STORM IN THE GULF OF THE FARALLONES: A SAILING DISASTER (10–11 APRIL 1982)

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Abstract

This paper investigates the development of the 10–11 April 1982 storm and its effect on sailing craft in the Gulf of the Farallones, the ocean approach to San Francisco. The storm was one of the area's most severe April storms known to date. New April wind speed records were set at San Francisco Airport on 10 April. The storm caused one of the worst small craft sailing disasters ever to occur in the area. This was in part due to over 100 small craft involved in a race to the Southeast Farallon Island. Six lives and seven sailing vessels were lost. Seventeen people and seven sailing vessels were rescued, mostly by the U.S. Coast Guard. The storm's severe impact was due to the suddenness and severity of its onset, the exceptional impact of wind, weather, waves and current in combination and the storm's duration. Its effect would have been more devastating had it not been for the rescue effort, the National Weather Service warnings that went out on the VHF marine radio channel and numerous cases of outstanding personal survival efforts.

Surface and upper air synoptic patterns are discussed. Hourly profiles of wave, wind, and rain data are given. The problems in forecasting the storm are described and the usefulness of enhanced infrared satellite imagery in analyzing and forecasting the storm is emphasized. Comments relative to the forecasting of serious weather events and a summary of the incidents involving the loss and rescue of people and vessels are presented.

1. Introduction

This is an article about the rapid development of a great April storm and its disastrous effect on people sailing in the ocean area west of San Francisco. The storm is considered from the forecaster's and the forecast user's point of view. It is hoped that this kind of presentation will be of interest and value to the meteorologist and sailor alike.

This section is given to presenting the geographical and navigational features of the Gulf of the Farallones and an overview of the sailboat race which led to over 100 boats being at risk on the day of the storm. In the following sections discussion will focus on the availability of data and definitions of terms, the temporal and spatial aspects of the surface and upper air meteorological conditions which preceeded the severe weather, the problems in forecasting the storm, the critical role of the enhanced infrared satellite photos in preparing the forecast, the nautical situation during the storm, and a summary of the boating incidents which resulted.

A. Geographical Features

As shown in Fig. 1, the coastline from Pt. Reyes southeastward to Pt. Bonita forms the northern boundary of the Gulf. The shaded area shows where the losses and rescues of people and vessels occurred, namely on or offshore from the northern boundary. Four reference features of the coastline are Drakes Bay, Duxbury Pt., Bolinas Bay, and the Golden Gate Bridge (GG). The area from Duxbury Pt. to the GG is noted for its strong northward flowing currents during heavy weather with strong southerly winds, according to Yetty (1988). There is no harbor of refuge along the northern boundary nor any anchorage that is protected from southerly winds. Pt. Bonita shows three heads. The lighthouse and the weather station are on the south head. The light is shown from a tower 124 ft above the water.

The coastline from Pt. Bonita southward to Half Moon Bay forms the Gulf's eastern boundary. The only harbor of refuge in the entire Gulf is just east of Pillar Pt.

The Farallon Islands mark the Gulf's western extent. The islands are a small rocky chain of islets extending 11 n mi northwestward from the Southeast Farallon Island. This island is only 95 acres in size. The few personnel that reside there are mostly involved in operating the lighthouse, the radio direction beacon or in supporting the work of the Farallon National Wildlife Refuge, which surrounds the entire island chain. There is no harbor of refuge nor any anchorage there.

The Fourfathom and South Banks flank the main channel to the west of the GG. The banks mark a submerged shallow area that extends in an arc from Pt. Bonita seaward some 7 n mi then back to the coast about 5 n mi south of Pt. Bonita. The shallow water can create hazardous sea conditions, particularly when the tidal current is ebbing and a west swell is occurring. The ebb current is accelerated through the GG. Once it passes Pt. Bonita, the ebb current fans out through the Bonita Channel, the main ship channel and the South Channel at a reduced speed. The most hazardous place is the shallowest part of Fourfathom Bank, the infamous Potatopatch Shoal.

B. Navigational Buoys

According to the National Ocean Survey (NOS, 1978), there are 12 navigational buoys (Fig. 1). Eight of these mark the main channel as it cuts between the Fourfathom and South Banks. These are numbered starting from the seaward side. All the even-numbered buoys are to the right and the odd numbers to the left as one approaches from the sea. Buoys "7" and "8" are identified in Fig. 1. Large vessels (e.g., tankers and container ships) must stay in this channel. Sailors typically use sightings of these buoys to confirm their boat's location and to avoid large vessel traffic.

The large navigational buoy "SF" marks the center of the precautionary circle. The precautionary circle passes through buoys "A", "B", and "C". These buoys also mark the center of the separation zones, which divide the three traffic approaches into the inbound and outbound traffic lanes used by large vessels. The separation zone for the northern traffic lane extends to the northwest of buoy "C." The separation zones for the main and the southern traffic lanes extend

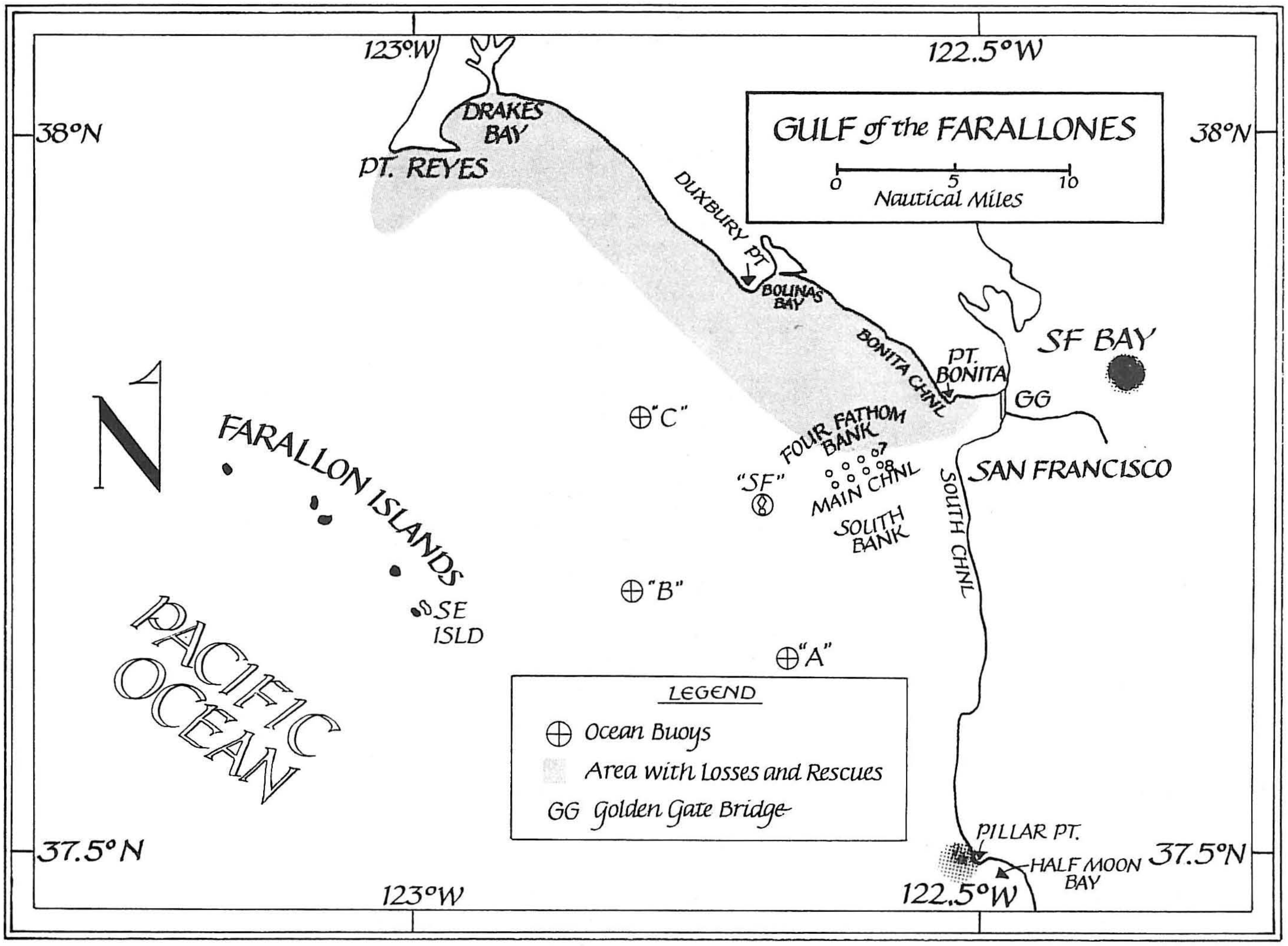

Fig. 1. Gulf of the Farallones. The sailing race course on 10 April 1982, was from the Golden Gate Bridge, around the Southeast Farallon Island, and back. Shaded area is where boats and people were lost or rescued.

to the southwest and to the south southeast of buoys "B" and "A", respectively.

