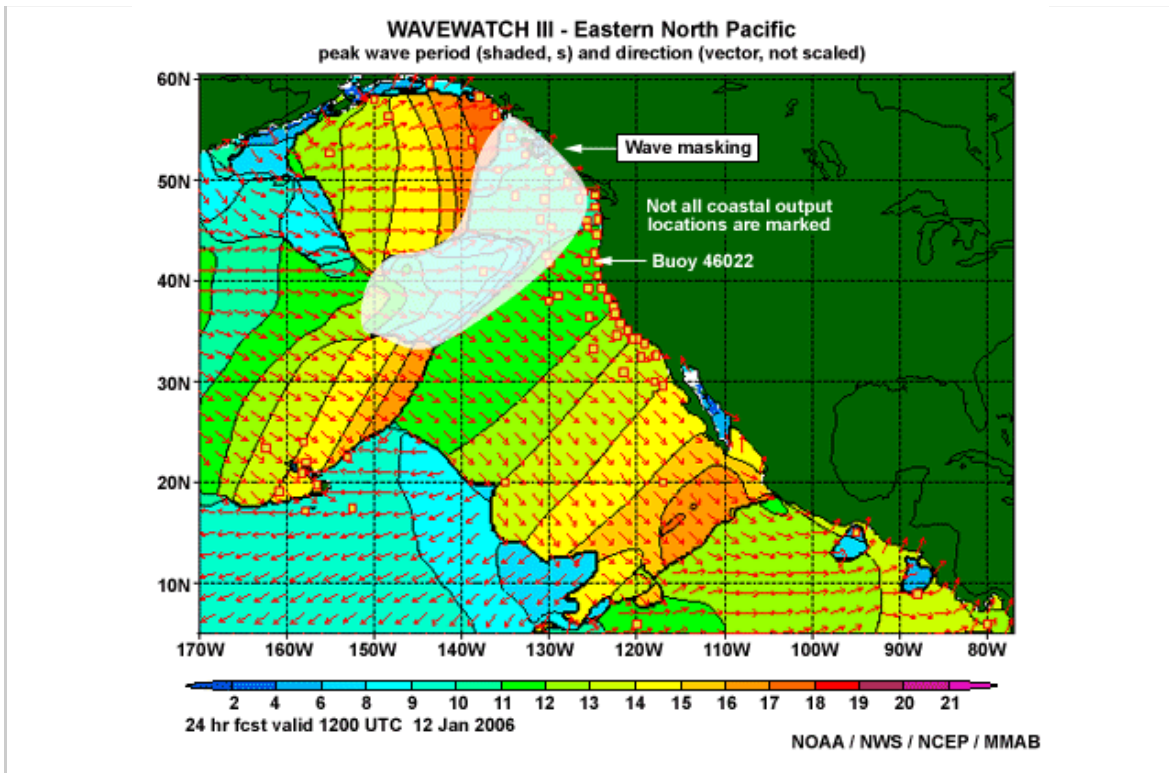
[Yes/No] From the spectral plot of buoy 46022 at 2300 UTC, is there any indication that swell group B has already arrived at the buoy and is being masked?

- a) Yes
- b) No

Done

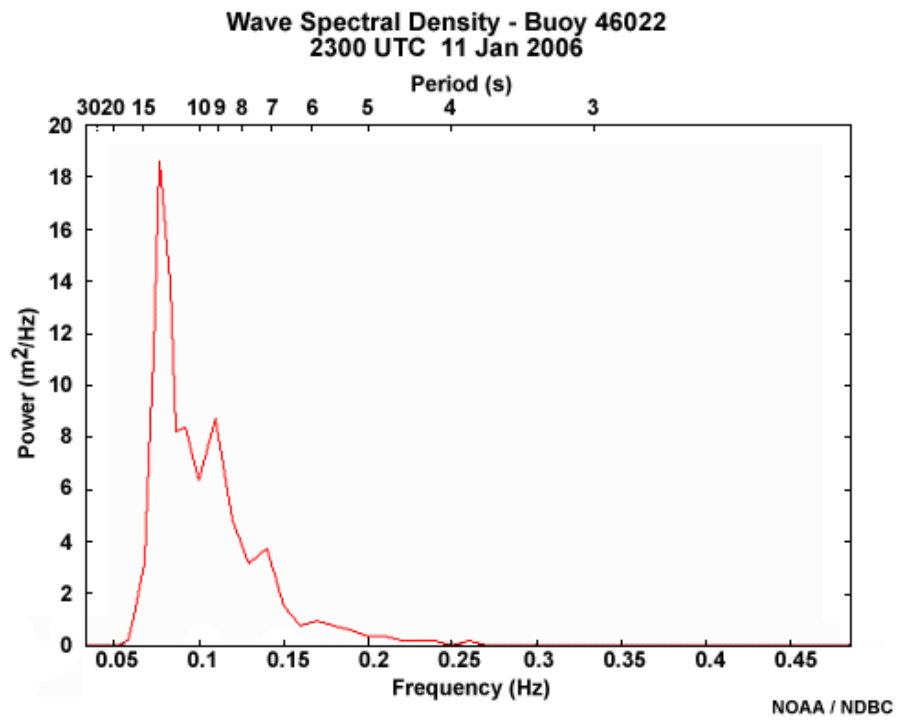
The correct answer is No.

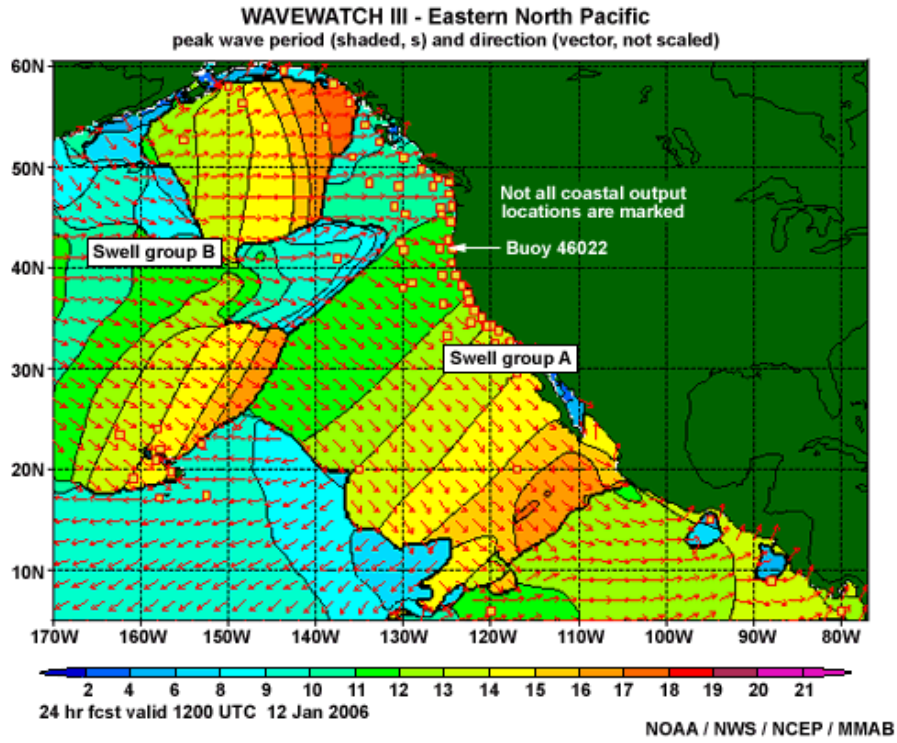
The spectral plot for the buoy shows that the 17 s group has not arrived at the buoy yet because the longest period swell in the spectrum graph is 13 s and is most likely associated with swell group A. However, the 17 s swell in the NWW3 2-D plot at the leading edge of group B is certainly being masked (along the rest of the swell front) by more energetic wind waves, as well as more energetic swell from the rear of swell group A (as indicated below in the 24-hour forecast).



