UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CR 87-02	5. MONITORING ORGANIZATION REPORT NUMBER(S) CR 87-02
6a. NAME OF PERFORMING ORGANIZATION Science Applications International Corp. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Naval Environmental Prediction Research Facility
6c. ADDRESS (City, State, and ZIP Code) 205 Montecito Avenue Monterey, CA 93940	7b. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5006
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Commander, Naval Oceanography Command 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00228-84-D-3187
8c. ADDRESS (City, State, and ZIP Code) NSTL, MS 39529-5000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. DN656794

11. TITLE (Include Security Classification)

Severe Weather Guide - Mediterranean Ports - 2. Naples (U)

12. PERSONAL AUTHOR(S)

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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 9/13/84 TO 11/1/86	1988, January	78

16. SUPPLEMENTARY NOTATION

Funding source: O & M, N-1

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Storm haven; Mediterranean meteorology
04	02		Naples port; Mediterranean oceanography

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This handbook for the port of Naples, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Perryman, Dennis C., contract monitor	22b. TELEPHONE (Include Area Code) (408) 647-4709 / 22c. OFFICE SYMBOL O&M,N-1

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

AN (1) AD-A191 317
FG (2) 040200
CI (3) (U)
CA (5) SCIENCE APPLICATIONS INTERNATIONAL CORP MONTEREY CA
TI (6) Severe Weather Guide - Mediterranean Ports. 2. Naples.
TC (8) (U)
DN (9) Final rept. 13 Sep 84-1 Nov 86,
AU (10) Englebretson, Ronald E.
AU (10) Gilmore, Richard D.
RD (11) Jan 1988
PG (12) 86
CT (15) N02284-84-D-3187
RN (18) NEPRF-CR-87-02
RC (20) Unclassified report
NO (21) See also 1, AD-A191 316.
DE (23) *WEATHER, HANDBOOKS, HAZARDS, LIMITATIONS, OCEANOGRAPHIC DATA, THUNDERSTORMS, VISIBILITY, WIND, MEDITERRANEAN SEA, PORTS(FACILITIES), ITALY, ADVERSE CONDITIONS, HAZARDS, OCEAN WAVES, OCEAN CURRENTS, OCEAN TIDES.
DC (24) (U)
ID (25) Naples(Italy), *Severe weather, WUDN656794.
IC (26) (U)
AB (27) This handbook for the port of Naples, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.
AC (28) (U)
DL (33) 01
SE (34) F
CC (35) 417277

#

Naval Environmental Prediction Research Facility
Monterey, CA 93943-5006
Contractor Report CR 87-02 January 1988

SEVERE WEATHER GUIDE: MEDITERRANEAN PORTS

2. NAPLES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

Naples Harbor is protected from most high wind and waves of the open ocean (Figure 2-1). However, the harbor is fully exposed to the southwest. Wind and waves from that quadrant will cause problems for ships at anchor and for boating operations.

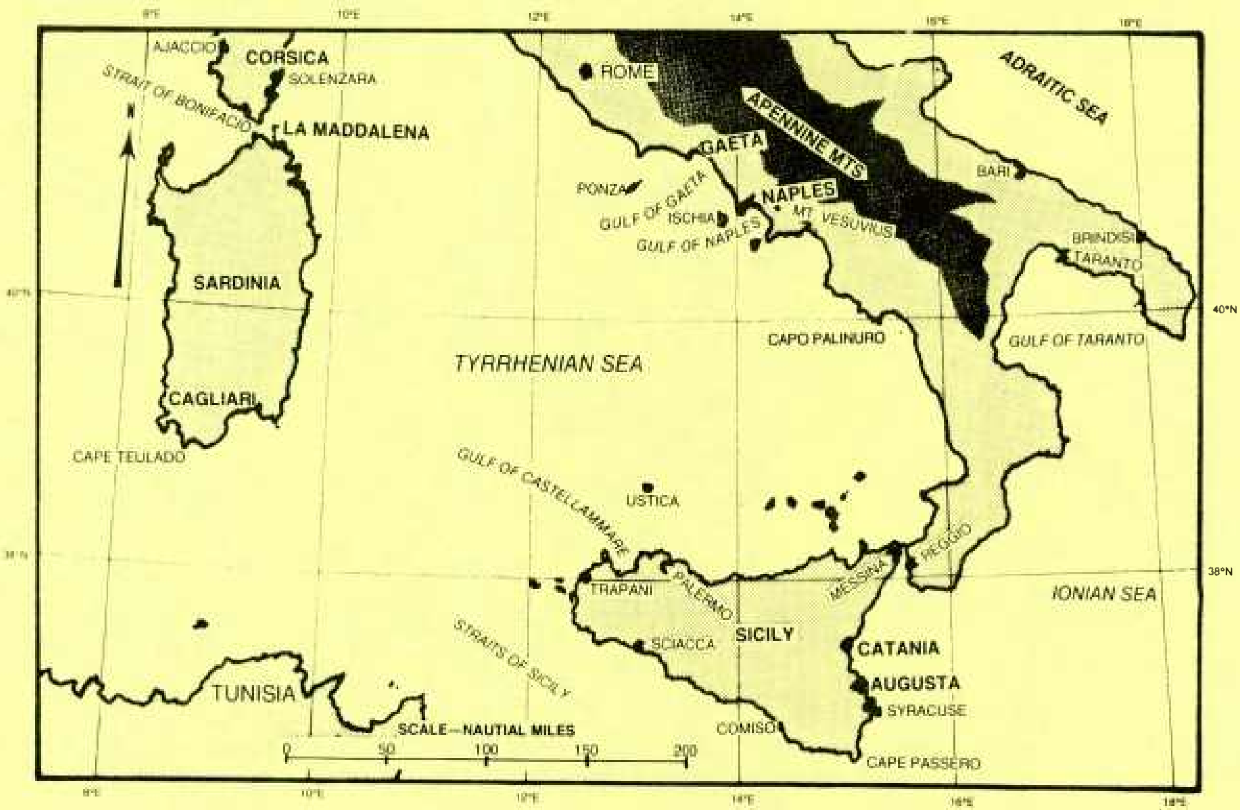

Figure 2-1. Ports of Italy, Sicily, and Sardinia.

All portions of the Gulf of Naples are well protected from northerly winds and waves. Relief from the troublesome southwesterly quadrant can generally be found in some of the bays or portions of the northern or southern part of the Gulf (Figure 2-2).

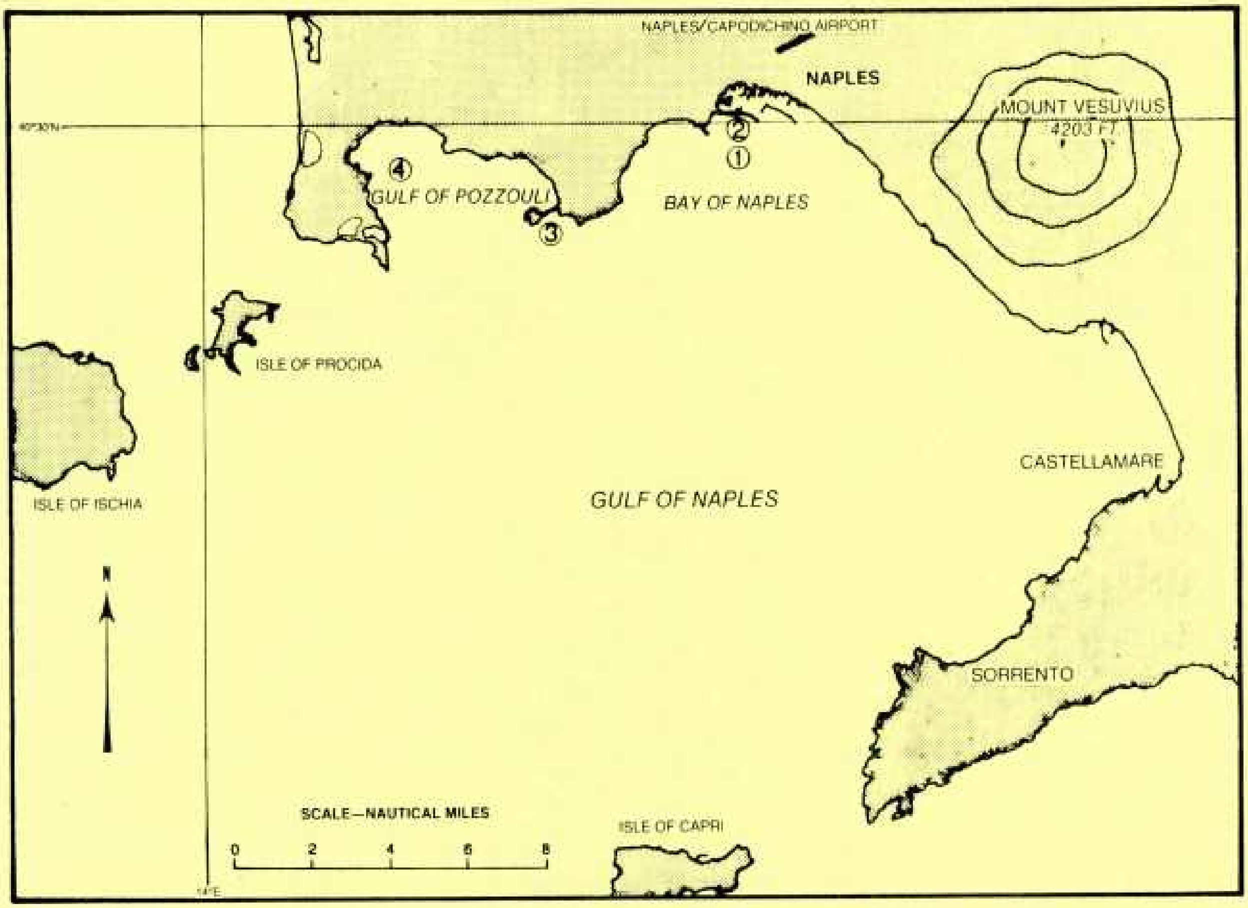

Figure 2-2. Gulf of Naples.

The harbor of Naples, including the anchorage area, is protected from northerly winds which may reach gale force along the coast. Because of fetch limitations, northeasterly winds over the harbor will seldom generate seas high enough to hamper boating conditions (Brody and Nestor, 1980). Moderate southwesterly winds, however, can generate high waves in Naples harbor. The inner harbor is generally protected by breakwaters. However, swell generated by southwesterly winds can enter into the west portion of the inner harbor making entry, berthing, and cargo handling unsafe (NWSED Naples, Italy,1970).