C. Overview of the Race

The Double-handed Race from the San Francisco waterfront, just east of the GG, around the Southeast Farallon Island and back was a western sailing event for April, 1982. A total of 159 boats filed entry forms, and 127 actually started the race. The official starting time was 0800 PST 10 April. The National Weather Service (NWS) broadcast a gale warning on the VHF radio weather channel at 0800 PST. The racing boats ranged in size from 20 to 61 ft length overall (LOA). The first boat to complete the 57 n mi course (a 36-ft catamaran) crossed the finishline at 1501 PST. The fastest three monohulls (50–55 ft LOA) finished between 1517 and 1555 PST. Thus, these larger and faster boats eluded the worst part of the storm which developed in the afternoon. The first small boat (30 ft LOA) finished at 1702 PST. Forty boats officially finished. At least four remained at sea overnight. The last boat to return on its own arrived around 1800 PST 11 April.

Following the race, serious questions were raised as to why the sailors went out in spite of the NWS gale warnings. Questions were also raised about: the lack of communication between the race's organizing committee and the NWS, the responsibilities of the race committee on 10 April, including why the race was not canceled, and the conduct of several rescue efforts.

2. Availability of Data and Definitions of Terms

In this section, the available data and the locations of the reporting stations are identified. The definitions of the wind and wave terms used in the article are also presented.

A. Availability of Meteorological Data

The key data available for the study area are listed in Table 1. The locations of the reporting stations are shown in Fig. 2. As shown, the coastal area with surface observations pertinent to this article extends from Pt. Arena southward to Pt. Pinos and Pt. Sur. This is also the area covered by the NWS

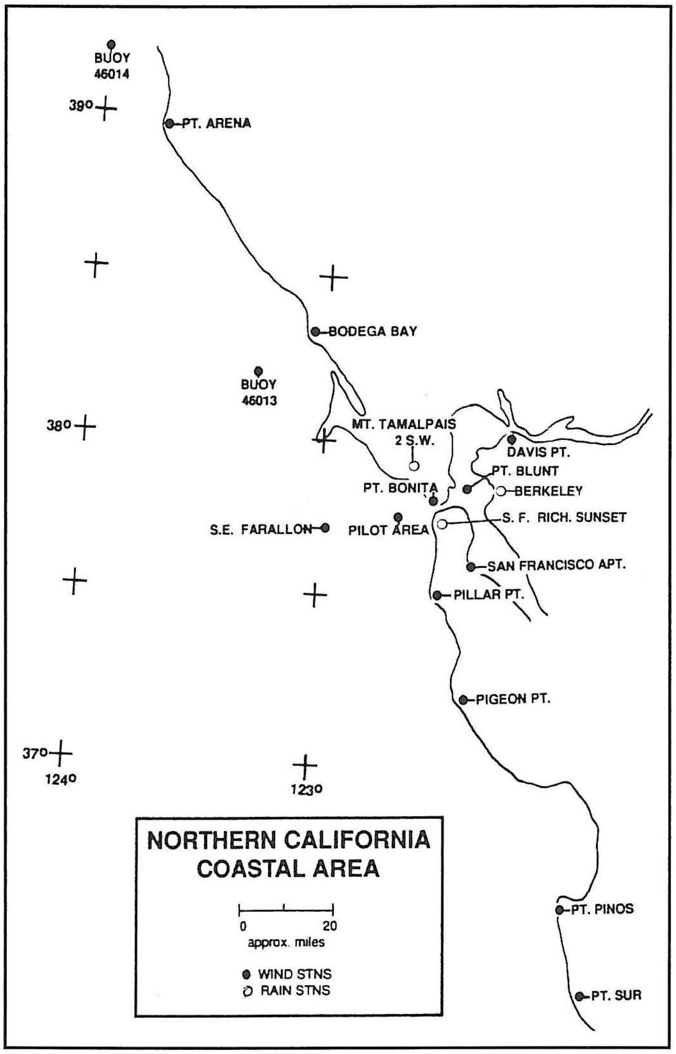

Fig. 2. Locations of weather reporting stations in the coastal area of northern California. The availability of data from these stations is given in Table 1.

Table 1

Availability of Selected Surface Meteorological Data (North to South), 10-11 April 1982

Station*	Freq of obs*	Peak wind*	Wind gust*	Wave ht*	Hrly pcpn*
Buoy 46014	hourly		x	x	
Pt. Arena	3-hourly	x			
Bodega Bay	3-hourly				
Buoy 46013	hourly		x	x	
Davis Pt.	3-hourly	x			
Mt. Tam.					x
Berkeley					x
Pt. Blunt	3-hourly	x			
Pt. Bonita	3-hourly	x			
Pilot Vsl.	3-hourly			x	
SF Richmond					x
SE Farallon	06,09,15			x	
SF Airport	hourly	x	x		x
Pillar Pt.	3-hourly				
Pigeon Pt.	3-hourly	x			
Pt. Pinos	3-hourly				
Pt. Sur	3-hourly				

* Locations given in Fig. 2, definitions in Sec. 2. Regular wind ob is at frequency stated.

coastal marine forecast described as "Pt. Arena to Pt. Pinos and out 60 miles."

As shown in Table 1, there were a total of 17 surface observation stations within the coastal area and the northern part of San Francisco Bay. Four of these stations reported hourly rainfall, according to the National Climatic Data Center (NCDC, 1982). The two buoy stations reported significant wave height (SWH); the SF Pilot Vessel and Southeast Farallon Island reported estimates of wave and swell height. Hourly wind and wind speed gust data were reported from the buoys and from San Francisco Airport (SFO). Nine land stations reported three-hourly wind observations; five of these also reported the peak wind speed that had occurred between the regular observations. SFO also reported peak wind speed and direction whenever the regularly observed wind speed was gale force or greater.

The surface synoptic charts referred to in this article were those prepared by the NWS National Meteorological Center (NMC) on 9–11 April 1982 and were obtained from NCDC. The synoptic upper air charts referred to were taken from the NMC facsimile transmissions of the original charts for 9–11 April 1982. Upper air data were available from the regular stations in the western United States. However, no data were available for the former ship station at 30°N–140°W.

The satellite photos that were used at the SFO Forecast Center on 10 April were obtained from San Jose State University.

The buoy (46013 and 46014) data were obtained from the National Oceanographic Data Center (NODC). There were no data available for buoy 46026, the only other buoy in this area. The logs from the San Francisco Pilot Vessel were obtained from Ware (1990). Only three observations a day were available from the Southeast Farallon Island station, and no data were available for the late afternoon and night of 10 April.

The lack of offshore surface and upper air measurements in the area where the storm developed made it exceptionally difficult for forecasters to anticipate this storm. Even in the retrospective analysis, where additional data as well as backward continuity were used, it was difficult to completely document the storm's development. This limit on the storm analysis was offset, in part, by additional information obtained in 1987–1989 (that was not available in April 1982).

This information included: reports of conditions offshore obtained during interviews with sailors who were out there on 10–11 April 1982, various documents from the U.S. Coast Guard (USCG) Search and Rescue Office obtained from Jones[1] (personal communication 1988), conferences with Lay[2] (personal communication 1988) and other meteorologists who were stationed at the NWS San Francisco Forecast Center in 1982, the publication by NODC (1982), and the report by Grotjahn (1987).

In conclusion, it should be noted that the lack of hourly surface observations along the coastline made this analysis dependent on three-hourly observations. That is why the discussion about wind severity largely revolves around the "peak winds" reported at the three-hourly stations. Fortunately, SFO was exposed to this storm, so there is a benchmark of hourly data which provides concurrent information about hourly wind speeds, wind speed gusts, and peak wind speeds during gale force conditions. On occasion, sailor's "quotes" have been given to complement the more conventional meteorological information. Quotes taken from other sources and a sample of quotes taken from personal interviews have been referenced, but it has not been feasible (nor did it seem necessary) to reference the entire body of interview information.

B. Definitions

The definitions apply to the data in this article. Some of the three-hourly reporting stations had equipment that enabled the station to record "peak wind speed." At these stations, the peak wind speed was the highest speed recorded during the period between the current observation and the observation taken three hours earlier.