Analyzing Swell: Wave Model Data » Wave Masking Exercise 2

Question 2





Location : 46022 (40.72N 124.52W)
 Model : Eastern North Pacific 0.25deg
 Cycle : 20060111 t12z

day &	Hst	n	x	Hs	Tp	dir	Hs	Tp	dir
hour	(m)	-	-	(m)	(s)	(d)	(m)	(s)	(d)
11 6	4.6	2		4.6	13.9	101			
11 7	4.5	3		4.5	13.7	102			
11 8	4.5	2		4.5	13.6	103			
11 9	4.4	3		4.4	13.5	103			
11 10	4.4	2		4.4	13.4	104			
11 11	4.3	2		4.3	13.4	104			
11 12	4.3	2		4.3	13.3	105			
11 13	4.2	2		4.2	13.3	105			
11 14	4.2	3		4.2	13.2	105			
11 15	4.1	3		4.1	13.2	105			
11 16	4.1	3		4.1	13.1	106			
11 17	4.0	3		4.0	13.0	106			
11 18	4.0	3		4.0	13.0	107			
11 19	3.9	4		3.9	12.9	107			
11 20	3.9	4		3.9	12.6	107			
11 21	3.8	4		3.8	12.4	107			
11 22	3.8	4		3.8	12.3	107			
11 23	3.7	4		3.7	12.2	107			
12 0	3.7	4		3.7	12.2	108			

NOAA / NWS / NCEP / MMAB

Another check of the model performance would be to look at the model bulletin output. This is the

NWW3 ENP model run for 1200 UTC on 11 January 2006 (starting 11 hours prior to the buoy observations at 2300 UTC) at the point collocated with the buoy.

[Yes/No] Does the bulletin's value of swell height (H_s) and period (T_p) compare well with the buoy data at 2300 UTC on 11 January 2006 which measured the wind wave height at about 11 ft, with a period of 4 s, and the most energetic swell at 11 ft at 13 s? (Remember, in this bulletin output from the NWW3 Web page; the wave height is in meters and the direction is "toward," not "from.")