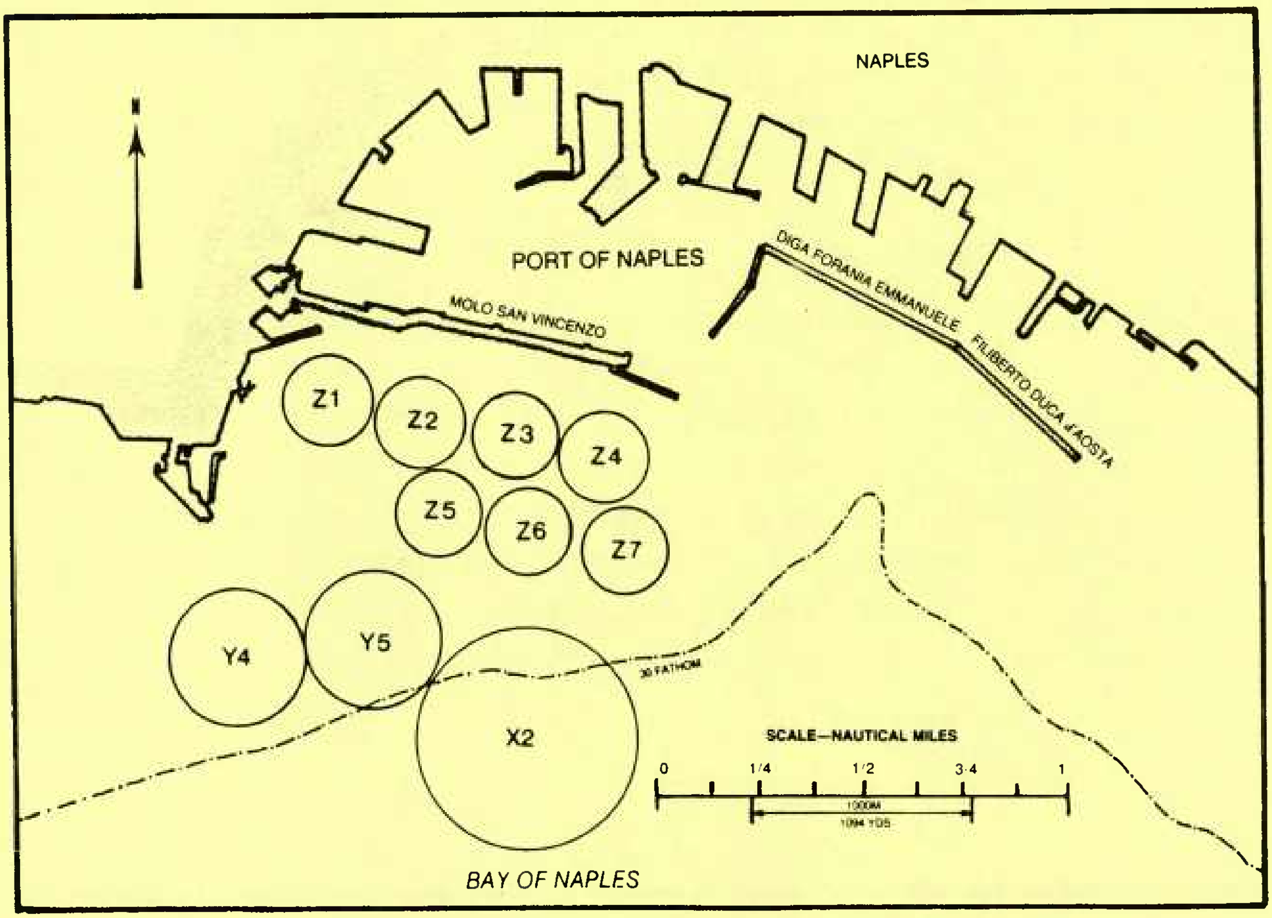

Figure 2-3. Port of Naples, Italy.

Southwesterly winds and waves can cause significant problems for vessels anchored in the outer harbor. Southwesterly waves tend to reflect off of the breakwater adjacent to the anchorage (Molo San Vincenzo) to create a hazardous confused wave pattern in the area making it dangerous for small craft, such as liberty boats, to operate to/from ships. According to U. S. Navy (1983), the "anchorage is exposed to south winds and should be abandoned at the first appearance of bad weather from that direction".

If the wind and swell directions are out of phase, i.e., from different directions such as might occur following a strong frontal passage, a different but no less hazardous condition develops. As the ship weather vanes into the northwesterly wind, the southwesterly swell becomes a beam swell. This causes a rolling of the vessel and dangerous conditions for combined operations involving small craft and larger vessels.

Ocean currents in the Gulf of Naples are not considered a hazard to fleet operations. Tides are minimal and do not exceed 1.5 ft (0.5 m) (U.S. Navy (Naples), 1981).

Specific hazardous atmospheric conditions, vessel situations, and suggested precautionary/evasion action scenarios are summarized in Table 2-1. Hazards for both inner harbor and anchorage areas are addressed.

Table 2-1. . Summary of hazardous environmental conditions for the Port of Naples, Italy.

HAZARDOUS CONDITION	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	INDICATORS OF POTENTIAL HAZARD
1. SW'ly wind/waves. Produces worst weather at Naples harbor. * Most likely to occur during period September - May. * Caused by steep pressure gradient associated with Genoa low and/or frontal system. * Winds commonly reach gale force (≥34 kts). 35 kt wind can result in 14 to 15 ft swell at anchorage. Persistent wind ≥ force 4 (11-16 kts) can produce problem waves. * SW'ly waves reflect off face of Molo San Vincenzo, causing chaotic wave conditions at anchorage. * SW'ly waves are quick to rise, slow to abate. If SW'ly wind blows for 2 days, SW'ly swell may take 2-3 days to diminish.	a. Mediterranean moored - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Tug assistance may be required if winds approach gale force (≥34 kts). * Minimize personnel exposure on weather decks. * Secure loose gear. (2) Inner harbor of Naples is relatively safe from the effects of SW'ly wind, but a swell often occurs in the W portion of the inner harbor and can make entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970). * Secure loose gear. * Wind may tend to force ships on/off berths. Several instances have occurred where med-moored auxiliary type ships have worked bollards loose during storms or high winds. NAVSUPPACTNAPLESINST 5000.1 (series) lists precautionary actions to be taken to avoid such problems. The following procedures are prescribed. * Mooring lines should have a maximum of spring. Wire is not desirable. Accordingly, 6", 8", or 10" manila or nylon lines doubled should comprise the riding lines and leads should be as long as practicable. * Lifting strains on bollards resulting from lines running from relatively high stern chocks to bollards directly astern or nearby should be avoided. * Wire and spring lines should be used as preventers only, paralleling the riding lines. Preventers should take no strain until the riding lines have nearly reached their limit of strength. * Wire and spring lay should also have a long lead in order to provide a maximum of catenary in the event it becomes a riding line due to parting of fiber riding lines. * Strain on bollards should be distributed and equalized on as many bollards as practicable. * Chafing gear should be provided on riding lines at each point of wear or friction.	Advance warning * Strong SW'ly flow at Naples can be expected if 3 isobars (with 4 mb spacing) can be drawn across Italy and steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong winds 3-6 hours later. * Watch for strong winds at Naples if winds at Isola di Ustica increase from the SW. * A 4 mb pressure difference between Ustica and Rome (Rome higher) will produce SW'ly winds of gale force (≥34 kt) at Naples. * Thunderstorm development over Sardinia and Corsica often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours. * During the period September to May, watch for cold air advection southward at 850 mb and 700 mb. Wind duration and intensity * When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest pressure gradient moves into the area. Although post-frontal winds can be strong winds will generally be strongest in advance of the trough. * After SW'ly winds shift to W or NW following a trough passage, SW'ly winds will normally die down within 12 hours but swell may persist for 2-3 days if trough was slow moving.
	b. Moored alongside pier/ wharf - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	c. Moored alongside with tended vessels nested.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	d. Anchored in designated anchorage.	(1) Worst conditions for ships in anchorage. * Exposed to full force of SW wind and waves. * Waves reflect off of Molo San Vincenzo and create amplified chaotic waves. * When wind shifts to NW following frontal passage, wind/waves will be 90° out of phase, causing rolling of anchored vessels. * Boating to/from anchorage may be curtailed or cancelled. * Vessels may need to depart anchorage for more protected area in Gulf of Pozzuoli.	
	e. Arriving/departing harbor.	(1) Tenders and aircraft carriers should not enter/leave the inner harbor when SW winds ≥ force 5 (17-21 kts) are forecast. (2) Vessels may need to depart anchorage for more protected area in Gulf of Pozzuoli. (3) Inner harbor of Naples is relatively safe from the effects of SW'ly wind, but a swell often occurs in the W portion of the inner harbor and can make entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970).	
	f. Small boat operations.	(1) Boating may be curtailed. * Chaotic waves caused by reflection of SW'ly waves off of Molo San Vincenzo may make boating to/from anchorage unsafe/impossible. * Swell to 3 ft may enter inner harbor through channel at end of Molo San Vincenzo. * When wind shifts to NW following frontal passage, winds and swell will be 90° out of phase, well deck/small boat operations can be hazardous.	

Table 2-1. (Continued)

HAZARDOUS CONDITION	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	INDICATORS OF POTENTIAL HAZARD
2. NE'ly wind - Tramontana. * Strong wind caused by cold outbreak in N Italy. * Most likely during late autumn, winter, and early spring. * May reach gale force (≥34 kts). * Strongest during daylight hours.	a. Mediterranean moored - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Tug assistance may be required if winds approach gale force (≥34 kts). * Minimize personnel exposure on weather decks. * Secure loose gear.	Advance warning and intensity * When NE'ly winds increase at Split and/or Novodovno, Yugoslovia, Naples will get them 6 hours later. * When the pressure gradient between Corfu, Greece and Venice, Italy is 12 mb or more (with Venice higher) Naples will get gale force (≥34 kt) NE'ly winds. * Orographic clouds on the north slope and over Mt. Vesuvius are indicators of potentially strong NE'ly winds at Naples (clouds form on the south and west slopes during sea breeze conditions).
	b. Moored alongside pier/ wharf - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	c. Moored alongside with tended vessels nested.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	d. Anchored in designated anchorage.	(1) Ships at anchor should not experience significant problems. * Off-shore wind component will not raise large sea. * Minimize exposure of personnel on weather decks.	
	e. Arriving/departing harbor.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	f. Small boat operations.	(1) Minimal impact on boating. * Inner harbor essentially unaffected. * Chop in outer anchorages may curtail routine boating.	

Table 2-1. (Continued)

HAZARDOUS CONDITION	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	INDICATORS OF POTENTIAL HAZARD
3. SE'ly wind. * Caused by steepening pressure gradient in advance of approaching low pressure system.	a. Mediterranean moored - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Tug assistance may be required if winds approach gale force (≥34 kts). * Minimize personnel exposure on weather decks. * Secure loose gear.	Advance warning * When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
	b. Moored alongside pier/ wharf - no nested vessels.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	c. Moored alongside with tended vessels nested.	(1) Wind may tend to force vessel off of mooring. * Secure loose gear. * Minimize exposure of personnel on weather decks. * Double lines as necessary. * Aircraft carriers should depart inner harbor if winds greater than force 5 (17-21 kts) are forecast.	
	d. Anchored in designated anchorage.	(1) Wind may raise fetch-limited sea. * Waves may curtail boating to/from anchorage. * Minimize exposure of personnel on weather decks. * Moving SE to vicinity of Castellammare or Sorrento in lee of mountains will reduce effects of wind/waves.	
	e. Arriving/departing harbor.	(1) Tenders and aircraft carriers should not enter/leave the inner harbor when SW winds ≥ force 5 (17-21 kts) are forecast. (2) Vessels may need to depart anchorage for more protected area in Gulf of Pozzuoli. (3) Inner harbor of Naples is relatively safe from the effects of SW'ly wind, but a swell often occurs in the W portion of the inner harbor and can make entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970).	
	f. Small boat operations.	(1) Boating may be impacted at anchorage but inner harbor should be unaffected.	