The hourly reports from SFO contained peak wind direction, speed and time of occurrence whenever gale-level or higher wind speeds were occurring (34–47 kt or higher). The peak wind speed was the highest speed recorded during the period between the current observation and the observation taken one hour earlier.

The two buoy stations (46013 and 46014) did not report peak wind data. For these stations, the "wind gust" was used as a measure of wind severity. The wind gust was the highest 8-sec window average obtained during an 8.5 min period. The 8.5 min period was the averaging time for the regular wind speed measurement, according to NCDC (1986).

The observed wind speeds reported by the coastal weather stations and the wind speeds given in the NWS forecasts are for "sustained winds only", according to Goudeau[3] (personal communication 1983) in the "Summary of Weather Observations and Forecasts Issued 10 April 1982." This is an important definition to recall when considering the forecasts given in section 5. It is also important to recognize that a value of sustained wind speed measured on an hourly or three-hourly schedule is not a fair measure of the wind severity experienced by a sailboat crew continuously exposed to the wind for a period of 10 to 40 h.

The two buoy stations reported wave height in terms of the "significant wave height" (SWH). The SWH is the average height of the highest one-third of the wave train. Once the SWH is known, an estimate can be made as to the range of wave heights that might be encountered. According to Lilly (1985), the average of the highest 10% of the waves is 1.3 × SWH, the average of the highest 1% of the waves is 1.7 × SWH, and one wave in 1,175 is 1.9 × SWH.

The Pilot Vessel reported an estimated sea height and swell height based in large part on the degree of the vessel's pitch and roll. In 1982, the typical terms used were "light, moderate and heavy." Light indicated heights less than 8 ft, moderate indicated 8 to 15 ft, and heavy indicated seas or swells more than 15 ft. A report was given for sea height and a separate report was given for the swell condition. In heavy seas, the concurrent wind speed was typically greater than 35 kt, according to Capt. Steven Ware, one of the pilots.

3. Synoptic Patterns

In this section, the general nature of the surface circulation over a large area of the North Pacific Ocean on 5 April is discussed, followed by the 500-mb, 850-mb and surface synoptic situations for the period 5–11 April.

A. General Nature of the Surface Circulation

A large-area view of the circulation at 1000 mb for 1600 PST 5 April is given in Fig. 3, according to Grotjahn (1987). As shown, a large, strong high pressure cell dominated circulation in the Alaskan Gulf and the area southward to about 35°N. This high blocked storms from following their normal path across the North Pacific. Blocking patterns have generally been an important feature of the general circulation in many major California storms, according to Weaver (1959). The predominance of meridional flow at the expense of zonal flow is characteristic. Storm tracks are diverted around the blocking highs, which establish themselves at middle and high latitudes.

This particular high intensity storm of relatively short duration appears to be similar to one of the types described

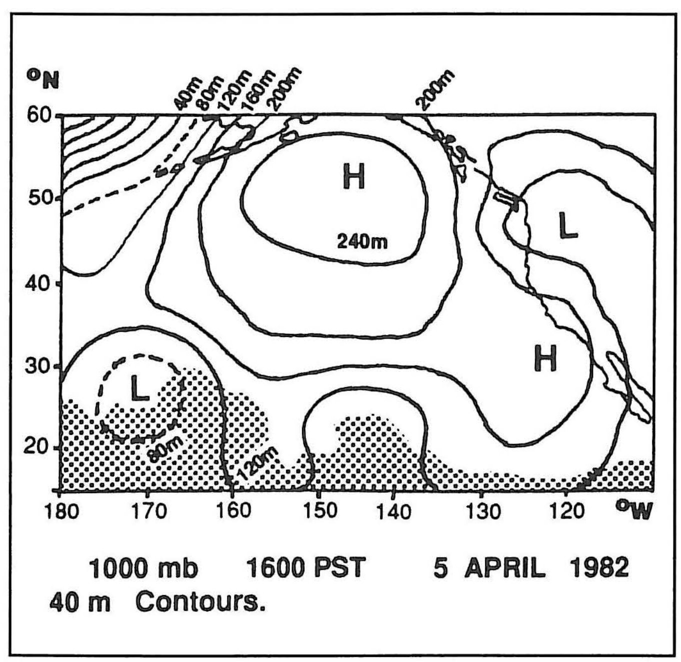

Fig. 3. A large-area view of the 1000-mb analysis on 5 April 1982. The incipient low, which was to develop into the storm that hit the northern California coast on 10 April, is shown near 24°N–143°W. The shaded area indicates a moisture level greater than 15 gm Kg^{-1}. Figure is based on chart by Grotjahn (1987).

1. R. S. Jones; U.S. Coast Guard, Maintenance and Logistics Command Pacific, General Law Branch, Alameda, CA 94501.
2. R. Lay; NWS Forecast Office, Honolulu, HI 96819.
3. D. Goudeau; NWS Forecast Office, Redwood City, CA 94063.

by Weaver. In that type, the block occurs in the eastern Pacific east of 160°W, the storm develops at low latitude, and a "trapped low emerges from the southwest to begin the storm." Rainfall is typically high in such a storm, and flood potential is markedly increased. One result of the blocking high shown in Fig. 3 was the appearance and development of two surface lows at southerly latitudes. The easternmost low was near 24°N–143°W and was the one which developed into the storm. The incipient low meandered eastward until the morning of 9 April, according to NODC (1982), when it reached a position near 30°N–135°W. It then underwent rapid cyclogenesis and moved quickly toward the north-northeast.

The 1000-mb chart given in Fig. 3 was chosen for reference because it covers a large area, and it also shows the area with a moisture level above 15 gm kg^{-1}. As shown, there was a moisture tongue to about 25°N in the easternmost low.

B. The 500-mb Circulation

The 5520 m contour, as shown in Fig. 4 for 0400 PST 5 April, defined a ridge which intruded into the Alaskan Gulf from the west. The southern extremity of this contour was at 39°N and helped define an incipient low centered about 200 n mi west of Seattle. The −35°C isotherm was oriented NNE-SSW from about 70°N–115°W to a position just south of the low center (46°N–130°W). This pattern persisted for days and was conducive to the advection of cold air to the south-southwest down the western edge of the extensive 500-mb trough.

During the course of the next two days (6th and 7th), the ridge continued to move eastward into Canada, while the advection of cold air shifted more towards the southwest, consistent with the strong northeasterly airflow which existed under the ridge from western Canada into the Pacific Ocean.

By 0400 PST 8 April, the elongated trough was oriented near east-west, and a closed low center had formed off the northernmost California coast (40°N–130°W). The temperatures in the low center were about −30°C.

As shown in Fig. 5 for 0400 PST 9 April, the low center had separated from the elongated trough and moved to the southwest. By 0400 PST 10 April, the low center was near 32°N–140°W. Temperatures in the northwest quadrant were now about −25°C.

The 500-mb pattern that was available to the forecaster on the evening shift the day before the storm is given in Fig. 6. The 0400 PST positions of the surface low centers for 8–11 April are also shown. The apparently large northward movement of the low center from 10–11 April was associated with the lowering of heights over the Alaskan Gulf due to the passage of a trough. It is also plausible that the low center on 10 April was further north than indicated by the original analysis shown in Fig. 6. As shown by the southern extremity of the −20°C isotherm, relatively cold air had reached to 28°N. The contour pattern to the east of the low center indicated a strong and broad southerly flow in the area from 28–38°N and 127–135°W, conditions favorable for the north-

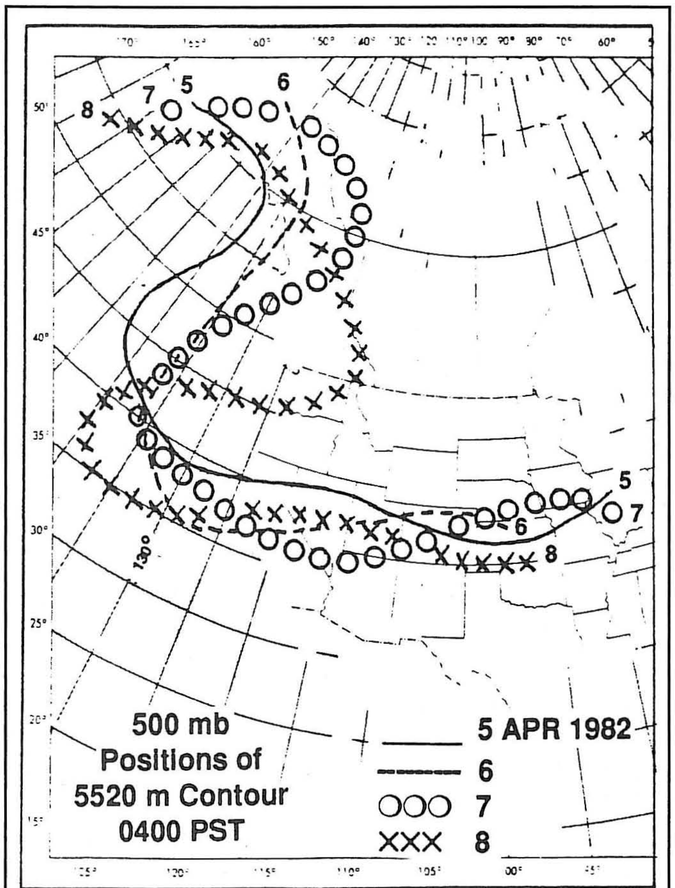

Fig. 4. Four daily positions of the 5520 m contour taken from the published NMC 500-mb charts for 5, 6, 7 and 8 April 1982.