a) Yes

b) No

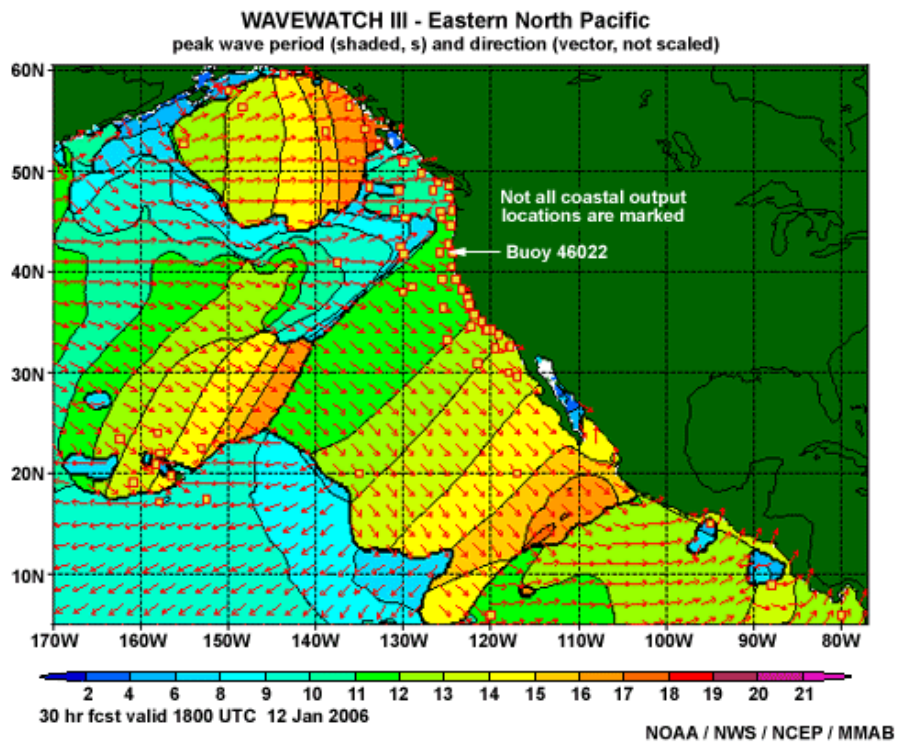
Done

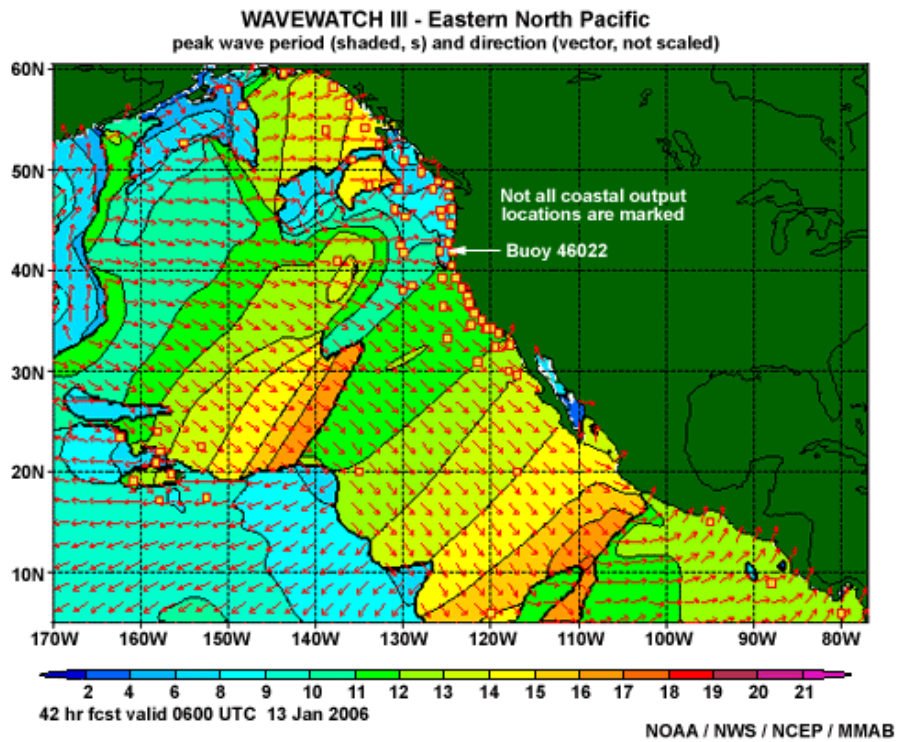
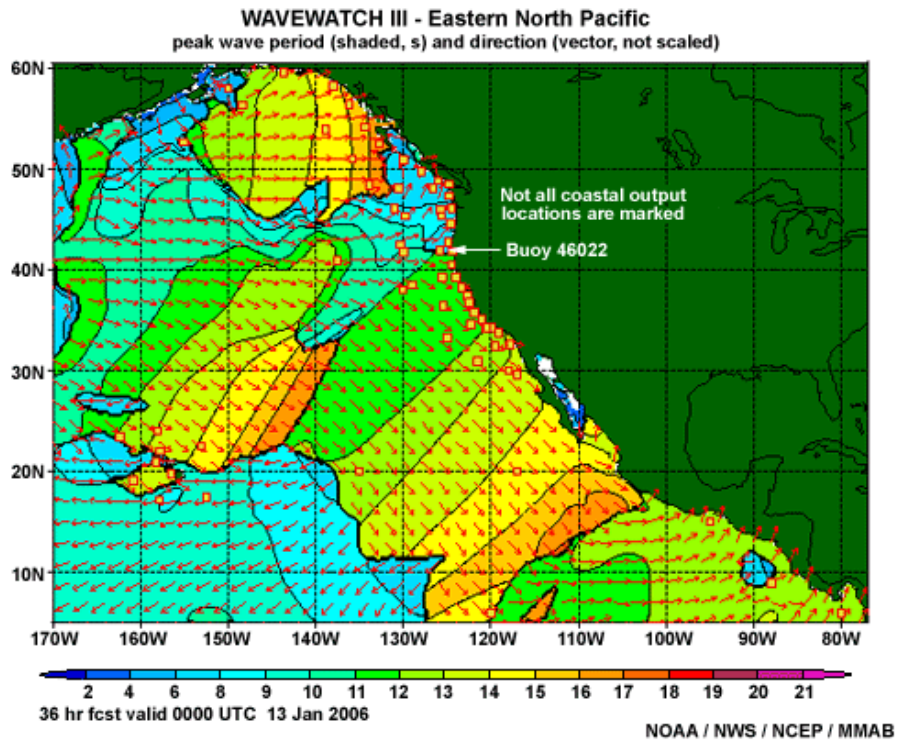
The correct answer is Yes.

The bulletin output for 2300 UTC is extremely close to the buoy observation for the dominant swell at this time. There is only a 1 ft and 1 s difference (11 ft vs. 3.7 m or 12.1 ft and 13 s vs. 12.2 s), which are fairly good given the magnitude of this swell.

So we can be reasonably confident that the model has a good handle on what is happening at buoy location 46022. The question then is when is the group B swell front going to arrive at the buoy?

Analyzing Swell: Wave Model Data » Wave Masking Exercise 2
Masking





As you can see in the 30-, 36-, and 42-hour forecast plots of peak period, the 17 s swell previously displayed is now totally masked, and it is difficult to estimate when the swell front will reach the buoy. Extending the swell front to include at least a 17 s component, one can infer that the swell

would arrive sometime around 0600 UTC on 13 January 2006. However, there is a large portion of swell front being masked due to the rear portion of swell group A having a larger wave energy in the same area.

The lesson here is that it is difficult to fine-tune your timing of the swell front if you only use the 2-D plots. Although these plots are useful for getting a quick overview of what is going on, the NWW3 text bulletin output will give you a much better feel for the model forecasts of height, period, and timing of the wave systems (assuming, of course, that the model has initialized well).

Analyzing Swell: Wave Model Data » Wave Masking Exercise 2

Here is a portion of the NWW3 text bulletin output for a point collocated with buoy 46022 from the 11 January 2006 ENP model run.

```

| 12 4 | 3.6 5 | 3.6 12.0 110 | | | | | |
| 12 5 | 3.6 5 | 3.6 11.9 110 | | | |
| 12 6 | 3.6 5 | 3.6 11.9 111 | | | |
| 12 7 | 3.6 5 | 3.6 11.8 111 | | | |
| 12 8 | 3.6 3 | 3.6 11.8 112 | | | |
| 12 9 | 3.6 3 | 3.6 11.8 113 | | | |
| 12 10 | 3.6 2 | 3.6 11.8 113 | | | |
| 12 11 | 3.6 3 | 3.6 11.8 114 | | | |
| 12 12 | 3.6 2 | 3.6 11.8 114 | | | |
| 12 13 | 3.6 3 | 3.6 11.7 114 | | | |
| 12 14 | 3.6 3 | 3.6 11.7 114 | | | |
| 12 15 | 3.6 3 | 3.6 11.7 114 | | | |
| 12 16 | 3.5 4 | 3.5 11.6 115 | * 0.7 3.8 20 | | | |
| 12 17 | 3.5 5 | 3.4 11.6 115 | 0.8 4.1 22 | | | |
| 12 18 | 3.4 5 | 3.3 11.5 115 | * 1.0 4.2 19 | | | |
| 12 19 | 3.3 5 | 3.1 11.5 114 | * 1.1 4.5 19 | 0.2 16.3 34 | | | |
| 12 20 | 3.2 5 | 3.0 11.4 114 | * 1.2 4.6 17 | 0.2 16.3 34 | 0.2 19.9 109 |
| 12 21 | 3.1 5 | 2.9 11.4 113 | * 1.2 4.6 15 | 0.2 16.3 34 | 0.2 19.9 108 |
| 12 22 | 3.0 6 | 2.8 11.4 113 | * 1.3 4.7 14 | 0.2 16.3 34 | 0.2 19.8 110 |
| 12 23 | 3.0 6 | 2.6 11.4 111 | * 1.3 4.7 13 | 0.2 16.3 36 | 0.2 19.8 109 |
| 13 0 | 2.9 6 | 2.4 11.4 115 | | 0.2 16.3 36 | 0.2 19.8 110 | 1.6 5.3 29 |
| 13 1 | 2.8 6 | 2.3 11.4 114 | | 0.2 16.3 36 | 0.3 19.6 109 | 1.7 5.5 27 |
| 13 2 | 2.8 7 | 2.2 11.4 114 | | 0.2 16.3 36 | 0.3 19.5 109 | 1.7 5.5 26 |