Table 2-1. (Continued)

HAZARDOUS CONDITION	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	INDICATORS OF POTENTIAL HAZARD
4. Thunderstorms. * Commonly occurs year-round, with greatest frequency in November. * Late autumn, winter, and spring storms usually associated with passing fronts/troughs. Strongest over water near coast. * Storms associated with fronts/troughs may produce hail. * Late spring, summer, and early autumn storms usually orographically induced. Strongest over land. * Associated winds commonly 20-25 kts with gusts to 40-45 kts. * Usually have small horizontal size but great intensity.	a. Mediterranean moored - no nested vessels.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft.	Advance indicators * Can be expected with front/trough passages during period September - May. * During period May - September, cumulus development over Apennine Mountains and Mt. Vesuvius may move over Naples.
	b. Moored alongside pier/ wharf - no nested vessels.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft.	
	c. Moored alongside with tended vessels nested.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft.	
	d. Anchored in designated anchorage.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft.	
	e. Arriving/departing harbor.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft.	
	f. Small boat operations.	(1) Hazardous conditions may persist for 1-2 hours. * Minimize exposure of personnel on weather decks. * Secure loose gear. * Secure small craft. Boating may be curtailed for 1-2 hours.	
5. Sea breeze. * SSW-W'ly sea breeze is a common occurrence during period 1000-1700 on warm summer days. * Usually force 3-4 (7-16 kts).	a. Small boat operations.	(1) Will seldom hamper boating to any degree. * Will raise chop in outer harbor. * Sailors may get wet.	Sea breeze should be expected daily in warm weather. * Orographic clouds form on the west and south slopes of Mt. Vesuvius during sea breeze conditions.

Table 2-2 provides the height classification and direction of shallow water waves to expect at points 1, 2, 3, and 4 (Figure 2-2) when the deep water wave conditions are known.

Example 1: Use of Table 2-2 for Naples Point 1.
Deep water wave forecast or a reported/observed deep water wave condition:
10 feet, 12 seconds, from 210°.
The expected wave condition at Naples Point 1, as determined from Table 2-2:.
8 feet, 12 seconds, from 200°.

The Naples Point 1 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height (10 ft) by the ratio of shallow to deep height (.8).

Example 2: Naples Points 1-4: If the known or forecast deep water wave condition outside Naples harbor is about 8 feet at 14 seconds from 210°; the expected harbor wave conditions are:	
Point 1:	6-7 feet, 14 seconds, from 200°
Point 2:	5-6 feet, 14 seconds, from 190°
Point 3:	8 feet, 14 seconds, from 190°
Point 4:	1-2 feet, 14 seconds, from 150°

Table 2-2 shows that all deep water swell from 180° to 240° entering Naples harbor back in direction as they approach the four points evaluated (Figure 2-2).

<u>NOTE</u>: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-2 for location of points).

FORMAT: Shallow Water Direction
Height ratio (shallow to deep):

NAPLES POINT 1:

Deep Water Period (sec)	6	8	10	12	14
Direction					
210°	210° .9	205° .9	205° .9	200° .8	200° .8
240°	220° .4	220° .7	230° .6	230° .3	220° .6

NAPLES POINT 2:

Deep Water Period (sec)	6	8	10	12	14
Direction					
210°	210° .8	200° .7	200° .7	195° .7	190° .7
240°	210° .2	210° .2	220° .2	220° .3	210° .4

NAPLES POINT 3:

Deep Water Period (sec)	6	8	10	12	14
Direction					
180°	180° .8	180° .8	180° .8	180° .7	180° .6
210°	205° .7	195° .7	195° .8	200° .9	190° 1.0
240°	230° .6	230° .5	215° .4	215° .4	210° .4

NAPLES POINT 4:

Deep Water Period (sec)	6	8	10	12	14
Direction					
180°	180° .6	175° .5	180° .5	165° .3	165° .3
210°	180° .4	170° .4	160° .3	150° .2	150° .2

The <u>local wind generated waves for fetch limited conditions</u>, based on the JONSWAP model (Hasselmann et al., 1976 and Thornton, 1986), are given in Table 2-3 for point 1 (see Figure 2-2). All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction (implied fetch length) in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean condition. When starting from a pre-existing lower wave height, the time to fetch limiting height will be shorter.

Table 2-3. Naples Bay near point 1. Local wind waves for fetch limited conditions related to point 1 (based on JONSWAP model).

<u>Format:</u> height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
ESE 6 n mi	1-2/3 1	2/3 1-2	2-3/3-4 1-2	3/3-4 1-2	3-4/4 1-2
SE 12 n mi	2-3/4 2	3/4 2	3-4/4 1-2	4-5/4-5 2	5-6/5 2
S 30 n mi	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3

<u>Example:</u> The local wind is from the southeast at about 24 kt. Fetch is limited to about 12 n mi. Enter Table 2-3 with SE (12 n mi) and 24 kt, obtain seas of 3 feet at 4 seconds after about 2 hours of sustained southeast 24 kt winds. Wind wave directions are assumed to be the same as the wind direction. Any location that meets the fetch

distance criteria of Table 2-3 or A-2 of Appendix A can use the values of height/period/duration from those Tables.

Combined wave heights are obtained by finding the square root of the sum of the squares of the swell and wind wave heights.

Example: Swell 10 ft, wind wave 5 ft.

$$\sqrt{10^2 + 5^2} = \sqrt{100 + 25} = \sqrt{125} \approx 11.2 \text{ ft.}$$

Note: Increase over larger heights is small. If both heights were equal, combined height would increase by a factor of 1.4. If one is half of the other, as in the example, increase over the larger of two is by a factor of 1.12.

Climatological factors of shallow water waves as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height) are given in Table 2-4. The data are provided by season for two ranges of heights: greater than 3.3 feet and greater than 6.6 feet. Four anchorage areas have been selected for Naples (see Figure 2-2).

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

NAPLES POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	23	11	6	22
Average Duration (hrs)	12	10	11	14
Period Max Energy (sec)	10	10	10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	5	3	1	5
Average Duration (hrs)	11	8	12	12
Period Max Energy (sec)	11	11	11	11
NAPLES POINT 2:	**WINTER**	**SPRING**	**SUMMER**	**AUTUMN**
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	7	2	1	5
Average Duration (hrs)	11	8	10	11
Period Max Energy (sec)	9	12	9	9
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<1	<<1	1
Average Duration (hrs)	9	6	6	9
Period Max Energy (sec)	12	12	14	12

Table 2-4 (continued)

NAPLES POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	32	17	10	32
Average Duration (hrs)	12	11	18	16
Period Max Energy (sec)	8	9	8	8
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	4	2	11
Average Duration (hrs)	9	9	8	11
Period Max Energy (sec)	11	11	11	9

NAPLES POINT 4:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	10	0	2	7
Average Duration (hrs)	12	NA	132	12
Period Max Energy (sec)	9	NA	9	9
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	<1	0	0	0
Average Duration (hrs)	8	NA	NA	NA
Period Max Energy (sec)	12	NA	NA	NA

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

WINTER (November thru February):

* Lows in Gulf of Genoa cause strong southwesterlies which can persist for 2-3 days. Generally 15 kt with 4 ft (1 m) waves but can reach 35 kt with 15 ft (4 m) waves.
* Ships anchored outside Molo San Vincenzo during southwest wave condition which can reflect off the molo may experience chaotic seas.
* Tramontana (northeasterly) wind funnels through mountain passes and reaches harbor at high speeds. Waves, however, are fetch limited.

SPRING (March thru May):

* Early spring similar to winter.
* Visibilities reduced late spring and summer due to morning fog/haze.

SUMMER (June thru September):

* Sea breeze 10-15 kt common daily occurrence which can raise light chop in harbor. Peak frequency in August.
* Thunderstorms occur an average of 3 days/month, usually during evening hours.

AUTUMN (October):

* Short transition season with winter-like conditions the norm by month's end.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

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Thornton, E. B., 1986: Unpublished lecture notes for OC 3610, Waves and Surf Forecasting. Naval Postgraduate School, Monterey, CA.

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3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of hazards and actions by season.

3.1 Geographic Location

The Port of Naples, Italy's second largest port, is located at 40°50'19"N 14°15'36"E, about 117 n mi (188 km) southeast of Rome on Italy's west coast (Figure 3-1). The port is situated on the north end of Rada di Napoli (Bay of Naples) which is located in the northern section of Golfo di Napoli (Gulf of Naples). The Gulf has approximate dimensions of 14 n mi northwest-southeast and 9 n mi northeast-southwest and is open to the southwest between the coastal islands of Capri and Ischia.

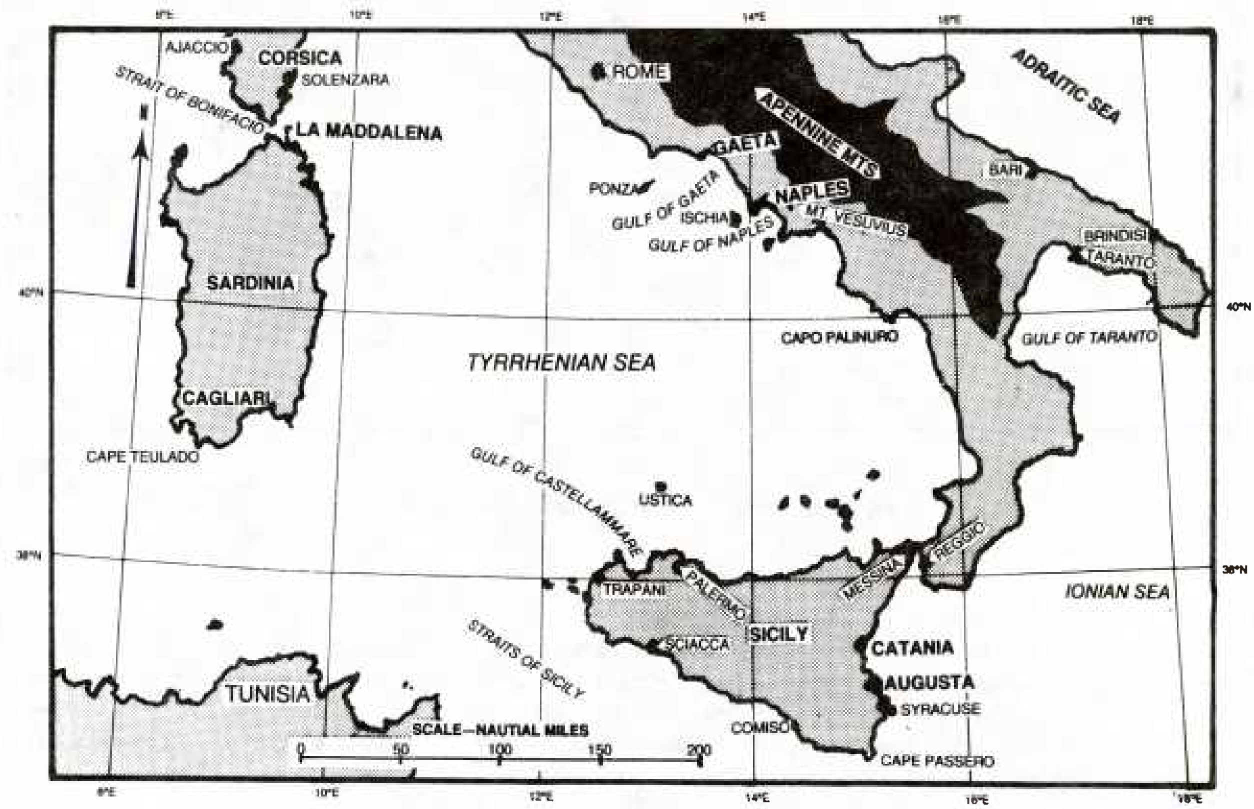

Figure 3-1. Ports of Italy, Sicily, and Sardinia.