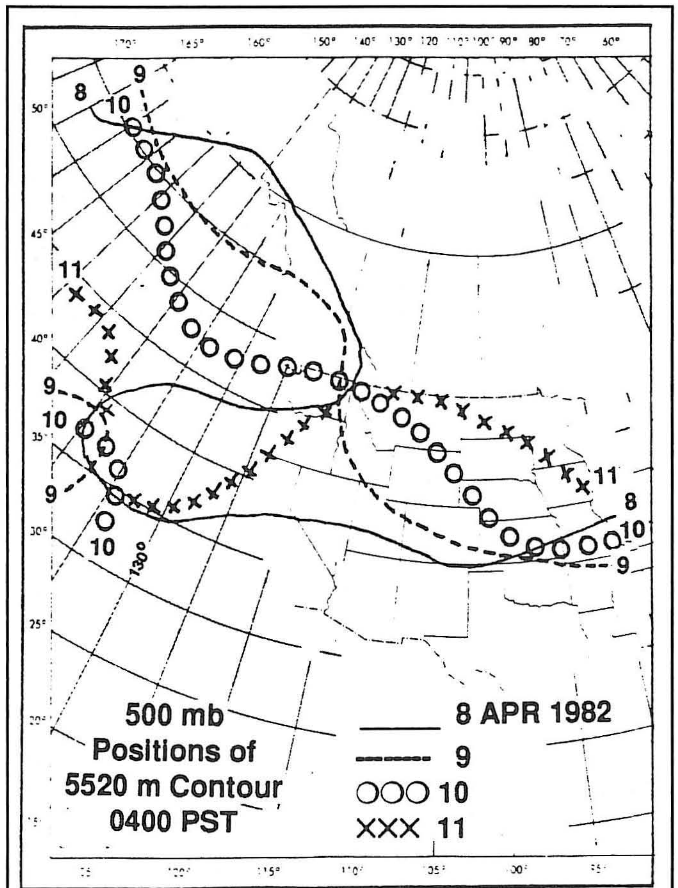

Fig. 5. Four daily positions of the 5520 m contour taken from the published NMC 500-mb charts for 8, 9, 10, and 11 April 1982.

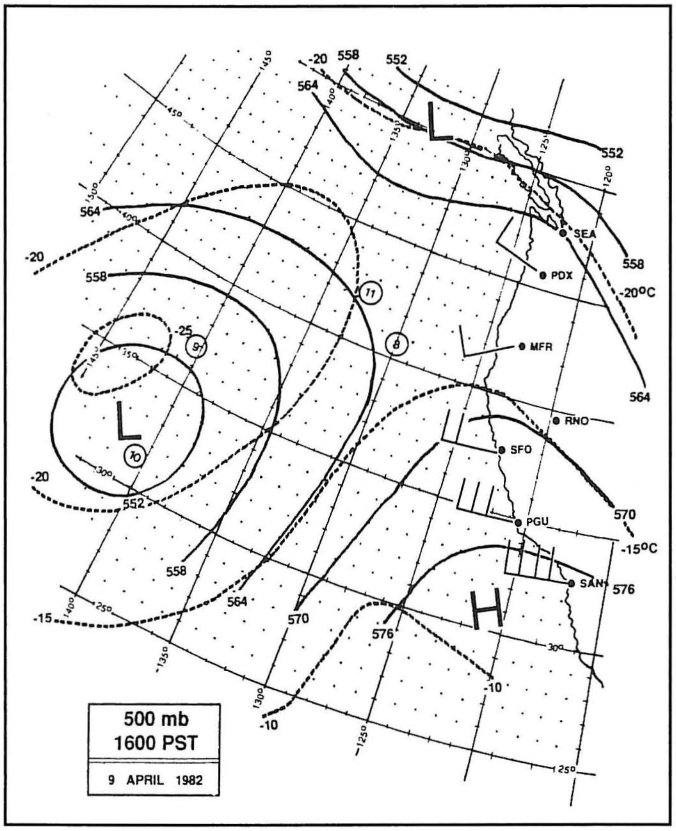

Fig. 6. Contour and isotherm pattern at 500 mb for 1600 PST 9 April 1982. Surface low centers for 0400 PST 8–11 April are shown by circled numbers. Figure is based on original NMC facsimile transmissions.

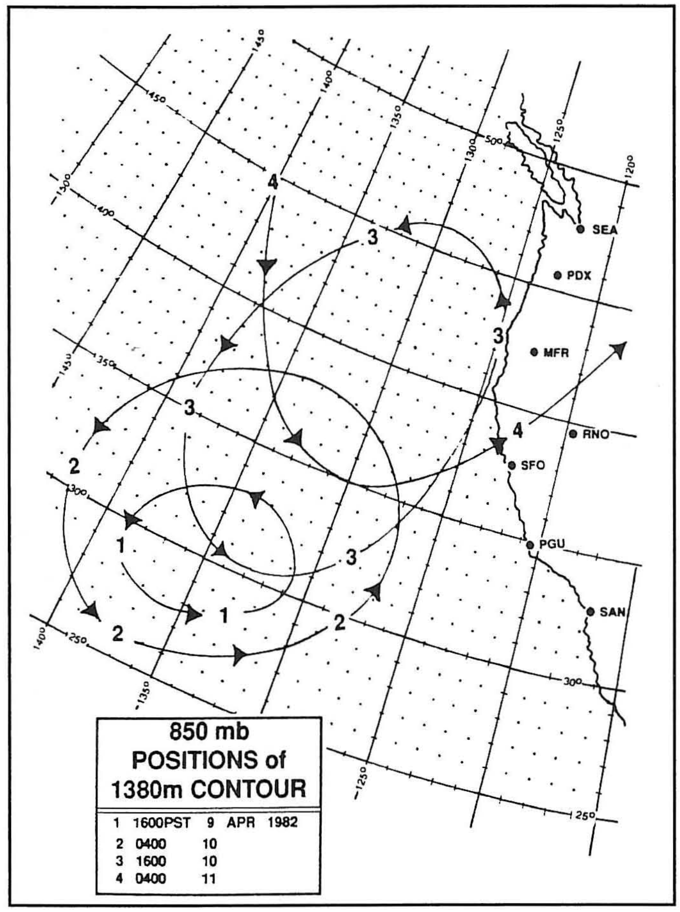

Fig. 7. Four 12-h positions of the 1380-m contour at 850 mb beginning at 1600 PST 9 April 1982. Figure is based on NMC original facsimile transmissions.

ward advection of moist subtropical air. No upper air data were available from the former ship station at 30°N–140°W. Hence, the analysis available in April 1982 and given in Fig. 6 was somewhat tenuous. From a forecast standpoint, the 500-mb pattern suggested the storm would be a major rain producer, and that was the nature of the NWS area forecast issued at 2100 PST 9 April.

C. The 850-mb Circulation

Four 12-h positions of the 1380-m contour at 850 mb are given in Fig. 7 to provide an overview of the changes in circulation which took place from 1600 PST 9 April to 0400 PST 11 April. The formation of a closed low was completed by stage 1 (1600 PST 9 April). By stage 2, there had been a major deepening and several degrees of latitude movement northward. By stage 3 (1600 PST 10 April), there had been continued deepening and about seven degrees movement to the north-northeast. By stage 4, the low center had merged into the northern trough.

D. Surface Circulation

In this section, the continuity of the surface low center and the frontal system associated with it is discussed. This sets the stage for the severe weather and forecast discussions given in sections 4 and 5.