```

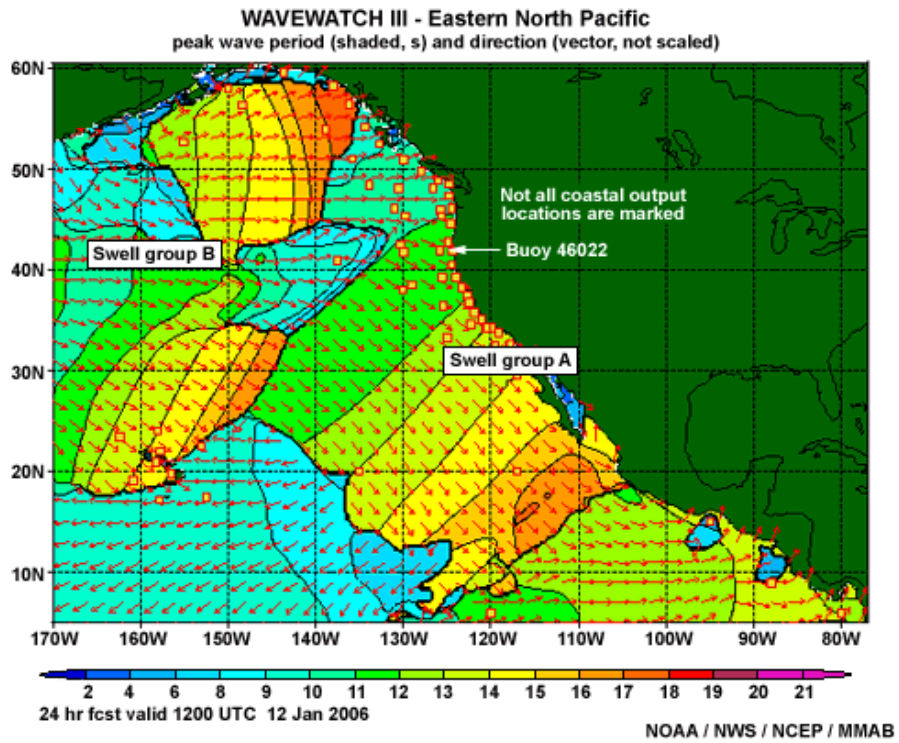
NOAA / NWS / NCEP / MMAB

At what time does the swell at the leading edge of group B (>17 s) show up in the ENP text bulletin output for this point? (Type your response in the box below.)

Done

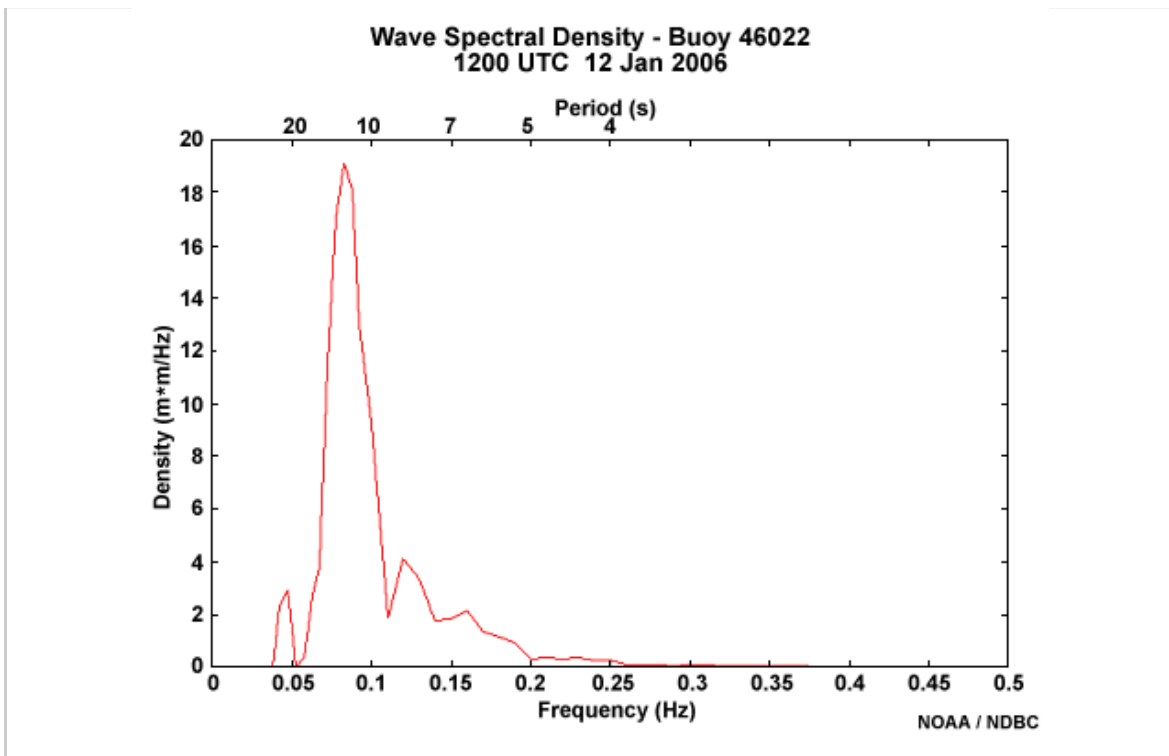
Feedback:

The edge of swell group B appears at 2000 UTC on 12 January 2006 and is expected to have a height of 0.2 m, a period of 19.9 s, and will be heading toward 109 degrees (or from the west-northwest). The text bulletin also has two other long-period groups. It shows a swell heading toward 110 degrees at 3.6 m and 12 s at the start of the data shown and passing by this point at all times, but this period is too short to be associated with swell group B. The other group is expected to begin passing the point at 1900 UTC and it has a period of 16.3 s. However, it is predicted to be moving toward the north-northeast, so it also is unrelated to group B.



Notice that the highest period swell shown in the 2-D plots was 17 s in the 24-hr forecast (which was showing evidence of masking), but the bulletin indicates a swell of 19.9 s. This means that there was considerably more masking occurring than was evident in the 2-D plots.