The Rada di Napoli (Bay of Naples) is protected from the west clockwise through east-southeast by the mainland of Italy. The Port of Naples is located in the northeast sector of the Bay. The most prominent landmark near Naples is Mt. Vesuvius*, a 4,203 ft (1,281 m) volcano located approximately 8 n mi east of the port (Figure 3-2).

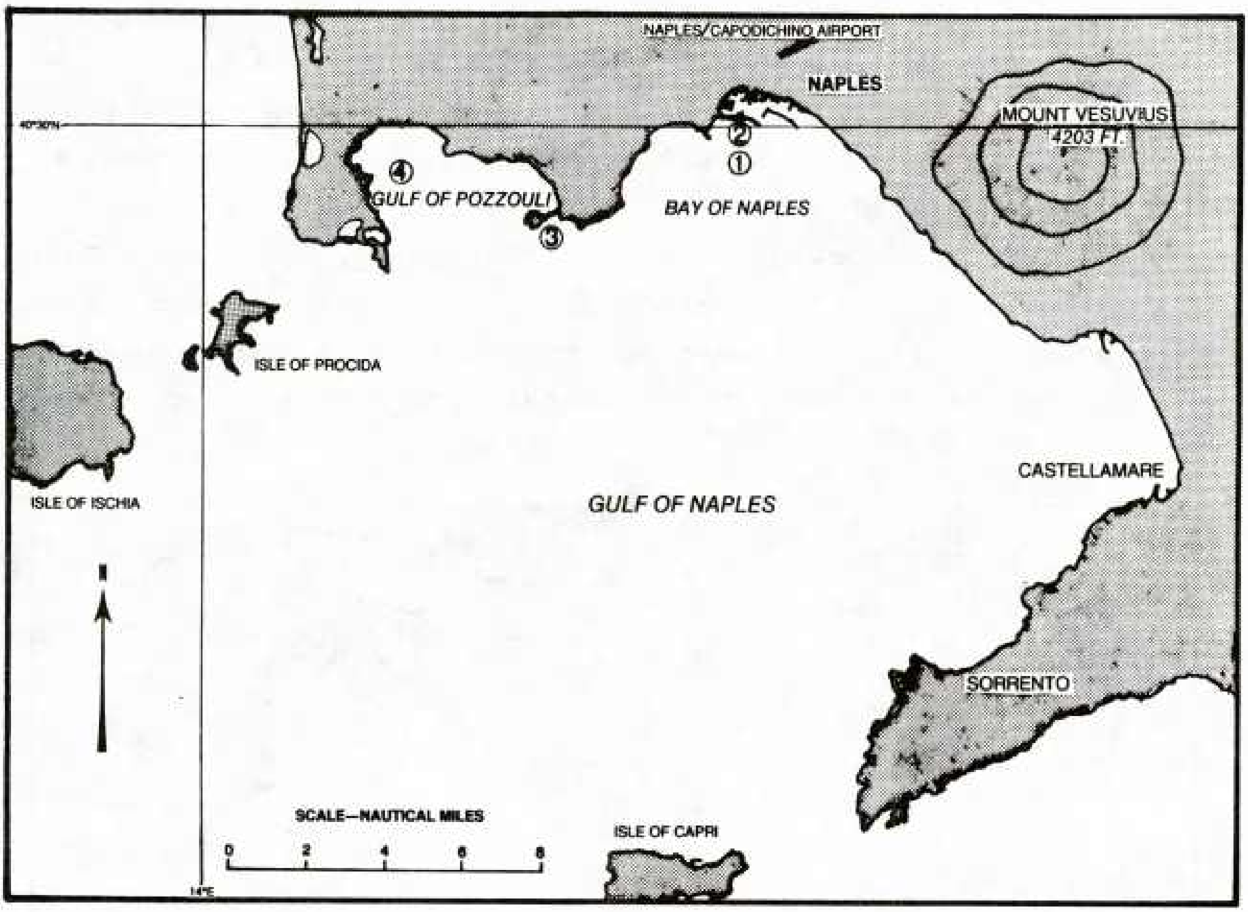

Figure 3-2. Gulf of Naples.

* Although Mt. Vesuvius is not "active" in the familiar sense of spewing rocks and lava, it is active underground. This activity, geologically known as "bradyism", includes bulging of the earth, tremors, and venting of steam and sulphur gases.

The Port of Naples consists of an inner and outer harbor (Figure 3-3). The inner harbor is largely protected by a detached breakwater, Diga Forania Emmanuele Filiberto Duca d'Aosta and an attached breakwater, Molo San Vincenzo. The entire harbor is bordered on the west clockwise through east by the mainland of Italy. The outer harbor is protected from the open sea waves except from south clockwise through west-southwest.

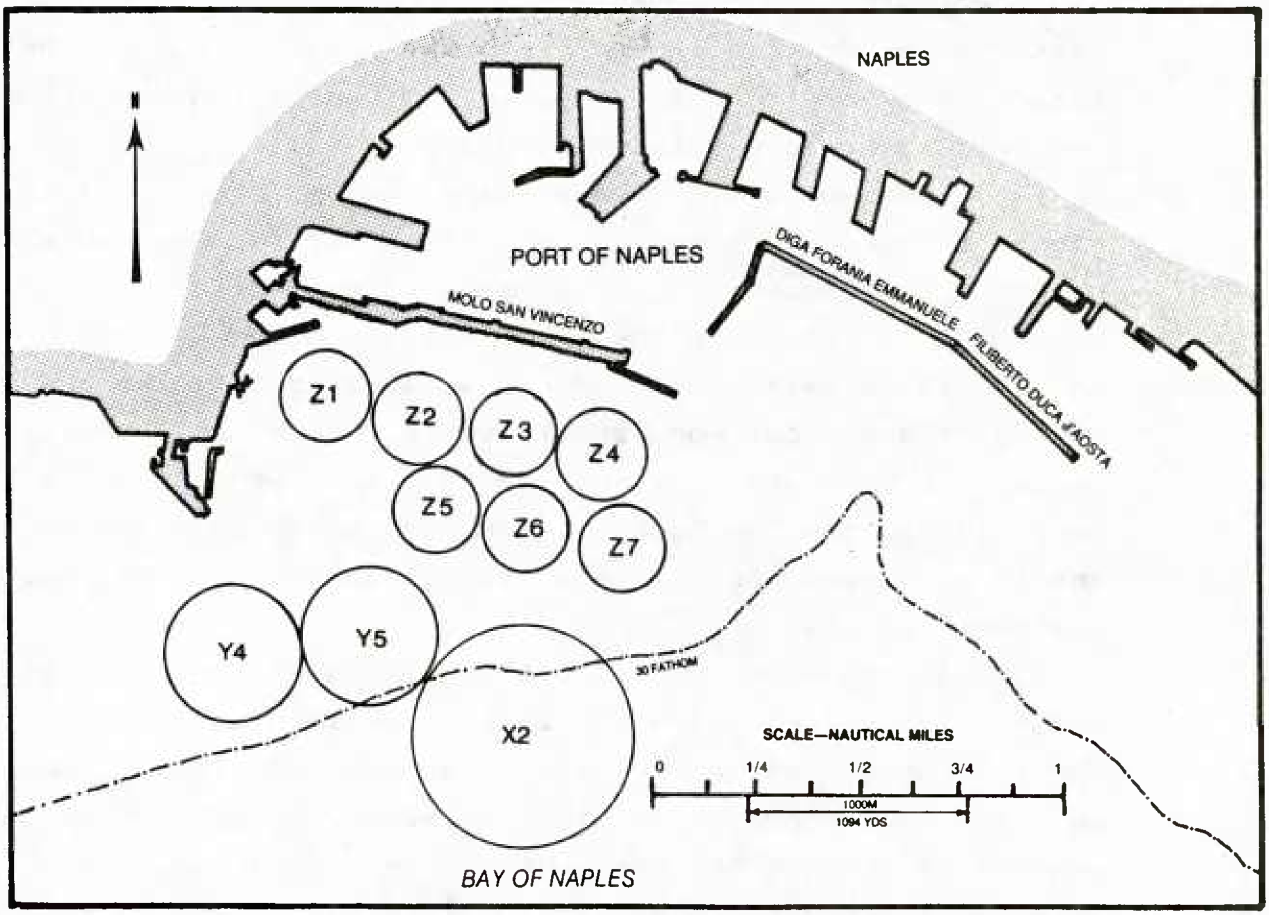

Figure 3-3. Port of Naples, Italy.

3.2 Qualitative Evaluation of Harbor as a Haven

The harbor of Naples, including the anchorage area, is protected from northerly winds which may reach gale force along the coast. Because of fetch limitations, northeasterly winds over the harbor will seldom generate seas high enough to hamper boating conditions (Brody and Nestor, 1980). Moderate southwesterly winds, however, can generate high waves in Naples harbor. The inner harbor is generally protected by breakwaters. However, swell generated by southwesterly winds can enter into the west portion of the inner harbor making entry, berthing, and cargo handling unsafe (NWSED Naples, Italy,1970).

Southwesterly winds and waves can cause significant problems for vessels anchored in the outer harbor. Southwesterly waves tend to reflect off of the breakwater adjacent to the anchorage (Molo San Vincenzo) to create a hazardous confused wave pattern in the area making it dangerous for small craft, such as liberty boats, to operate to/from ships. According to U. S. Navy (1983), the "anchorage is exposed to south winds and should be abandoned at the first appearance of bad weather from that direction".

If the wind and swell directions are out of phase, i.e., from different directions such as might occur following a strong frontal passage, a different but no less hazardous condition develops. As the ship weather vanes into the northwesterly wind, the southwesterly swell becomes a beam swell. This causes a rolling of the vessel and dangerous conditions for combined operations involving small craft and larger vessels.