The 1600 PST locations and central pressures of the low centers for 6–10 April have been estimated by retrospective analysis. They are shown in Fig. 8 along with the analysis of the surface synoptic chart for 1600 PST 10 April. In the retrospective analysis, the data sources listed in section 2 were used, as well as all the original data available in April 1982, particularly the satellite imagery.

As shown in Fig. 8, the retrospective analysis shows the low center moved generally eastward and deepened about 9 mb during the two-day period (1600 PST on the 6th to 1600 PST 8 April). It then appears to have moved generally northward and deepened about 15 mb during the next two-day period (1600 PST on the 8th to 1600 PST 10 April). There is little difference between the retrospective and the original analyses during the first 48-h period. However, the trajectory of the low center on the retrospective analysis is quite different than that given on the original analysis for the 36-h period beginning 1600 PST on the 8th. For example, the low center on the original analysis for 1600 PST the 9th was at 31°N–135°W, NODC (1982). As shown by the retrospective analysis in Fig. 8, the center appears to have been well to the north and east of that indicated in the original analysis. This also appears to be the case for 0400 PST the 10th; on the original NMC chart the center was shown at 31°N–135°W, while the center by interpolation on Fig. 8 appears near 37°N–130°W. By 1600 PST, the two analyses show similar patterns, and both low centers are near 39°N–130°W.

The above continuity situation is also evident in the frontal patterns associated with the low centers. Even now, the patterns before 9 April are difficult to determine with any real confidence. However, the frontal continuity dilemma

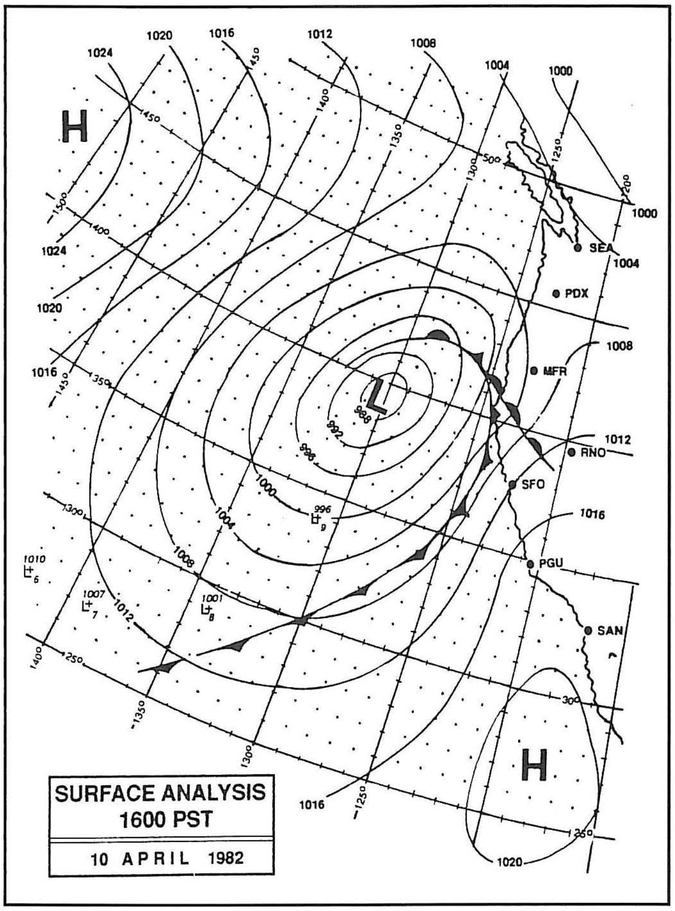

Fig. 8. Frontal system and surface pressure pattern for 1600 PST 10 April 1982. Surface low centers and central pressures are shown for 1600 PST 6, 7, 8, 9, and 10 April 1982. Figure is based on author's analysis.

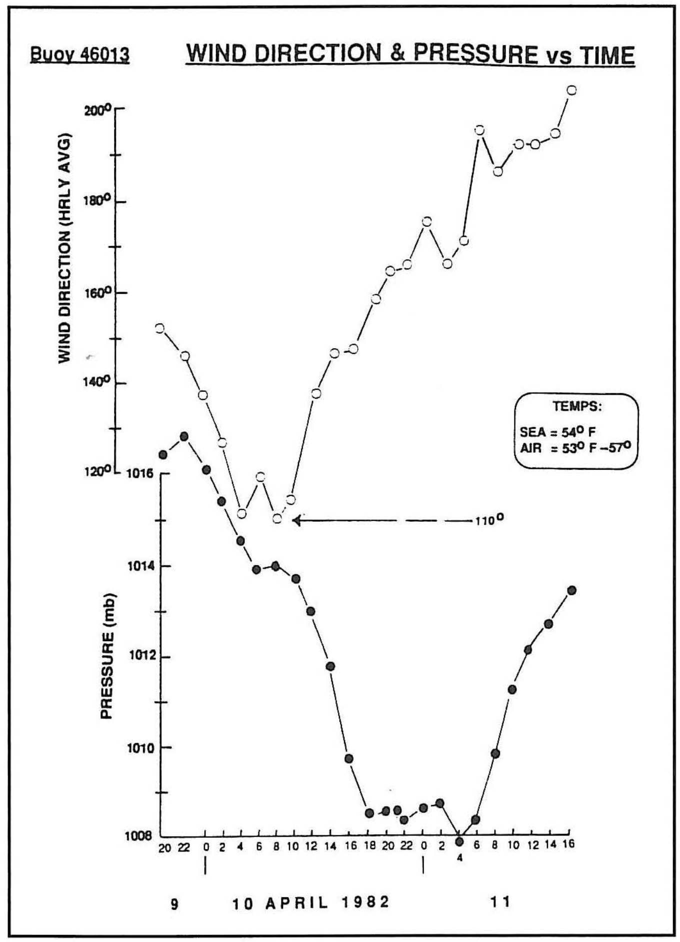

Fig. 9. Profiles of average wind direction and surface pressure at ocean buoy 46013, by 2-h intervals, 10–11 April 1982.

can be illustrated by noting the change which took place on the original NMC charts from 0400 to 1000 PST 10 April. On the 0400 PST chart, a labeled "trough" extended southward from the low center 31°N–135°W, and a weak cold front was positioned east of the low and parallel to the isobars from 35°N–130°W to 25°N–133°W. Six hours later the analysis showed a fully developed cold front occlusion from 38°N–129°W to 35°N–125°W, thence a cold front extending to the southwest and a warm front extending to the southeast. The indicated 6-h pressure decrease at 38°N–129°W (the location of the low center at 1000 PST 10 April) was 18 mb. It is noteworthy that all the original analyses of the synoptic situation through 0400 PST (10 April) were handicapped by a lack of surface observations in the sector bounded by 25–40°N and 125–140°W. Hence, the forecast issued at 0800 PST was highly dependent on the satellite imaging received after map time and discussed in section 5. For a detailed discussion of some of the problems in operational surface frontal analysis, the reader is referred to Mass (1991) and Uccellini, et al. (1992).

The hourly profiles of wind direction and pressure at ocean buoy 46013 provide a graphic picture of the storm's approach and passage and are given in Fig. 9. The hourly average wind directions at 46013 backed to 110° until near 1000 PST 10 April and then veered throughout the balance of the period. It is interesting to note the pressure continued to fall long after the wind began veering and that the veering continued throughout the 12-h period it took for the pressure trough to pass. The pressure bottomed out as the wind shifted through 180°, suggesting a little further deepening at the time the low offshore passed northwards.

The severe weather bracketed the trough,and its passage was reflected in the veering winds just above the surface; e.g., the Oakland radiosonde winds at 1000 ft MSL were 145 deg 35 kt at 1600 PST on the 10th and 185 deg 43 kt at 0400 PST on the 11th.

4. Severe Weather

In this section, the severe weather caused by the storm is highlighted. Severe weather for this study is defined as heavy rain (hourly amounts of .3 in. or more); gale-force wind speeds (34 kt or more), cumulonimbus, heavy showers or thunderstorms, and significant wave heights 3.5 m or higher. It is noteworthy that these conditions occurred in various combinations from the afternoon of the 10th through the morning of the 11th. According to Semanek[4] (personal communication 1988), a sailor who spent the entire night of 10–11

4. W. Semanek; Sunnyvale, CA 94806.

April in a monohull sailboat (LOA 25 ft) in a general area south of Pt. Reyes, the combinations were what made the going so difficult.