Below is the observed spectral plot for the buoy at 1200 UTC on 12 January 2006. You can see that the very long-period swell (about 20 s) has already arrived from the Aleutians. Thus the ENP was off in timing by at least 8 hours in this case.

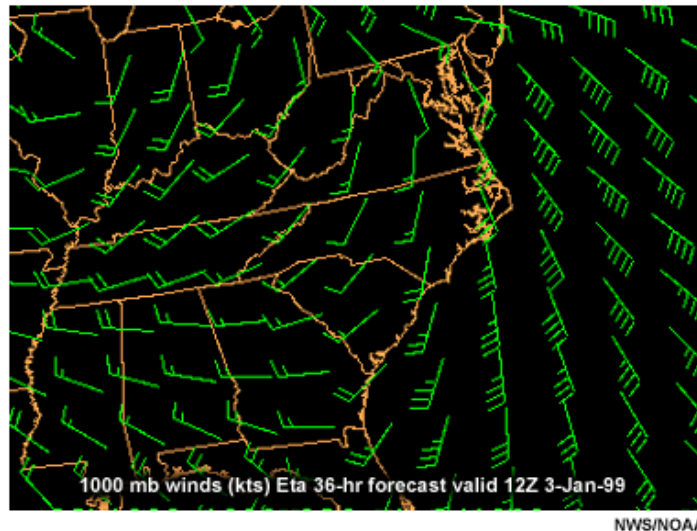


Analyzing Swell: Wave Model Data » Wave Masking Exercise 2

Summary

This case illustrates that although the model output can capture the magnitude and period of events very well, it is important to look closely at the potential for timing issues. To get a better understanding of the timing, forecasters should be looking at upstream buoys if available. If the model has moved a swell front through a particular buoy location at a specific time, then the buoy should have observed its passage at that time. If the buoy does not show its passage, then it can be assumed that the model is too fast with the swell front's progression or has developed swell that has a period that is too long. Likewise, if the wave model has not passed a swell front through at a specific buoy location and time, and the buoy shows that a passage had already occurred, then it is safe to assume that the model is either too slow or too weak. In either case, one needs to consider adjustments to the forecast. With respect to rip current forecast schemes, it is important to identify the swell with the largest energy in the spectrum whose direction of propagation could contribute to rip current development. As in the East Coast case, the wave period fields can be harder to partition when there is another, more dominant wave group present that is masking the swell that will contribute to rip current formation for a given location. Typically, this problem can be magnified along the West Coast, where there is a greater potential for numerous swell groups with long periods.

Analyzing Winds



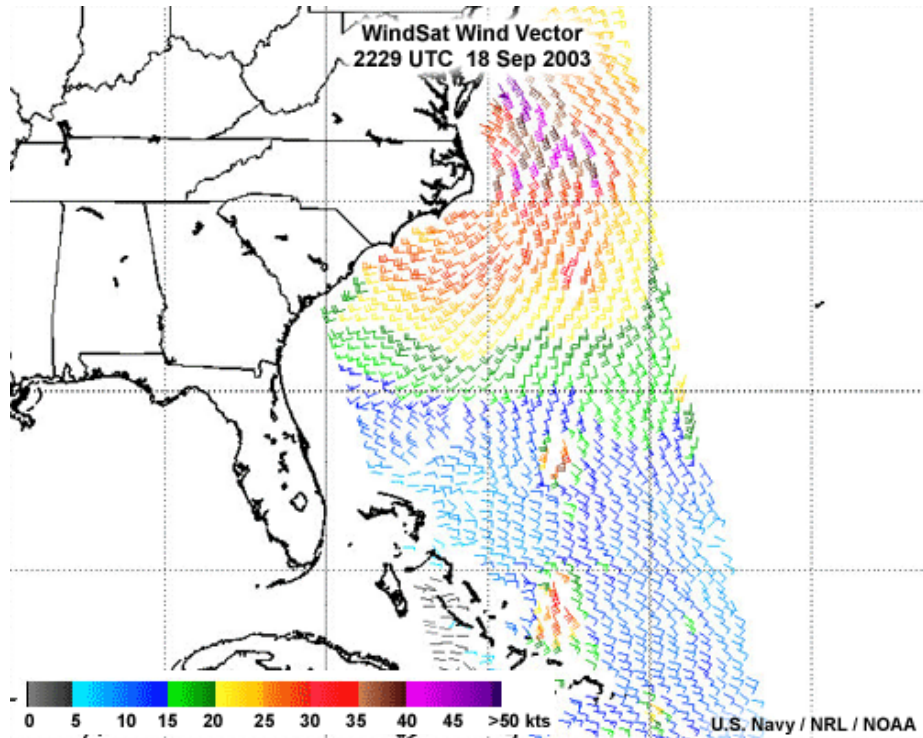
Most rip current forecast schemes address wind waves through a factor that takes into account the wind's direction, speed, and persistence. We will not address this topic in depth because you are already familiar with using observed and model-forecasted winds over land. As in those situations, you'll need to look at current and past conditions, decide how well the models have been initialized, and choose the model that is doing the best job with winds over the marine environment. You will also need to define for your local beaches the range of wind directions and speeds as well as the length of persistence that lead to favorable rip current development, keeping in mind nearshore bathymetry and shoreline structures.

If the flow is onshore or has been onshore, especially over a significant period of time, your concern about rip current potential should increase. Persistent onshore flow over a couple of days, given a sufficient fetch length, results in wind waves with breaking wave heights that are non-uniform. This increases the difference between areas of local high and low setup that lead to convergence of longshore currents and eventual rip currents. The time it takes to reach the favorable wave setup also depends partially on the magnitude of the wind speed over this persistent time period. Since wave height is directly related to the strength of the persistent onshore winds, a strong persistent wind over the same fetch, time period, and location will more quickly pile water against the beach than a weak persistent wind. Remember that Factor 2 on the example rip current [worksheet \(worksheet.pdf\)](#) accounts for this persistence, but it does not weight this factor based on the wind speed. The forecaster may need to subjectively adjust the "persistence factor" (i.e., Factor 2 of the Wilmington worksheet) based on the strength of the persistent wind even if the guidelines are not quite met.

Rip current risk often persists after a synoptic, onshore wind event has ended. At the beginning of a synoptic event, rip current channels form in the underwater sandbars. Near the end of the event, these channels persist and the rip current danger continues. This is largely due to residual wave energy that developed well offshore and has continued propagating toward the coast as swell. Also,

a small shift in wind direction near the end of a rip current event may cause an additional wave train that interacts with the initial wave group to form additional rip currents.