3.3 Currents and Tides

Ocean currents in the Gulf of Naples are not considered a hazard to fleet operations. Tides are minimal and do not exceed 1.5 ft (0.5 m) (U.S. Navy (Naples), 1981).

3.4 Visibility

Visibility in the Naples area can be reduced by industrial and automotive pollution, a condition especially evident when warm, stagnant air masses (which prevail during the summer) dominate the region. Visibility at 0800 local time at the nearby U.S. Naval Air Facility (located adjacent to Capodichino Airport) is in the 2-5 n mi range over 50% of the time in all months except February, and that month's figure is 47%. January and February share the highest incidence visibility in the 0-1/2 n mi range during early morning with 4% frequency of occurrence (NWSED Naples, 1970). The generally poor visibilities, due to haze, at Naples can be expected to improve rapidly 1-6 hours before the passage of a cold front (Brody and Nestor, 1980).

Another phenomenon which may occasionally reduce visibility at Naples (and most of southern Italy) is the "Scirocco", an invasion of warm air from North Africa that is heavily laden with dust. Scirocco events have a maximum frequency of occurrence during March-June, but can occur year-round. Typically, visibilities in the Naples area are reduced to 1-2 n mi during Scirocco conditions.

3.5 Hazardous Conditions

The Port of Naples is exposed to various large- and small-scale hazardous wind and wave conditions. A seasonal summary of known environmental hazards that may be encountered in the Port of Naples follows.

A. Winter (November through February)

The winter season at Naples is a period of cool temperatures, frequent precipitation, and strong winds. Like other ports on the Tyrrhenian Sea, the proximity of Naples to the Gulf of Genoa -- one of the most active regions of cyclogenesis in the world -- dictates that unsettled weather conditions will prevail.

The most hazardous winter weather for the Port of Naples comes from the southwest. Low pressure systems, frequently generated in the Gulf of Genoa, move southward and cause a steepening of the pressure gradient along the west coast of Italy. This results in southwesterly winds and high waves near Naples. A stagnant or slow-moving low can cause strong southwesterly winds to persist for 2-3 days. Steady winds of only 10-15 kt are sufficient to produce a 4 ft swell in Naples Harbor and adversely impact small boating in the anchorage. Stronger winds will raise higher waves with prolonged winds (over 8 hours) from the southwest at 35 kt typically producing swell in the 14-15 ft range.

The orientation of Molo San Vincenzo and its location adjacent to the anchorage produces a unique and particularly bothersome problem for anchored ships. Southwesterly waves impact and reflect from Molo San Vincenzo and raise a chaotic, amplified wave condition that frequently prohibits small boat operations to/from the anchorages shown in Figure 3-3.

According to personnel at Naples, southwesterly swell builds up slowly but is also slow to stop. Swell from a fast-moving trough will diminish about 12 hours after trough passage. But if southwesterly winds have blown for 2 days or more, the swell will persist for 2-3 days after the winds die down. Secondary shortwave troughs are common during periods of slow moving long wave troughs. The secondary troughs result in intensification of the southwesterly winds and prolonged and increased high waves.

In general, ships are not safe in the anchorage if south-southwest winds exceed force 5 (17-21 kt). Under such flow it is best to leave the port to ride out the storm or move to the Gulf of Pozzuoli (Figure 3-2) where the anchorage is more protected. If the winds are southeasterly, moving the ship toward Castellammare or Sorrento (southeastern sector of the Gulf of Naples) will result in a reduced sea state condition.

Another problem facing ships at anchor occurs after a strong front or trough has passed Naples. The wind will shift to the west or northwest causing anchored vessels to take a heading perpendicular to the southwesterly swell. The beam swell can cause significant rolling and create hazardous conditions for small boat operations at the anchored vessels. Consequently, boating may have to be cancelled.

Personnel at Naples say it is dangerous to bring a tender or CV into the inner harbor with southwest winds greater than 20 kt. CV's should leave the inner harbor if winds greater than force 5 (17-21 kt) are forecast.

Naples can also be impacted by a strong northeasterly wind known locally as the "Tramontana". It is a cold, dry wind caused by a strong north-to-south pressure gradient which occurs when a cold high pressure system invades northern Italy. The cold air funnels through mountain passes to the west coast. Because it is an off-shore wind it does not raise a bothersome sea in the harbor, but the wind velocities can reach dangerous levels. Boating in the anchorage, especially the outer areas, can be adversely affected. Helicopter operations may be curtailed because of turbulence from the surface through 10,000 ft. An estimate of the force of the Tramontana wind at Naples can be made by determining the surface pressure difference between Venice, Italy and Corfu, Greece, both of which are on the Adriatic Sea. If the difference is 12 mb or more (with Venice higher) gale force winds can be expected at Naples. The onset of gale force winds will be about 6 hours after they occur along the eastern shore of the Adriatic Sea (Split is a good indicator).

Thunderstorms occur at Naples year-round, but they occur over the water most often during the winter in association with passing cold fronts and troughs. Hail frequently accompanies the storms. Boating can be disrupted for 1-2 hours.

The lowest recorded surface air temperature at Naples (Capodichino Airport) is only 24°F (-4°C), but the wind chill (temperature combined with wind) can be much colder. For example, a temperature of 30°F (-1°C) and a wind velocity of 15 kt results in a wind chill of 10°F (-12°C). Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	40	35	30	25	20	15	10	5	0
		Equivalent Chill Temperature								
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

B. Spring (March through May)

Unsettled weather usually persists in the Naples area until about mid-May after which generally good weather lasts until approximately mid-September.

The worst weather for Naples during spring is the same as that of winter -- strong southwesterly winds and waves which result from southward-moving low pressure systems and associated fronts and troughs (see section 3.5 A). The cyclonic activity becomes less frequent after April and the more pleasant weather of summer starts to predominate.

Cold northeasterly winds, known locally as the "Tramontana", may occur in the Naples area through April. As discussed in section 3.5 A, their off-shore trajectory minimizes their impact on harbor operations. Because they are relatively cold and can reach gale velocities, Tramontana winds pose a wind chill hazard to personnel working in exposed locations.

During spring, thunderstorms occur on an average of about 3 days each month. Those occurring early in the season would likely be associated with passing fronts or troughs, while those in May may be either frontal-type or orographically produced as a result of moist southerly flow being forced over the Apennine Mountains or Mt. Vesuvius.

Visibility in Naples harbor is seldom reduced below 1 n mi, with the worst visibility conditions being observed in the early morning between 0600 and 0800 LST. Haze, which obscures mountains and coastal features from seaward, usually persists from late spring through summer.

C. Summer (June through September)

Until mid-September, summer is a period of relatively settled weather conditions and light winds in the Naples area. Extratropical storm activity is at a minimum, resulting in a commensurate decrease in significant wind and wave activity. Precipitation is reduced throughout the season with July being the driest month of the year. Temperatures continue to increase through August, the warmest month of the year.

A break in the summer weather pattern is usually evident by mid-September as temperatures show significant decreases, and cloudiness and precipitation increases. An increase in the incidence of the north-northwest winds of autumn can be noticed by the end of the month.

During June and July thunderstorm activity remains at an average of about 3 days per month but starts to increase in August and September. Since extratropical cyclone and frontal activity is at a minimum during the summer, most of the thunderstorm activity is likely the result of orographic lifting over the Apennine Mountains and/or Mt. Vesuvius.

South-southwest to west sea breezes during the period 1000-1700 LST are the daily norm but seldom exceed force 3-4 (7-16 kt). Other than for the light chop raised by the sea breeze, generally smooth wave conditions prevail in the outer harbor during July and

August. Wave heights for June exceed 5 ft only about 2% of the time. Boating conditions in the outer harbor deteriorate during the latter half of September as the more inclement weather of autumn starts to affect the region.

Visibility during summer is the worst of the year with the morning visibility between 0600-0800 LST being the most restricted. Even then, visibility is seldom reduced below 1 n mi. Visibilities of ≤300 m are observed only 3-5 times per year. Summer haze frequently obscures the horizon, coastal landmarks and terrain features of the mountains. When the hot, humid weather accompanying a Scirocco (warm air invasion from North Africa) penetrates as far north as Naples, the prevailing visibility is commonly reduced to about 1 to 2 n mi.

D. Autumn (October)

According to Brody and Nestor (1980), autumn lasts only for the month of October over the Tyrrhenian Sea area. The month is characterized by an abrupt change to winter-type weather. The mean temperature drops to 62°F (17°C). Precipitation increases to an average of over 4 inches for the month as measurable amounts of rain can be expected to occur on about 8 days.

October brings an increase in cyclogenesis and associated frontal activity with frontal systems passing through Naples approximately every 4-6 days. Wind velocities increase during the month and are accompanied by an associated increase in wave heights in the outer harbor. Waves exceed 5 ft about 7% of the time.

As with winter and spring, the most hazardous autumn weather comes from the southwest. Low pressure systems, frequently generated in the Gulf of Genoa, move southward through the area and cause southwesterly winds, high waves, and inclement weather. As the season progresses, and cold air starts to make strong incursions into northern Italy, a locally strong, cold northeasterly wind known as the "Tramontana" may affect the weather at Naples (see section 3.5 A).

Thunderstorms, frequently accompanied by hail, are relatively common during October, occurring on an average of 5 days during the month (a number which closely approximates the number of frontal passages expected).

Although autumn temperatures continue to drop significantly from the warm days of summer, they are not cold enough to present serious wind chill concerns. The coldest temperature recorded at Capodichino Airport during any October (through 1980) is 44°F (7°C).

3.6 Harbor Protection

The harbor of Naples is protected from wave action from west-southwest clockwise to east-northeast. From east-northeast clockwise to south, the effects of wave action are mitigated by the relatively short fetch area between Naples Harbor and the coastline surrounding the Gulf of Naples and Capri Island. The harbor area is vulnerable to winds and waves from south through west-southwest.

3.6.1 Wind and weather

Naples is located on the west coast of Italy with the base of the Apennine Mountain range some 15 miles to the east. The Port of Naples, including the anchorage area, is protected from northerly winds. The worst weather at Naples comes from the southwest quadrant -- the direction from which the harbor is most vulnerable.

The cold northeasterly winds of the local Tramontana reach speeds of 35 kt or more (see section 3.5 A) in the harbor. Due to their off-shore component, and therefore lack of fetch, no significant wave related problems are generated except for the outermost anchorages. Small boat operations are usually not restricted by local Tramontana conditions.

On the average, winds in the Naples area are not strong. Exceptions are associated with a passing low pressure system or an intense anticyclone located over central or eastern Europe. The diurnal variation of the wind, alternating between a sea breeze during the day and a land breeze at night, is pronounced in the warmer months, and is noticeable even during the cold season within periods of fine weather.

Prevailing wind directions throughout the year are between south and southwest with the latter predominating. Frequently in winter, and occasionally in summer, northwest winds blow steadily for some length of time. Such winds are weak in the Bay of Naples but are fresh outside the islands of Ischia and Capri.