A. Rainfall

The storm was one in the series that had already produced new monthly records for 24-h rainfall at SFO in January (5.71 in.) and March (2.46 in.); these records still stand at year end 1991. It also came near the end of an exceptional rainy season and considerable moist subtropical airflow. By 9 April, the season-to-date rainfall at San Francisco was 34.86 in. vs. a normal-to-date of 18.94 in. and a seasonal normal of 20.66 in.

The storm produced considerable rainfall over most of California, and the two-day total at SFO was 17% above the April normal. The highest two-day total (10–11 April) along the coast was 6.37 in. at Pt. Sur. Following this rain, a major section of coastal highway near Pt. Sur was buried by a gigantic mud slide.

To depict the hourly occurrence of rainfall, three land stations were selected that reported hourly rainfall and appeared representative of conditions in the Gulf. No hourly rainfall data were available from the ocean buoys. The three stations selected are listed in Table 1 and shown in Fig. 2. They are: Mt. Tamalpais 2 SW (just north of the GG), Berkeley (just east of the GG) and San Francisco Richmond Sunset (just south of the GG). The hour-by-hour data from each of these three stations was examined, and the highest individual hourly amount for 10 April is given in Fig. 10. As shown, there were reports of heavy hourly rainfall for the hours ending at 1000, 1100 and 1200 (10th). Moderate rain showers were reported at SFO at 0900, 1000, 1030, 1100, and 1200 PST. "Heavy" rain during the morning hours was also reported by the sailors in the area west of GG. There were no other measurements of heavy hourly rain amounts from the above three stations on the 10th or 11th. The rain ceased about noontime as the rainbands and the warm front moved northward. The cessation of rain gave the sailors the misleading impression that weather conditions might be improving, when in reality they were about to deteriorate rapidly.

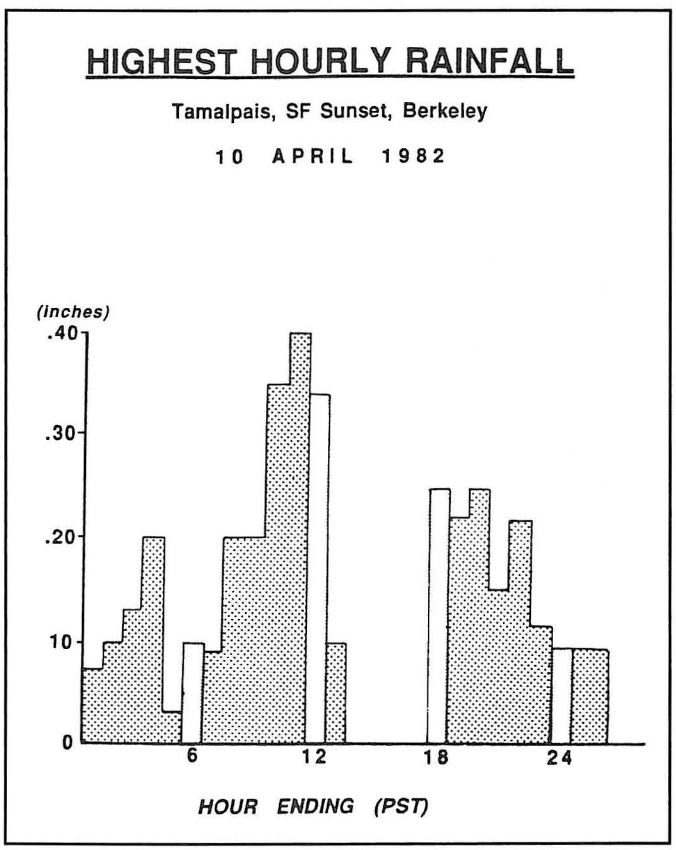

Fig. 10. Highest hourly rainfall on 10 April 1982 in an area close to the eastern boundary of the Gulf of the Farallones. Rainfall shown each hour is the highest of the individual hourly amounts measured at the three land stations cited.

B. Winds

The maximum reported wind speeds, by station, are given in Table 2 for 10–11 April. As shown in column two, the highest winds reported by the coastal three-hourly stations ranged from 50 to 67 kt, while the highest wind speeds reported by SFO and the other two stations in the San Francisco Bay area ranged from 46 to 53 kt. These two stations (Pt. Blunt and Davis Pt.) are shown in Fig. 2. As shown in column one, the first observations of wind speeds 48 kt or higher were given in the 1600 PST report and indicate a near uniform arrival of storm force winds along the entire coastline, shown in Fig. 2. This is essentially the marine forecast area, "Pt. Arena to Pt. Pinos."

The individual 3-h wind data for Pt. Arena, Pt. Bonita and Pigeon Pt. are given in Table 3. These are the coastal stations which routinely reported peak wind speed. These data allow for a comparison of the wind speed observed at 3-h intervals with the peak wind speed which occurred between those

Table 2

Maximum Surface Wind Speeds 10-11 April 1982

		MAXIMUM VALUE REPORTED AS:			
Station	Onset time* (PST)	Peak wind (kt)	Gust wind (kt)	Rglr hrly (kt)	Rglr 3-hrly (kt)
Buoy 46014		--	50	38	--
Pt. Arena	1600	50	--	--	29
Bodega Bay		--	--	--	30
Buoy 46013		--	39	29	--
Davis Pt.	0100(11)	52	--	--	42
Pt. Blunt		46	--	--	36
Pt. Bonita	1600	67	--	--	35
Pilot Vsl.		--	--	--	40**
SF Airport	1800	53	51	41	--
Pillar Pt.		--	--	--	40
Pigeon Pt.	1600	51	--	--	39
Pt. Sur		--	--	--	32

* First report of wind speed 48 kt or higher.

** No observations for 1800 and 2100 PST 10 April.

Table 3

Wind Direction, Speed and Peak Wind Speed for Selected Stations* 10-11 April 1982

	Pt. Arena			Pt. Bonita			Pigeon Pt.		
Obs Time (PST)	Dir	Obs Speed (kt)	Peak Wind (kt)	Dir	Obs Speed (kt)	Peak Wind (kt)	Dir	Obs Speed (kt)	Peak Wind (kt)
01	S	21	27	WNW	8	10	SE	16	23
04	SSE	9	15	NE	11	20	ESE	20	26
07	SE	15	27	ENE	18	20	ESE	22	29
10	SE	15	32	ENE	18	20	ESE	20	31
13	SE	19	30	ENE	5	19	ESE	32	40
16	SSE	29	50	ESE	30	55	SE	37	49
19	SE	27	49	E	38	66	ESE	39	51
22	S	26	44	NE	25	67	SE	25	49
01	SSE	19	35	W	35	56	SSE	34	46
04	S	23	39	W	29	48	SE	26	44
07	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	S	19	34	W	25	49	SE	17	36
13	S	16	29	W	22	34	SSE	16	22
16	S	22	40	WSW	28	36	S	17	21
19	SSW	17	--	WSW	25	42	S	14	22
22	S	10	13	W	19	34	SSW	14	23

* These are the coastal stations that routinely reported peak wind speed every three hours. Please see Fig. 2 for locations.

observations. As shown, the peak wind speed provides a measure of wind severity. The approach of the cold front can be seen in the speed increases between 1300–1600 PST at Pt. Arena and Pt. Bonita and in the increase between 1000–1300 PST at Pigeon Pt. The strongest winds occurred from the afternoon of the 10th through the morning of the 11th; all of the peak winds at Pt. Bonita were 48 kt or more.

The peak winds at Pt. Blunt and Davis Pt. (not given in Table 3) indicate the storm seriously impacted the inland waterways as well as the coastal and offshore ocean area. The strongest winds occurred from the night of the 10th through the afternoon of the 11th; peak wind speeds at Pt. Blunt and Davis Pt. ranged from 36 to 46 kt and 34 to 52 kt, respectively.

Three of the stations in Table 2 (Bodega Bay, Pillar Pt. and Pt. Sur) only reported wind speeds for the regular 3-h observation time. Additionally, the Bodega Bay station is actually in Bodega Harbor to the east and north of Bodega Head. Hence, the wind speed data from these stations do not provide a fair measure of the maximum wind severity.

The hourly wind data from SFO and buoys 46013 and 46014 are given in Table 4. These data cover the period with the strongest wind speeds and the period surrounding the time of the new record April 1-min wind speed occurrence at SFO (180° 41 kt at 2354 PST on the 10th), a record that still existed through 1991. Three kinds of wind speed data are available for SFO. This facilitates comparison with the data in Table 3 as well as giving three measures of wind severity at one station. It is noteworthy that there were six reports of peak wind speeds at SFO in the range 48–53 kt during the 1600–0400 PST period that Pt. Bonita reported peak wind speeds in the range 48–67 kt. The slightly higher speeds at Pt. Bonita appear appropriate considering the exposure of the two stations. Attention is also called to the sudden increase in SFO wind speed between 1600–1700 PST.