Analyzing Winds Data and Resources



One source of ocean wind data is the NWS' [Marine Modeling and Analysis Branch's Website](http://polar.ncep.noaa.gov/marine.meteorology/marine.winds/) (<http://polar.ncep.noaa.gov/marine.meteorology/marine.winds/>). This site provides graphics of wind observations from buoys and ships in the "Regional" section of the site.

To learn more about winds in the marine environment, see these COMET modules:

- Webcast by Dr. Michael Freilich on [Remote Sensing of Ocean Wind Speed and Direction: An Introduction to Scatterometry](http://www.meted.ucar.edu/npoess/scatterometry/index.htm) (<http://www.meted.ucar.edu/npoess/scatterometry/index.htm>) (<http://www.meted.ucar.edu/npoess/scatterometry>)
- [Advances in Microwave Remote Sensing: Ocean Wind Speed and Direction](http://www.meted.ucar.edu/npoess/ocean_winds/index.htm) (http://www.meted.ucar.edu/npoess/ocean_winds/index.htm) (http://www.meted.ucar.edu/npoess/ocean_winds/)
- [Winds in the Marine Boundary Layer](http://www.meted.ucar.edu/marine/mbi/index.htm) (<http://www.meted.ucar.edu/marine/mbi/index.htm>) (<http://www.meted.ucar.edu/marine/mbi/>)

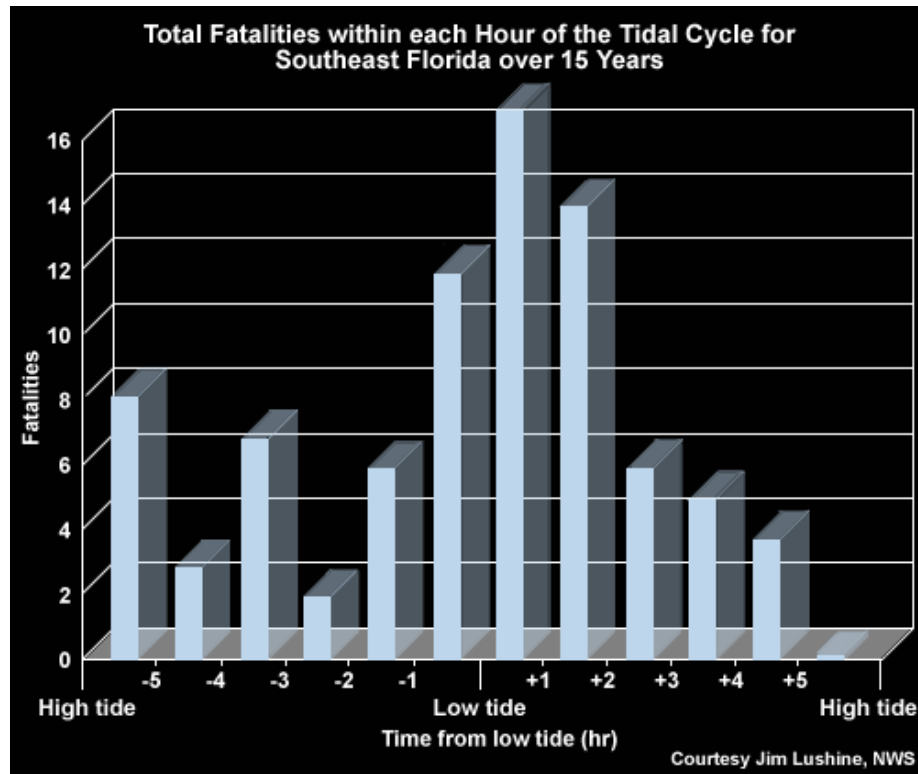
Other Factors

Up to this point our discussion has centered on using observations and model output to detect wave and swell groups and wind evolution. However, other factors should be considered when analyzing rip current potential, including the timing of the swell with respect to tides, the persistence of rip current conditions, and situational awareness.

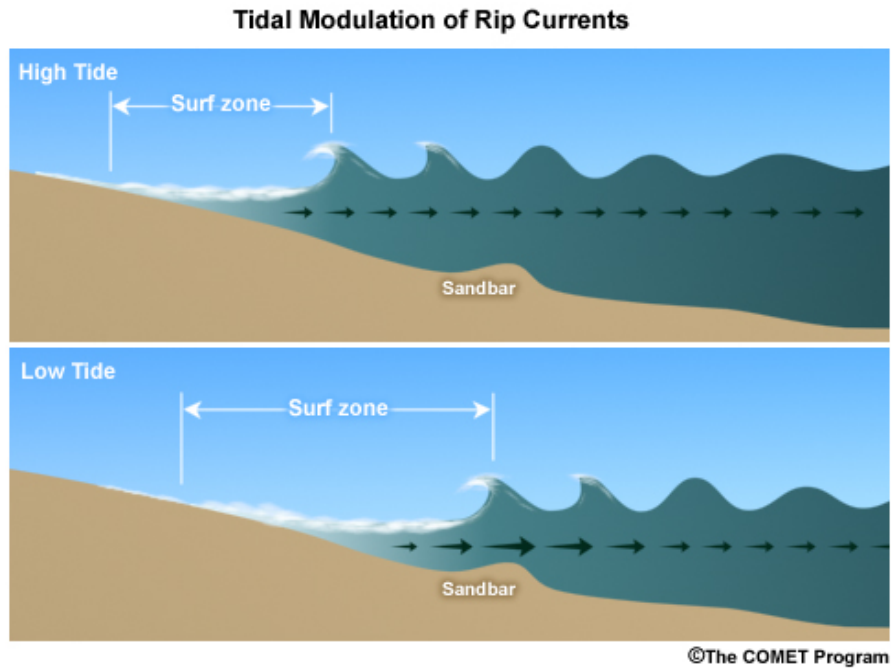


Other Factors

Tides



Most fatalities due to rip currents occur at low tide or in the two hours surrounding it. This is because rip currents along shorelines with sandbars are more likely to peak in velocity under certain combinations of water depth over the sandbar, wave height, period, and direction. The velocities can increase when those factors force more water to collect landward of the bar. Bar elevations on many beaches make this more likely to happen near low tide. Under optimum wave and water level conditions, return flow over the bar is restricted, which increases velocity in deeper rip current channels. At high tide, more return flow can occur over the bar, allowing less water to accumulate behind the bar and less flow in any channels across the bar.