3.6.2 Waves

The most severe weather at Naples emanates from the southwest quadrant. Because the harbor area is unprotected in that direction (Figure 3-2), any wind of force 4 (11-16 kt) or greater can raise waves which will adversely affect harbor operations, especially in the anchorage area. Waves of 4 ft or greater are considered cause for cancellation of boating. Although southwesterly waves can be generated in a relatively short time, they are slow to diminish, and southwesterly swell will sometimes persist for 2-3 days after the local southwesterly winds have subsided.

Because of reduced fetch length, seas resulting from winds from west-southwest clockwise to east-northeast will not cause a disruption in harbor operations. Winds from east clockwise through south, though fetch limited, may generate bothersome seas if the winds exceed 20-25 kt. Inner harbor operations should not be hampered.

Table 3-2 provides the shallow wave conditions at the four designated points (Figure 3-2) when deep water swell enters the harbor. Users are reminded that the model used to generate shallow water wave conditions contains limited physical considerations and the results should be used as a first approximation.

Example: Use of Table 3-2.

For a deep water wave condition of:
8 feet, 12 seconds, from 210°

The approximate shallow water wave conditions are:
Point 1 7 feet, 12 seconds, from 200°
Point 2 6 feet, 12 seconds, from 200°
Point 3 9 feet, 12 seconds, from 200°
Point 4 5 feet, 12 seconds, from 160°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction for the four selected points shown in Figure 3-2.

FORMAT: Shallow Water Direction
Height Ratio

NAPLES POINT 1:

Deep Water Period (sec)	6	8	10	12	14
Direction 210°	210° 1.0	205° 1.0	205° 1.0	200° .9	200° .9
240°	220° .4	220° .8	230° .7	230° .4	220° 1.2

NAPLES POINT 2:

Deep Water Period (sec)	6	8	10	12	14
Direction 210°	210° .9	205° .8	205° .8	200° .8	200° .9
240°	210° .3	210° .3	220° .2	220° .4	210° .5

NAPLES POINT 3:

Deep Water Period (sec)	6	8	10	12	14
Direction 180°	180° 1.0	180° 1.1	180° 1.3	180° 1.3	180° 1.3
210°	205° .8	195° .9	195° .9	200° 1.1	190° 1.1
240°	230° .7	230° .7	210° 1.1	200° 1.1	195° 1.2

NAPLES POINT 4:

Deep Water Period (sec)	6	8	10	12	14
Direction 180°	180° 1.0	175° .8	180° .9	165° 1.0	165° 1.0
210°	180° 1.0	170° .9	160° .6	160° .6	160° .6

Situation specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-2 while the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. If the actual or forecast deep water wave conditions are known, the expected conditions at the four specified harbor areas can be determined from Table 3-2. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-3.

Example: Use of Tables 3-2 and 3-3.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:

9 feet, 12 seconds, from 210°

Expected shallow water conditions and duration:

	Point 1	2	3	4
height	8 feet	7 feet	10 feet	5 feet
period	12 seconds	12 seconds	12 seconds	12 seconds
direction	from 200°	from 200°	from 200°	from 160°
duration	11 hours	9 hours	9 hours	12 hours

Interpretation of the information provides guidance on the local wave conditions expected tomorrow at the various harbor points (Table 3-2). The duration values are mean values for the specified height range and season (Table 3-3). Knowledge of the current synoptic pattern should be used when available.

Possible applications to small boat operations are selection of the mother ship's anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information could be of use in selecting anchorage configuration and related small boat operations.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

NAPLES POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	23	11	6	22
Average Duration (hrs)	12	10	11	14
Period Max Energy (sec)	10	10	10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	5	3	1	5
Average Duration (hrs)	11	8	12	12
Period Max Energy (sec)	11	11	11	11
NAPLES POINT 2:	**WINTER**	**SPRING**	**SUMMER**	**AUTUMN**
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	7	2	1	5
Average Duration (hrs)	11	8	10	11
Period Max Energy (sec)	9	12	9	9
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	1	<1	<<1	1
Average Duration (hrs)	9	6	6	9
Period Max Energy (sec)	12	12	14	12

(See next page for Points 3 and 4.)

Table 3-3 (continued)

NAPLES POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	32	17	10	32
Average Duration (hrs)	12	11	18	16
Period Max Energy (sec)	8	9	8	8
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	4	2	11
Average Duration (hrs)	9	9	8	11
Period Max Energy (sec)	11	11	11	9

NAPLES POINT 4:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	10	0	2	7
Average Duration (hrs)	12	NA	132	12
Period Max Energy (sec)	9	NA	9	9
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	<1	0	0	0
Average Duration (hrs)	8	NA	NA	NA
Period Max Energy (sec)	12	NA	NA	NA

There is a general shift of maximum energy to the longer period waves between the greater than 3.3 ft group and greater than 6.6 ft group. This tendency was found to continue for higher wave heights, with the extreme heights having maximum energy at periods near 14 seconds for Naples harbor.

Table 2-3 of the summary provides information on local wind waves for fetch limited conditions. Note that Table 2-3 wave heights are lower than those given by Brody and Nestor (1980). Their values appear to be based on the co-cumulative spectra from H.O. 603 (Pierson, et al., 1955). The H.O. 603 approach has been found to over forecast wave heights. Table 2-3, repeated here as Table 3-4, is based on the JONSWAP model (Hasselmann et al., 1976 and Thornton, 1986) which was developed using observed wave conditions in an enclosed sea (see Appendix A).

Local wind wave conditions provided in Table 3-4 are for Naples point 1 (Figure 3-2). In Table 3-4 the fetch lengths are related to site specific (point 1) directions. However, resulting wave conditions versus wind speed are applicable to any direction and/or location with the given fetch lengths. The time to reach fetch limited height is based on an initial flat ocean condition. When starting from a pre-existing lower wave height, the time to fetch limiting height will be shorter.

<u>Example: Small boat wave forecast</u> (based on the assumption that swell is not a limiting condition).

<u>Forecast for Tomorrow</u>:

Time	Wind	Waves
prior to 0700 LST	light and variable	< 1 ft
0700 to 1200	ENE 8-10 kt	< 2 ft
1200 to 1500	SE 22-26 kt	3 ft at 4 sec by 1400
1500 to 2000	SE 28-32 kt	4 ft at 4 sec by 1600-1700
2000 to 2200	SE 14-18 kt	3 ft or less at 4 sec by 2100

<u>Interpretation</u>: Assuming that the limiting factor is waves greater than 3 feet, small boat operations would be marginal by 1400 and restricted from about 1600 to 2100. Night operations could commence after 2100.

Table 3-4. Naples Bay near point 1. Local wind waves for fetch limited conditions related to point 1 (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \ (n mi)	Local Wind Speed (kt) 18	24	30	36	42
ESE 6 n mi	1-2/3 1	2/3 1-2	2-3/3-4 1-2	3/3-4 1-2	3-4/4 1-2
SE 12 n mi	2-3/4 2	3/4 2	3-4/4 1-2	4-5/4-5 2	5-6/5 2
S 30 n mi	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined height is only 1.4 times the common height. In cases where one of the heights is twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave data uses and considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period, and therefore length of wind waves, is generally short relative to the period and length of waves propagated into the harbor. The shorter period and length result in wind waves being characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond in different motions to the different wave lengths present. The information on wave periods and lengths (see Appendix A and other tables) should be considered when forecasts are made for joint operations of various length vessels.

3.7 Protective/Mitigating Measures

3.7.1 Moving to new anchorage

When a relatively high wind from southeast clockwise through south is forecast, a more favorable anchorage may be found in the lee of the mountains near Sorrento or Castellammare southeast of Naples. In the case of force 5 winds (17-21 kt, or greater), it is best to leave the designated Naples anchorage and move to the Gulf of Pozzuoli.

3.7.2 Sortie/remain in port

Local port authorities recommend that aircraft carriers leave the inner harbor if winds greater than force 5 (17-21 kt) are forecast. Also, it is dangerous to bring an aircraft carrier or tender in/out of the inner harbor with southwest winds greater than 20 kt. Because of impaired ship handling, a sortie should be completed prior to the onset of 20 kt winds.

3.8 Local Indicators of Hazardous Weather Conditions

The conditions which pose the greatest potential for difficulties in the Port of Naples include: (1) southwesterly winds and waves caused by a transient "Genoa low" and its associated front/trough, (2) southeasterly winds and waves, and (3) the northeasterly winds of Tramontana origin. The following guidelines may provide some insight into each phenomenon and assist in gaining some forewarning of each event.

Southwesterly winds and waves - While southwesterly winds and waves may be caused by other situations, the most common circumstance is a southerly moving low pressure center which has been generated in the Gulf of Genoa. One indicator of such a development is cold air advection southward at 850 mb and 700 mb during the period September to May. Other indicators include:

* If 3 isobars (with 4 mb spacing) can be drawn across Italy (lower pressures in the northwest sector), strong southwesterly flow can be expected at Naples if steepening gradient is forecast. An equivalent indicator for those ships/individuals with access to weather reports, but without weather charts, would be a difference of 16 mb or more in the sea level pressures between locations in northwest Italy such as Genoa, Milan, or Turin and reporting stations in southern Italy, such as Brindisi, Taranto, or Reggio.

* If the wind increases from the southwest at Isola di Ponza (located about 60 n mi west-northwest of Naples harbor), Naples will have strong southwest winds 3-6 hours later.

* If winds at Isola di Ustica (located about 135 n mi south-southwest of Naples harbor, north of Sicily) increase from the southwest, watch for strong winds at Naples. When winds at Ustica shift to west or northwest, southerly winds will die down in Naples about 3 hours later.

* Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be strongest in advance of the trough.

* Winds at Naples' Capodichino Airport can be misleading. Increasing southwesterly winds are generally 10-15 kt <u>less than at the anchorage</u> while northeasterly winds are stronger.

* A 4 mb pressure difference between Ustica and Rome (Rome lower) will produce southwesterly winds of gale force (≥34 kt) at Naples. Watch hourlies.

* After southwesterly winds shift to west or northwest following a trough passage, southwesterly waves will normally die down within 12 hours. If the low/trough was slow moving, southwesterly waves may persist at Naples for 2-3 days. Thunderstorm development over Sardinia and Corsica often indicates a secondary trough which can bring renewed southwesterly flow problems to Naples with a 4-6 hour time lag.

<u>Southeasterly winds</u>

* When Comiso, Sicily (located near the southeast tip of Sicily near Capo Passero) has a southerly gale, Naples will have a southeasterly gale within 6 hours.

<u>Northeasterly winds (Tramontana)</u>

* When northeasterly winds increase at Split, (LYST) or Novodovno, Yugoslavia (LYDW), Naples will get them 6 hours later.

* When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is 12 mb or more, (with Venice higher) Naples will get gale force (≥34 kt) northeasterly winds.

* Orographic clouds on the north slope and over Mt. Vesuvius are indicators of potential northeasterly winds.