The buoy data in Table 4 show a maximum wind speed of 29 kt at 46013 and 48 kt at 46014 and maximum wind gusts of 39 kt and 50 kt, respectively. Overall, the wind speeds from 46013 appear to be less than expected from a view of the data in Tables 2–4. The 46013 wind data can also be compared to that from the Pilot Vessel given in Table 5. As shown for the observations taken between 1600 PST (10th) through 0700 PST (11th), the pilot wind speeds were all in the range 30–40 kt while the wind speed range at 46013 was only 16–29 kt. The Pilot Vessel data are consistent with conditions reported by Semanek (personal communication 1988). When his boat was spotted by USCG helicopter at 1021 PST (11th), it was "25 n mi out (west) from GG under its own (sail) power."

One possible explanation of the apparently low wind speeds at 46013 is that the airflow reaching the station may have been slowed by a land trajectory before reaching the

Table 4

Hourly Wind Data* for San Francisco Airport and Buoys 46013, 46014
10-11 April 1982

		SFO			46013			46014		
Obs Time (PST)	Dir (deg)	Obs Speed (kt)	Obs Gust (kt)	Peak Wind* (kt)	Dir (deg)	Obs Speed (kt)	Obs Gust* (kt)	Dir (deg)	Obs Speed (kt)	Obs Gust* (kt)
16	140	11	--	--	150	26	35	165	34	44
17	160	25	35		151	27	36	166	48	49
18	170	30	45	48	158	29	38	170	37	50
19	170	25	36	53	158	28	38	175	34	49
20	180	18	32	36	165	26	35	172	30	46
21	190	19	28	--	165	29	37	176	25	41
22	200	21	29	--	168	29	39	174	26	37
23	200	35	49	47	183	21	35	174	25	34
24	180	41	51	52	171	22	28	173	27	33
01	180	32	50	52	165	20	26	177	26	37
02	200	37	48	52	165	19	26	173	28	39
03	210	39	50	50	172	21	26	177	25	37
04	210	32	40	45	170	20	26	196	21	32
05	190	16	32	44	195	19	25	182	22	29
06	200	22	32	40	193	17	26	170	23	28
07	190	19	29	37	183	16	20	169	24	30
**				**						

* Please see section 2 for definitions.

**Peak winds of 38-39 kt were also reported at SFO on the 11th at 1100, 1200 and 1500 PST.

Table 5

Observations from the SF Pilot Vessel*
10-11 April 1982

Time PST	Wind (kt)	Sea*	Swell*	Baro (in)	Vsby (mi)
0400	S 15	Lt S	Low W	29.98	4
0700	NE 15	Lt NE	Mdt SW	-	-
1000	S 10	Lt S	Low SW	29.94	3
1300	S 15	Lt S	Mdt SW	29.93	3
1600	S 35	Mdt S	Mdt SW	29.88	3
1900, 2200	-	-	-	-	-
0100	S 30	Mdt S	Mdt SW	29.82	3
0400	S 30-40	Hvy S	Hvy SW	29.80	4
0700	S 30	Hvy S	Hvy SW	29.81	2
1000	-	-	-	-	-
1300	SW 20	Small	Mdt SW	29.90	8
1600	S 22	Mdt S	Mdt S	29.93	8
1900	S 20	Mdt	Mdt S	29.96	8

*Location shown in Fig. 2; definitions in sec. 2.

buoy. However, this explanation does not seem compelling, since most of the wind directions indicate the likelihood of a south-southeasterly trajectory. It has also been suggested that the anemometer height might have been at 5 m. However, it is noted that 46013 is a 10 m discus-type buoy, and the stated exposure height is 10 m, according to NCDC (1986). In view of the above and no known instrument malfunction, the question of the wind speed accuracy at buoy 46013 remains unresolved.

The wind speed history of the storm at buoy 46014, the northernmost station in Fig. 2, is graphically presented in Fig. 11 along with the pressure profile and mean wind directions that accompanied the highest wind speeds. As shown, the gust wind speed increased from 10 to 50 kt during the first 18 hr of 10 April. It then decreased, but not without two secondary periods characterized by increases in speed. The profile of the peak wind speeds at SFO (Table 4) also show a similar uneven profile of decreasing speeds. As shown by the SFO data, there were no peak winds reported at 2100–2200 PST as the wind decreased below gale force after the 53 kt maximum. However, there were five hours of peak wind speeds 47–52 kt in the secondary period. The continued occurrence of peak wind speeds near 50 kt at SFO and Pt. Bonita into the early morning hours of the 11th presented a special hazard to the crews and vessels still at sea. Other additional indicators of wind severity include: the ship observation at 35.5°N–126°W which showed 54 kt at 2200 PST 10 April, and "wind speeds gusting to 70 kt (in the search area) throughout the evening and night of 10 April", according to the USCG's Search and Rescue Situation Report issued at day's end, 11 April. (Jones, personal communication 1988.)

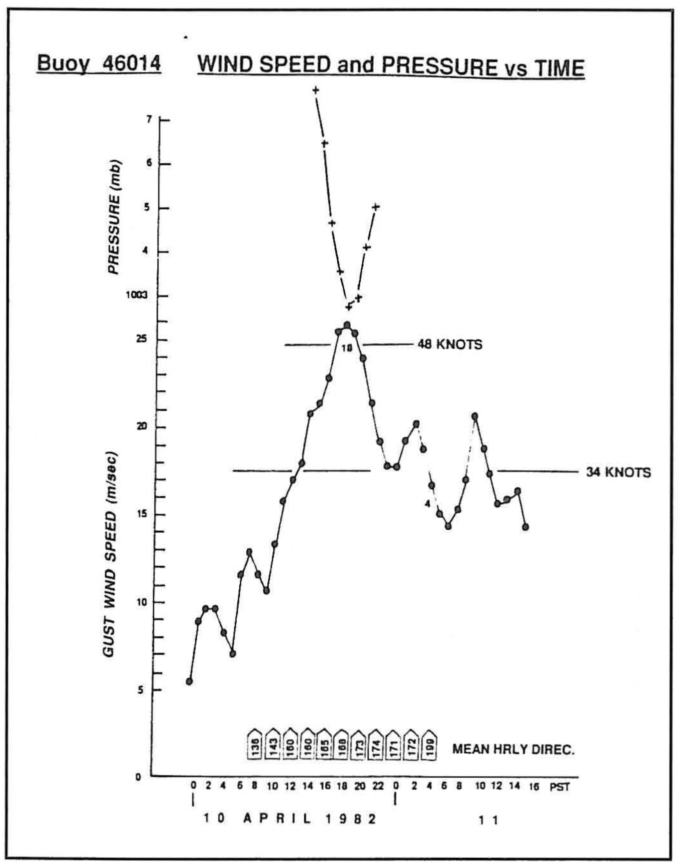

Fig. 11. Profiles of gust wind speed and surface pressure at ocean buoy 46014, by hourly intervals, 10–11 April 1982.

C. Thunderstorms

The thunderstorm period at SFO on the 10th started at 1700 PST with a report of "CB to N and SE moving E" and continued with reports such as "CB all quadrants moving NE" until the last report, "CB all quadrants" at 2200 PST. The following observation illustrates the severe weather: SFO 1847 PST; 400 scattered 2300 overcast, visibility 1½ mi, heavy rainshower, fog, pressure 1009.5 mb, temperature 63°F, dewpoint 57°F, peak wind 170° 53 kt (at 1808 PST). Five land stations in the area east of the Gulf reported thunderstorm activity on the 10th between 1800 and 2300 PST. Examples of these reports include: Alameda NAS (just E of SFO), "thunderstorm ended at 1750 PST," and "thunderstorm, moderate rain shower, thunderstorm E moving NE" at 2200 PST; Travis AFB (47 mi NE of SFO), "thunderstorm moved NE" at 2015 PST; and McClellan AFB (86 mi NE of SFO), "CB to W moving NE" at 2300 PST.

As shown in Fig. 10, the heavy rainshower and thunderstorm period of activity occurred in the rain period that started with the hour ending at 1800 PST. Although the total rain in this turbulent period was substantial at the three stations closest to the ocean, there were no individual hours with "heavy rain." The rain in this period is attributed to the cold front and the trough behind it. Sailors reported the cold front as a "squall line" and said, "it rained so hard, you couldn't see the bow of the boat." One skipper said, "it rained so hard, that it totally flattened the waves over the Potatopatch Shoal for five minutes", according to Latitude 38, (1982).