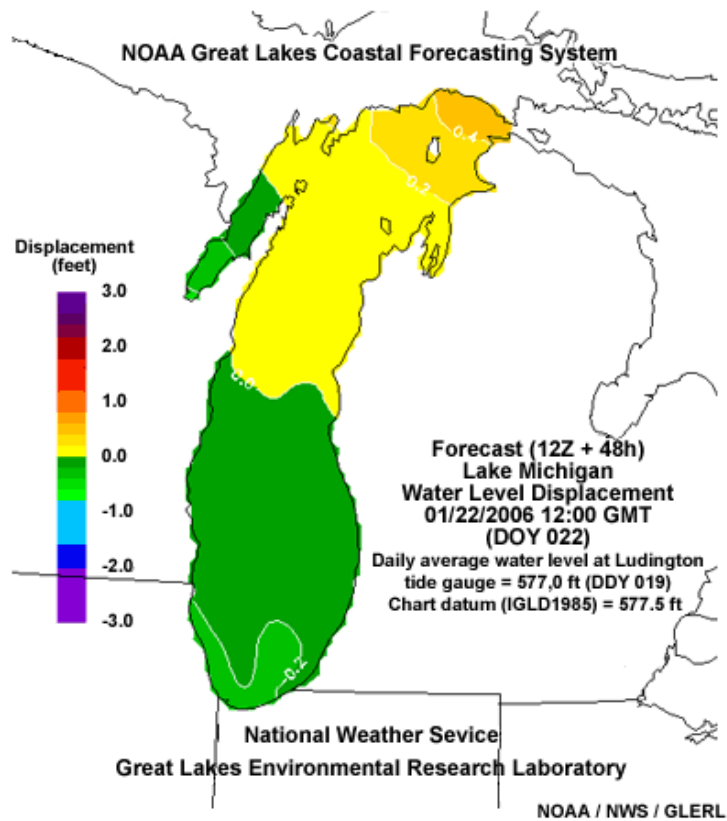


In addition to the physical differences in the nearshore environment produced by tides, there are other risk factors to consider. During low tide, beachgoers (especially weak or inexperienced swimmers) are able to move farther offshore. If caught in a rip current, they are less likely to be able to escape. Keep in mind that when a person is in a rip current, the seaward flow of water makes it difficult to stand, and it is harder to reach shallower water to regain footing due to the water's force.

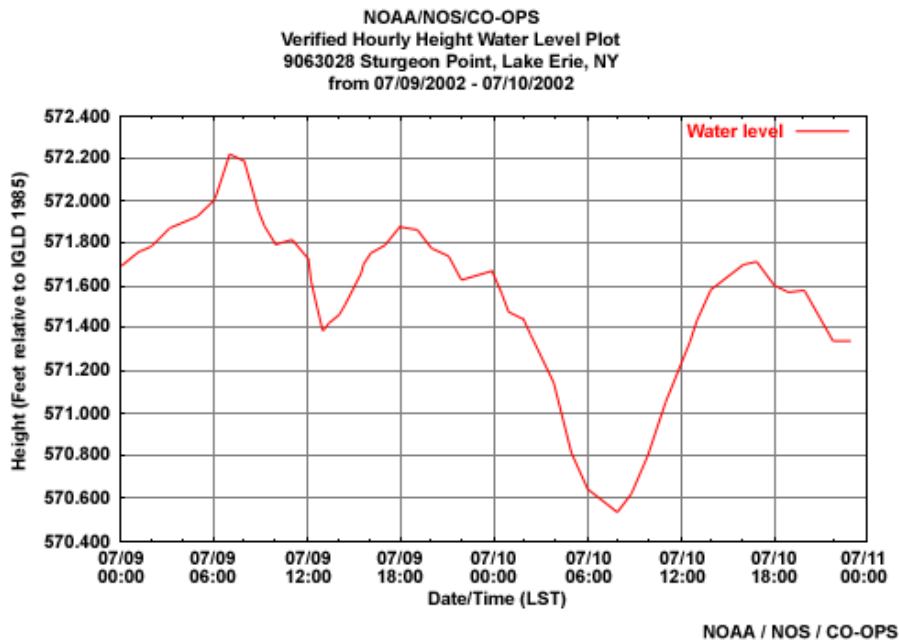
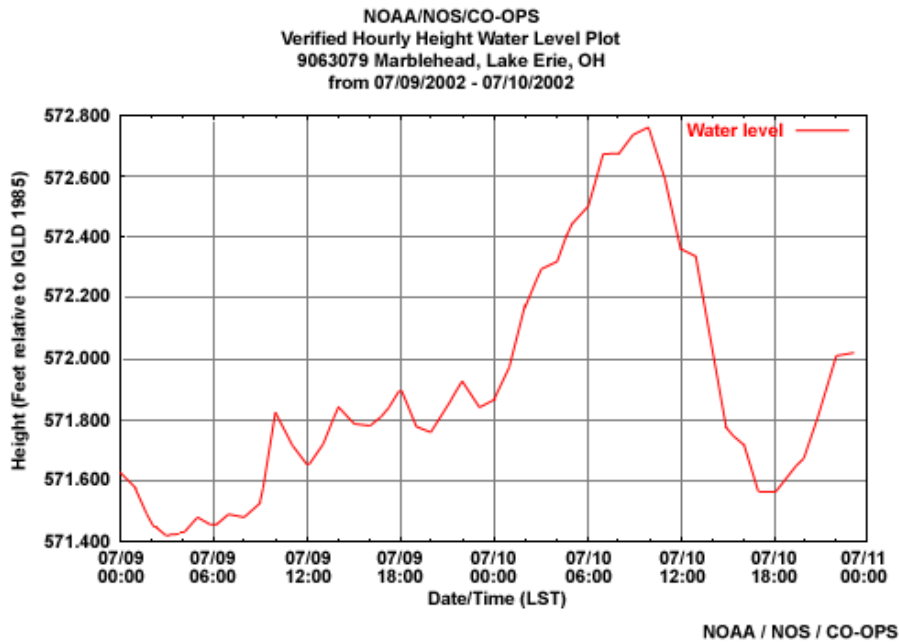
Although dangerous rip currents are more likely to occur around the time of low tide, variations in local conditions may make them dangerous at any tidal stage. Sandbars change relatively slowly, so if the rip currents were most dangerous at a specific stage of the tide on one day and the wave conditions persist, it is likely they will also be dangerous at the same tidal stage on the following day.

Other Factors

Lake Levels and Seiches



Fatalities occur more often when lake levels are lower than normal. Just as with low tide, when the water levels are low, the waves break farther offshore, increasing the surf zone width and decreasing the depth between the water surface and the sandbar. Unlike tides, low lake levels can continue through most of the year, producing an entire season of increased risk. Information on lake levels can be found at the Army Corps of Engineers' [Weekly Great Lakes Water Levels Website](http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/waterlevelforecasts/weeklygreatlakeswaterlevels/) (<http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/waterlevelforecasts/weeklygreatlakeswaterlevels/>) (<http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/waterlevelforecasts/weeklygreatlakeswaterlevels/>) of and GLERL's [Great Lakes Coastal Forecasting System \(GLCFS\) Website](http://www.glerl.noaa.gov/res/glcfs/) (<http://www.glerl.noaa.gov/res/glcfs/>) (<http://www.glerl.noaa.gov/res/glcfs/>), as in this graphic.