<u>Scirocco</u> - Although a Scirocco occurrence is not in itself considered hazardous weather, it does bring an invasion of warm, moist air to the region and reduces visibility below desirable limits. One sign of an approaching Scirocco is a thin, yellow colored streak across the southeast sky with a darker tone on top.

3.9 Significant Historical Environmental Events

The following cited examples of recorded (or otherwise substantiated) events are presented to provide insight into how certain environmental conditions can impact fleet operations.

In Port

Ship Type	Month	Environmental Condition	Effect
CV	October	Wind southeast 18-22 kt, waves 6 ft due to low pressure system in Gulf of Genoa (6 ft waves likely reflect combined height rather than local seas alone)	Boating cancelled.
LPH	March	Northerly full gale along coast, 5-10 kt winds in harbor	Example of protection Naples harbor provides from north winds.
LPH	September and October	Wind southwest 30-40 kt Swell 5-7 ft	No way to position ship to avoid hazardous swell and surf in well deck.
LPH	October and January	Wind southeast 10 kt increasing to 20 kt gusting to 30-35 kt due to low pressure system in Gulf of Genoa	High winds in anchorage area.

Unspecified	December	Wind 240°/65 kt Deep trough extended past Balearic Islands into North Africa	Ship dragged two anchors and had to get underway. Two launches lost, accommodation ladder torn off.
Unspecified	January	Wind southwest 28-32 kt with gust to 50 kt, combined waves of 13-15 ft due to low pressure system in Southern Tyrrhenian Sea	Equipment van overturned by high seas, sea wall boulders scattered by high seas, widespread coastal damage.

Adjacent Open Sea

Ship type	Month	Environmental Condition	Effect
LPH	February and June	Fog around Capo Teulado, Sardinia (southwest tip of island)	Landing exercise delayed.
LPH	December	High winds/waves, direction unspecified	Ship had to remain in lee of Sardinia to complete underway replenishment.

3.10 Summary of Problems, Actions, and Indicators

Table 3-5 is intended to provide easy to use seasonal references for meteorologists forecasting for ships using the Port of Naples. Table 2-1 of the summary section summarizes Table 3-5 and is intended primarily for use by ship captains or others where direct forecaster support is not available. Tables 3-2 through 3-4 provide additional information on local wind waves, swell propagated into the harbor, and shallow water climatology. Hazardous conditions are summarized by season in paragraph 3.5 of this section.

Table 3-5. Potential problem situations at Port of Naples - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Mediterranean moored - no nested vessels. Winter Spring Rare in Summer Autumn	a. SW wind - Produces Naples' worst weather when caused by steepening pressure gradient ahead of an approaching low pressure or frontal/trough system. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. A rare event during summer.	a. With SW wind, swell often occurs in the W portions of the inner harbor making entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970). Wind may tend to force ships on/off berths. Instances have occurred where med-moored auxiliary type ships have worked bollards loose during high winds. NAVSUPPACTNAPLESINST 5000.1 (series) lists the following precautionary actions. * Mooring lines should have a maximum of spring. Wire is not desirable. Accordingly, 6", 8", or 10" manila or nylon lines doubled should comprise the riding lines and leads should be as long as practicable. * Lifting strains on bollards resulting from lines running from high stern chocks to bollards directly astern or nearby should be avoided. * Wire and spring lines should be used as preventers only, paralleling the riding lines. Preventers should take no strain until the riding lines have nearly reached their limit of strength. * Wire and spring lay should also have a long lead in order to provide a maximum of catenary in the event it becomes a riding line due to parting of fiber riding lines. * Strain on bollards should be distributed and equalized on as many bollards as practicable. * Chafing gear should be provided on riding lines at each point of wear or friction.	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if a steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours.
Winter Spring Uncommon in Summer Autumn	b. Tramontana wind - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Uncommon in late spring through early autumn.	b. Instances have occurred where med-moored auxiliary type ships have worked bollards loose during high winds. NAVSUPPACTNAPLESINST 5000.1 (series) lists the following precautionary actions. * Mooring lines should have a maximum of spring. Wire is not desirable. Accordingly, 6", 8", or 10" manila or nylon lines doubled should comprise the riding lines and leads should be as long as practicable. * Lifting strains on bollards resulting from lines running from high stern chocks to bollards directly astern or nearby should be avoided. * Wire and spring lines should be used as preventers only, paralleling the riding lines. Preventers should take no strain until the riding lines have nearly reached their limit of strength. * Wire and spring lay should also have a long lead in order to provide a maximum of catenary in the event it becomes a riding line due to parting of fiber riding lines. * Strain on bollards should be distributed and equalized on as many bollards as practicable. * Chafing gear should be provided on riding lines at each point of wear or friction.	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDN), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. SE wind - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Instances have occurred where med-moored auxiliary type ships have worked bollards loose during high winds. NAVSUPPACTNAPLESINST 5000.1 (series) lists the following precautionary actions. * Mooring lines should have a maximum of spring. Wire is not desirable. Accordingly, 6", 8", or 10" manila or nylon lines doubled should comprise the riding lines and leads should be as long as practicable. * Lifting strains on bollards resulting from lines running from high stern chocks to bollards directly astern or nearby should be avoided. * Wire and spring lines should be used as preventers only, paralleling the riding lines. Preventers should take no strain until the riding lines have nearly reached their limit of strength. * Wire and spring lay should also have a long lead in order to provide a maximum of catenary in the event it becomes a riding line due to parting of fiber riding lines. * Strain on bollards should be distributed and equalized on as many bollards as practicable. * Chafing gear should be provided on riding lines at each point of wear or friction.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
Frontal, Winter Spring Orographic, Summer Autumn	d. Thunderstorms - Commonly occurring with/after frontal passages but may be orographically induced in late spring through early autumn. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts.	d. Secure loose gear. Avoid unnecessary personnel activity on weather decks.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. <u>Moored alongside pier/wharf. No nested vessels.</u> Winter Spring Rare in Summer Autumn.	a. <u>SW wind</u> - Produces Naples worst weather when caused by steepening pressure gradient ahead of an approaching low pressure or frontal/trough system. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. A rare event during summer.	a. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast. A swell often occurs in the W portion of the inner harbor during a SW wind and can make entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970).	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if a steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours.
Winter Spring Uncommon in Summer Autumn	b. <u>Tramontana wind</u> - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Uncommon in late spring through early autumn.	b. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast.	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDN), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. <u>SE wind</u> - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
Frontal, Winter Spring Orographic, Summer Autumn	d. <u>Thunderstorms</u> - Commonly occurring with/after frontal passages but may be orographically induced in late spring through early autumn. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts.	d. Secure loose gear. Avoid unnecessary personnel activity on weather decks.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Moored alongside with tended vessels nested. Winter Spring Rare in Summer Autumn	a. SW wind - Produces Naples' worst weather when caused by steepening pressure gradient ahead of an approaching low pressure or frontal/trough system. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. A rare event during summer.	a. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast. A swell often occurs in the W portion of the inner harbor during a SW wind and can make entry, berthing, and cargo handling unsafe (NWSED Naples, Italy, 1970).	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if a steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours.
Winter Spring Uncommon in Summer Autumn	b. Tramontana wind - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Uncommon in late spring through early autumn.	b. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast.	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDW), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. SE wind - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Normal precautions must be taken. Secure loose gear. Wind may tend to force vessels on/off berths. Line doubling or tug assistance may be required to avoid undesirable vessel movement. Aircraft carriers should leave inner harbor if winds greater than force 5 (17-21 kts) are forecast.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
Frontal, Winter Spring Orographic, Summer Autumn	d. Thunderstorms - Commonly occurring with/after frontal passages but may be orographically induced in late spring through early autumn. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts.	d. Secure loose gear. Avoid unnecessary personnel activity on weather decks.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4. Anchored in designated anchorage. Winter Spring Rare in Summer Autumn	a. SW'ly wind and seas - Worst weather condition for ships in outer harbor, and can impact operations in inner harbor. Persistent winds force 4 (11-16 kts) or more can produce problem sea; wind of 35 kts can produce 14-15 ft swell at anchorage. SW'ly swell may persist for 2-3 days after wind dies down. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. Not common during summer.	a. SW'ly wind and seas pose worst weather problems for ships at anchor, with sea causing most problems. When wind and sea are from same direction, anchored vessel's movement is minimized as ship will head into wind. Biggest problem is caused by wave reflection off of Molo San Vincenzo, causing chaotic wave action at anchorage which is higher than SW'ly waves alone. Operation of small craft to/from anchored vessels is often curtailed. Moving vessel to Gulf of Pozzuoli will provide a more protected anchorage.	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if a steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours.
Winter Spring Uncommon in Summer Autumn	b. Tramontana wind - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Not common in late spring through summer. Strong occurrence can raise chop in outer anchorage area but should pose no significant problem to anchored vessels.	b. Chop raised by off-shore wind may impact small boats operating to/from vessels using outer anchorages, but seldom causes cancellation of boating. Sailors may get wet. Secure loose gear.	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDW), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. SE wind - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Seas from SE'ly winds will be minimized because of limited fetch length. Boating to/from anchorage may be curtailed. Conditions can be minimized by moving to SE part of Gulf of Naples near Sorrento or Castellammare.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours. Also seas 8-10 ft in Naples harbor in less than 12 hours should be predicted if SE'ly (130° or more) winds 20-30 kts are occurring along the SW coast of Italy (Brody and Nestor, 1980).
Frontal, Winter Spring Orographic, Summer Autumn	d. Thunderstorms - Commonly occurring with/after frontal passages but may be orographically induced late in spring and through summer. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts.	d. Secure loose gear. Avoid unnecessary personnel activity on weather decks.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.
Winter Spring Autumn	e. Wind and waves out of phase - SW'ly swell can persist for 2-3 days after wind shifts with frontal passage. Anchored vessels will head into wind, bringing swell on port beam and causing ship to roll.	e. As ship heads into wind, vessel will become perpendicular to swell movement, causing rolling. Operation of small boats to/from accomodation ladders and/or wells in amphibious vessels can become unsafe. As wind becomes more N'ly, Naples harbor comes under the protection of terrain. Wind speeds may differ by 40-45 kts between Capri and the outer harbor at Naples.	e. Likely occurrence after frontal passage. Expect up to 12 hour duration unless low/front was slow moving. If the latter is true, swell duration may be extended to 2-3 days. NW'ly wind over Naples harbor will flatten seas generated by a SE-W wind. The stronger the NW wind, the faster the seas will diminish (Brody and Nestor, 1980).

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
5. <u>Arriving/departing harbor.</u> Winter Spring Rare in Summer Autumn	a. <u>SW wind</u> - Produces Naples' worst weather when caused by steepening pressure gradient ahead of an approaching low pressure or frontal/trough system. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. Not common during summer.	a. It is unsafe to bring an aircraft carrier or tender in/out of the inner harbor with SW winds greater than 20 kts. Aircraft carriers should leave the inner harbor if winds greater than force 5 (17-21 kts) are forecast. Also, SW'ly wind will produce N moving current along the shore of Gulf of Naples, so it may be necessary to use tugs to align the ship into the current.	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours.
Winter Spring Uncommon in Summer Autumn	b. <u>Tramontana wind</u> - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Not common in late spring through summer.	b. Aircraft carriers should leave the inner harbor if winds greater than force 5 (17-21 kts) are forecast.	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDW), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. <u>SE wind</u> - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Aircraft carriers should leave the inner harbor if winds greater than force 5 (17-21 kts) are forecast.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
Frontal, Winter Spring Orographic, Summer Autumn	d. <u>Thunderstorms</u> - Commonly occurring with/after frontal passages but may be orographically induced in late spring through summer. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts.	d. Secure loose gear. Avoid unnecessary personnel activity on weather decks.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.

Table 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
6. Small boat operations. Winter Spring Rare in Summer Autumn	a. SW wind - Worst weather condition for ships in outer harbor, and can impact operations in inner harbor. Persistent winds force 4 (11-16 kts) or more can produce problem sea; wind of 35 kts can produce 14-15 ft swell at anchorage. SW'ly swell may persist for 2-3 days after wind dies down. Winds exceeding gale force (≥34 kts) with higher gusts are not uncommon. Frequency of occurrence diminishes rapidly after April. Chaotic sea that is raised in anchorage adjacent to Molo San Vincenzo makes boating conditions hazardous if not impossible. Swell sometimes enters inner harbor through main channel at end of Molo San Vincenzo causing problems with boats operating from vessels moored therein. A rare event during summer.	a. SW'ly wind and seas pose worst weather problems for ships at anchor, with sea causing most problems. When wind and sea are from same direction, anchored vessel's movement is minimized as ship will head into wind. Biggest problem is caused by wave reflection off of Molo San Vincenzo, causing chaotic wave action at anchorage which is higher than SW'ly waves alone. Operation of small craft to/from anchored vessels is often curtailed. Moving vessel to Gulf of Pozzuoli will provide a more protected anchorage. Small boat operations in inner harbor should be minimally affected.	a. Strong SW'ly winds (and resultant seas) are caused by a steepening pressure gradient associated with low pressure/frontal system. Advance indicators include: * Cold air advection southward at 850 mb and 700 mb. * If 3 isobars (with 4 mb spacing) can be drawn across Italy, strong SW'ly flow can be expected at Naples if steepening gradient is forecast. * If the wind increases from the SW at Isola di Ponza, Naples will have strong SW winds 3-6 hours later. * If winds at Isola di Ustica increase from the SW, watch for strong winds at Naples. When winds at Ustica shift to W or NW, winds will die down in Naples about 3 hours later. * Naples' wind will increase when the steepest gradient moves into the region. Although post-frontal winds can be strong, the winds will generally be stronger in advance of the trough. * Winds at Naples' Capodichino Airport can be misleading. Building SW'ly winds are generally 10-15 kts less than at the anchorage. (Wind information can be obtained via 344.6 MHz Pilot-to-Forecaster service.) * A 4 mb pressure difference between Ustica and Rome will produce SW'ly winds of gale force (≥34 kts) at Naples. Watch hourlies. * After SW'ly winds shift to W or NW following a trough passage, SW'ly seas will normally die down within 12 hours. If the low/trough was slow moving, SW'ly seas may persist at Naples for 2-3 days. * Thunderstorm development over Corsica or Sardinia often indicates a secondary trough which can bring SW'ly flow problems to Naples in 4-6 hours. Also, steady winds of 15 kts or more for a period of 12 hours or more at the following stations will adversely affect boating in the harbor at Naples (Brody and Nestor, 1980). Winds from south or southwest at: Sciacca, Sicily (LICS), Ustica, Sicily (LICU), or Trapani, Sicily (LICI), Winds from the west or northwest at: Guardiavecchia, Sardinia (LIEG), Solenzara, Corsica (LFKS), Ajaccio, Corsica (LFKJ) or Bastia, Corsica (LFKB).
Winter Spring Uncommon in Summer Autumn	b. Tramontana wind - Strong NE'ly wind which may reach gale force (≥34 kts). Caused by cold outbreak in N Italy forcing air through mountain passes. Strongest in daylight hours. Minimal impact on inner harbor operations. Not common in late spring through summer. NE'ly winds to 35 kts don't significantly affect boating because of off-shore component and limited fetch.	b. Chop raised by off-shore wind may impact small boats operating to/from vessels using outer anchorages, but seldom causes cancellation of boating. Sailors may get wet. Secure loose gear. Because of fetch limitations, NE winds over Naples harbor will seldom generate seas to hamper boating conditions (Brody and Nestor, 1980).	b. Advance indicators of NE'ly winds include: * When NE'ly winds pick up at Split (LYST) or Novodovno (LYDW), Yugoslavia, Naples will get them 6 hours later. * When the pressure difference between Corfu, Greece (LGKR) and Venice, Italy (LITA) is ≥12 mb (Venice higher), Naples will get gale force (≥34 kts) winds. * Orographic clouds on the north slope and over Mt. Vesuvius. * Fast moving cold fronts approaching from the west produce surface NE'lys in the Naples area following frontal passage. A good indication of frontal passage at Naples is the wind's becoming variable 10-15 kts at Capri and Capo Palinuro.
Winter Spring Uncommon in Summer Autumn	c. SE wind - Most often occurs in advance of approaching low pressure system/trough. Frequency of occurrence diminishes rapidly after April.	c. Boating in outer harbor may be curtailed. Inner harbor operations should not be affected.	c. When Comiso, Sicily has S'ly gale (≥34 kts), Naples will have SE'ly gale within 6 hours.
Frontal, Winter Spring Orographic, Summer Autumn	d. Thunderstorms - Commonly occurring with/after frontal passages but may be orographically induced in late spring through early autumn. May be accompanied by hail. Associated peak gusts normally are about 40-45 kts with mean speeds of 20-25 kts. Passing thunderstorms can disrupt boating for 1-2 hours.	d. Small boat operations may be curtailed for 1-2 hours during thunderstorm passage.	d. During winter in the Naples area, it appears that convective activity reaches its greatest intensity over the water just before moving inland, so the same situation should apply to early spring storms. The associated showers are much weaker at Capodichino Airport than on the coast (Brody and Nestor, 1980). Orographically induced storms, such as those of late spring through early autumn, would not be expected to have the same characteristics. Summer thunderstorms usually develop over the Apennine Mountains or Mt. Vesuvius, and may drift over the Naples harbor area.
Late Spring Summer Early Autumn	e. Sea breeze - SSW-W'ly wind commonly occurring during period 1000-1700 daily on warm days. Most often in force 3-4 (7-16 kt) range.	e. Sea breeze will raise chop in outer harbor but will seldom hamper boating. Sailors may get wet.	e. Can be expected daily in warm weather. * Orographic clouds form on the west and south slopes of Mt. Vesuvius during sea breeze conditions.

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PORT VISIT INFORMATION

JUNE 1985. NEPRF meteorologists R. Fett and R. Picard met with NOCD meteorologists LT Thayer and Chief Massman, Port Captain RADM Marzio and Sr. Pilot Mr. Fappiano to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch \ Length \ (n mi)	Wind Speed (kt) 18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

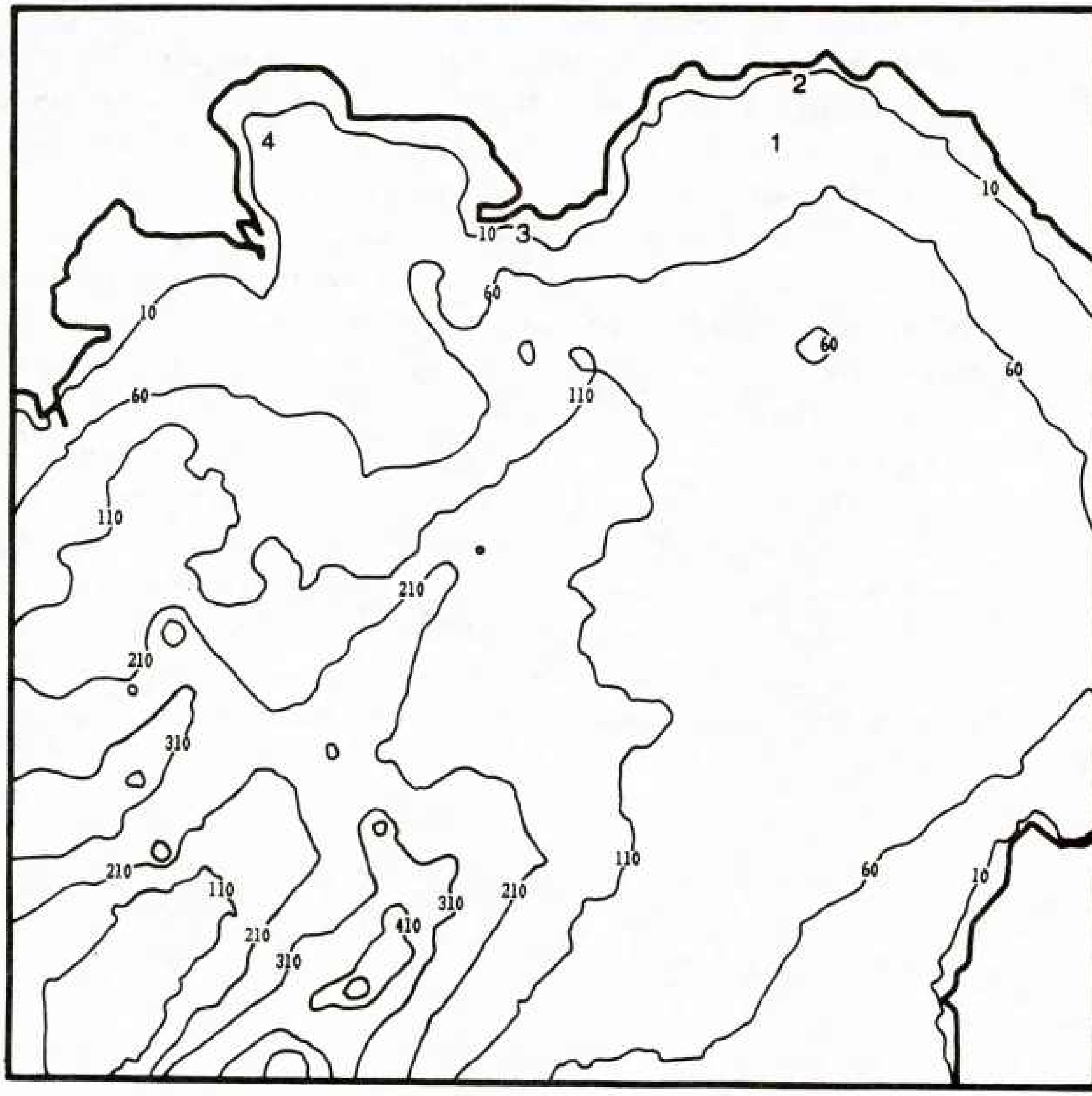

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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