On the Great Lakes, seiches and changes in lake levels due to storms have an effect similar to ocean tides on enhancing the danger of rip currents. These two events produce the same type of slosh, but each event is generated differently. A lake seiche is caused by strong winds over an entire basin that pile up water and then release it, while a storm surge is usually caused by a large thunderstorm cell or squall line moving across the lake. Unlike lake levels and tides, Great Lakes storm surges and seiches last for minutes instead of days and can occur several times within a few hours. Changes in water levels can continue long after a squall line has passed, so forecasters need to be aware of this potential marine hazard during severe atmospheric conditions.

Other Factors

Situational Awareness



Forecasters should also be aware of situational issues in their area before making final forecast decisions. Beach Patrol attendance records show that more people come to the beach on weekends, holidays, and during periods of good weather and warm water. In these cases, a borderline moderate/high risk might be declared a high risk because the probability of rescues or fatalities due to rip currents is naturally higher when the number of potential victims is greater.

For example, the Wilmington WFO addresses this issue by adding 0.5 to their forecast scheme factor total when it is a nice weekend and the forecaster is on the fence in choosing between low and moderate risk or moderate and high risk.

Another situation in which you might increase the risk factor is when several rescues attributed to rip currents have already been reported or when lifeguards on duty at the beach have observed rip currents and communicated this to the forecast office.

Similarly, the time of day affects the number of rip current rescues, since the hours from noon to 4 PM are when more people go to the beach. While this doesn't affect the forecast process, it might impact your staff's situational awareness and collaboration with beach safety personnel, particularly at times of extreme low tides coupled with other favorable rip current factors. Also, you can provide information on when rip currents will be strongest in the body of a Coastal Hazard Message.

The examples of situational awareness presented here are analogous to WFOs providing timely and detailed short-fused products for severe weather in major metropolitan areas during rush hours when a maximum number of people will be affected.

Tips and Take-Aways

The following are tips from experienced rip current forecasters. You will need to evaluate whether they apply in your area.

- Fair weather doesn't mean the rip current risk is low. For example, tropical cyclones often produce swell groups that travel to shores where the storm itself does not have a direct impact. The hazard these long-period swells represent can be magnified by the fact that fair weather may exist at the time, encouraging a large number of people to go to the beach.
- In many cases the greatest threat is after wind waves have diminished. More people go into the water, but lingering long-period swell and dangerous rip currents can lead to multiple rescues and/or drownings.
- If rip currents occurred the previous day, you may want to forecast a moderate or high risk category even though winds have diminished or shifted to an offshore direction.
- If you have a high risk of rip currents one day when the weather is poor and a low risk the next day when the weather improves, you may want to keep a higher risk in the forecast unless you're very certain the risk is low or lifeguards tell you that no rip currents were observed. Beach activity often increases right after poor weather, which can put more people at risk.
- The wave height of long-period incoming swell will increase due to shoaling in shallow water. When the models or buoy observations show long-period swell offshore in deep water, especially with relatively large heights, the probability of rip currents increases.
- Forecasters will often encounter times when there are multiple swell groups present in the wave field. If the different groups have similar magnitudes, you should consider going with a moderate or high risk because phasing of the wave groups may create short periods of higher breaking wave heights in the surf. If there are two swell components and one is very weak, then you should consider only the stronger of the swell components.
- Confirmed rip current reports yesterday are one of the best indicators of rip current risk today, even if favorable wave conditions have weakened. Forecasters should consider issuing a moderate or high risk even when their forecast schemes indicate a low risk if numerous rip current rescues or fatalities were reported the day before (or possibly even two days before).
- If you're on the fence about the risk category, but you notice that there's a relatively large variation in tides or more than one swell of nearly equal power, you should choose the higher category.

Tips and Take-Aways

Take-Aways



Rip current forecasting in the NWS is in its infancy and will undoubtedly improve in the future. Some offices have given it a great deal of thought, while others are just beginning. Important points from this module depend partly on the location of your office and where you are in the process of developing a rip current forecast scheme. The quiz you take at the end of this module will reinforce the main objectives. However, a more valuable take-away from this module will be your own list of what you think is important and your thoughts on how forecasting in your office can be improved (or even begun).

So, in order to get the most from this module, we suggest that you take a few minutes to jot down things you might want to remember and to reflect on how you can apply what you've learned to improve rip current forecasting at your office.

Examples of things you could include in your list are:

- "To-do" reminders such as, "Contact the closest NOAA Sea Grant University" or "Look for local wave masking examples and develop training on them"
- Job aids such as the tips on the previous page
- The Wilmington [worksheet \(worksheet.pdf\)](#) to use as an example for creating your own (<http://meted.ucar.edu/marine/ripcurrents/forecasting/content/worksheet.pdf>)
- Additional training: COMET marine modules: (https://www.meted.ucar.edu/training_detail.php?page=1&topic=10) (https://www.meted.ucar.edu/training_detail.php?page=1&topic=10)
- Notes about URLs provided in the module that you want to visit:
 - NCEP Marine Modeling and Analysis Branch Operations Products Website (<http://polar.ncep.noaa.gov/mmab/oper.shtml>) (<http://polar.ncep.noaa.gov/mmab/oper.shtml>)
 - NWW3 primer (http://polar.ncep.noaa.gov/waves/pres/primer/primer_1.html) (http://polar.ncep.noaa.gov/waves/pres/primer/primer_1.html)
 - Links to the NWW3 interfaces (<http://polar.ncep.noaa.gov/waves>) (<http://polar.ncep.noaa.gov/waves>)
 - Ocean Wind Data on the NWS' Marine Modeling and Analysis Branch's Website (<http://polar.ncep.noaa.gov/marine.meteorology/marine.winds/>) (<http://polar.ncep.noaa.gov/marine.meteorology/marine.winds/>)

[/marine.meteorology/marine.winds/](#))

- o Great Lakes Coastal Forecasting System (GLCFS, <http://www.glerl.noaa.gov/res/glcfs/> (<http://www.glerl.noaa.gov/res/glcfs/>))
- o Army Corps of Engineers Weekly Great Lakes Water Levels (<http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/waterlevelforecasts/weeklygreatlakeswaterlevels/> (<http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/waterlevelforecasts/weeklygreatlakeswaterlevels/>))

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