D. Waves

This discussion of wave heights during the storm is largely based on sea and swell observations from the Pilot Vessel and significant wave heights (SWH) measured at buoy 46013. The locations of the stations are shown in Fig. 2, and the use of SWH to estimate the frequency of occurrence of higher wave heights was discussed in section 2. The SWH is the average of the highest one third of the wave train.

Observations of wave heights at 3-h intervals from the Pilot Vessel are given in Table 5. The crew of the Pilot Vessel (a 95-ft cutter) observed and generally described the seas and swell as "light", moderate", or "heavy." These terms are defined in section 2. The term "heavy" also indicates that waves are breaking over the banks to the north and south of the main channel, according to Ware (1990). As shown in Table 5, heavy southerly seas and heavy southwest swells were reported at 0400 and 0700 PST on the 11th. The strongest winds reported were southerly 40 kt at 0400 PST. The lowest reported barometer, 29.80 in., was also reported at that time. Moderate southerly seas and moderate southwest swells were characteristic of the reports before and after those reported as heavy.

The SWH and gust wind speeds at buoy 46013 are given in Fig. 12. As shown, the gust wind speed increased slowly until 1000 PST. During the next hour, it increased from 10 to 14.6 m s^{-1} and continued to increase until the maximum value of 20.2 m s^{-1} was reached at 2200 PST. The SWH increased from less than 0.5 m at 2100 PST 9 April to 3.0 m at 1700 PST on the 10th. It then increased to 3.7 m during the next hour. The times just before the marked increase in speed and wave height (1000 and 1700 PST) are shown in Fig. 12. The difference in time is probably related to the wind duration time required to produce the local waves, given the particular fetch and wind speed.

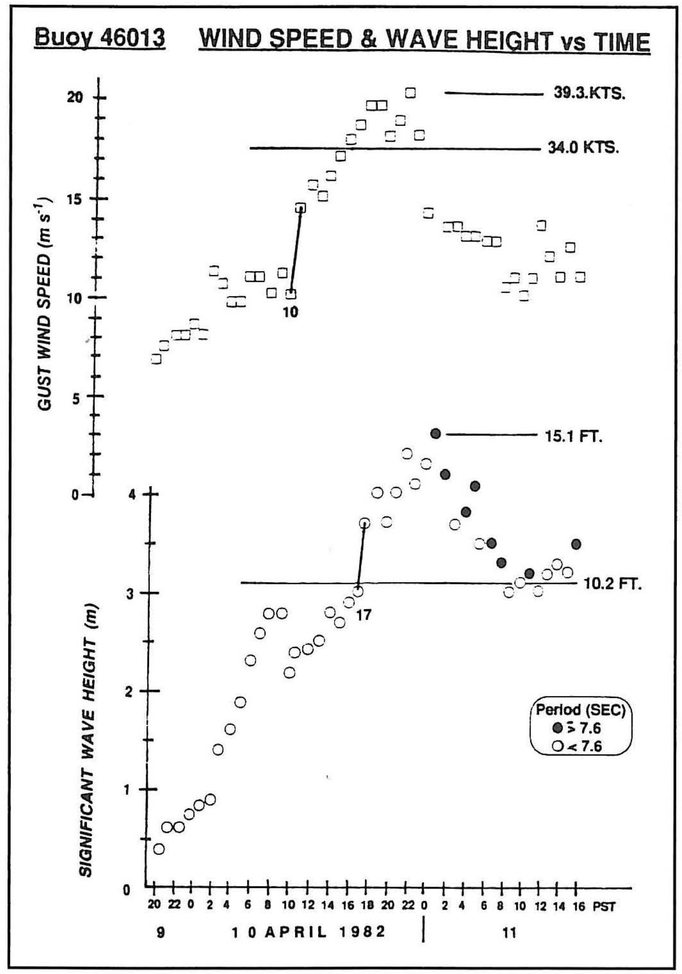

Fig. 12. Profiles of gust wind speed and significant wave height at ocean buoy 46013, by hourly intervals, 10–11 April 1982.

The highest SWH was 4.6 m and occurred during the period 1800 (10th) to 0300 PST (11th) when SWH were generally greater than 3.5 m. This period also contained all the reported winds from SFO that were 48 kt or more. It is concluded from the data and interview information that this group of relatively high waves was generated by the strong local south-southeast airflow.

As shown in Fig. 12, there was a lull in the occurrence of high waves (3.5 to 4.6 m) after 0500 PST 11th. The lull was followed by a second group of high waves (not shown in Fig. 12) that occurred from 1600 PST to midnight (11th). Samples of the 46013 surface conditions associated with each wave group are given below.

Group	Baro (mb)	Dir (deg)	Gust Speed m s^{-1}	SWH (m)	Period (sec)
1 (10/1900)	1008.2	158	19.7	4.0	6.7
2 (11/1900)	1014.9	226	9.5	4.2	8.2

These and other data suggest that the second group of waves was not local but was generated in an area more distant and to the south-southwest of 46013. The longer wave period for group 2 is also consistent with the occurrence of waves with less steep faces than those of group 1.

In summary, the moderate and heavy seas observations from the Pilot Vessel imply wave heights of 12 to more than 15 ft occurred during the period 1600 (10th) to 0700 PST (11th). The measurements from buoy 46013 (Fig. 12) indicate wave heights were mostly 12 to 15 ft SWH during this same period. It is concluded that the two sets of data are in general agreement, especially considering the limited nature and number of vessel observations and that the 46013 wave heights were SWH. It is also noted that the relatively short wave periods (less than 7.6 sec) reported at 46013 on the 10th were consistent with the steep wave faces reported by Warren[5] (personal communication 1989). As the wave heights and wave steepness increased, the adverse impact on the sailing vessels and the crew did likewise. For example, with steep waves, a vessel slams easily into the waves if too much headway is made. It pitches uncomfortably in following seas. If the waves are abeam, they can cause extreme rolling and risk of capsizing, according to Lilly (1985).

E. Current

The tidal current data at the Golden Gate (GG) for 10–11 April are given in Table 6, according to NOS (1982). As shown, there were alternating flood and ebb currents into and out of the GG. The time, strength and direction of the maximum ebb and flood currents are given along with the time of slack water, the period during which the direction gradually changes from ebb to flood and vice versa.

The period with ebb current is the most critical time for sailors returning to the GG from the seaward side. The ebb current is a potential hazard because it acts to increase the tendency of waves to break over the two offshore banks to the north and south of the main channel. According to California Boating and Waterways (1986), even without large local waves a very dangerous condition may develop over the banks whenever large swells reach the coast, and shoaling of the swells takes place over the shallow water banks. This "piling up" of the water over the shoals is also worsened by an ebb tidal current. The ebb also acts to slow boats as it flows seaward and fans to the north and south after it passes Pt. Bonita. The one fortunate event during this storm was the lack of a serious ground swell on 10 April, according to Latitude 38 (1982).

The ebb on 10 April was a problem, since its maximum occurred at 1725 PST, just as a number of returning boats were approaching the GG and darkness ensued (sunset was at 1841 PST). Although this predicted ebb was not particularly strong, it added one more adverse influence to the already difficult time that some boats were experiencing in clearing Pt. Bonita. The ebb current was significant from about 1525 to 1925 PST (2 hr before until 2 hr after the time of maximum ebb current).

Wind-driven currents have been studied at the old San Francisco Lightship location near the present site of buoy "SF." The wind-driven current increases from about 0.3 kt at 10 mph to about 0.7 kt at 50 mph, according to NOS (1982).

Table 6

Predicted Tidal Currents at the Golden Gate

10-11 April 1982

Time (PST)	Curr Max (kt)	Dir* (deg)	Type
10/0201	----	----	Slack
0502	4.3	245	Ebb
0847	----	----	Slack
1141	3.4	065	Flood
1459	----	----	Slack
1725	2.9	245	Ebb
2051	----	----	Slack
2328	2.6	065	Flood
11/0231	----	----	Slack
0539	4.1	245	Ebb
0929	----	----	Slack
1224	3.1	065	Flood
1548	----	----	Slack
1804	2.4	245	Ebb
2127			Slack

* Direction towards which current is flowing.

5. Forecasting and Sailing the Storm

In this section the NWS weather forecasts, the critical role of the forecast broadcast on the VHF radio, the nautical situation during the storm, and an exceptional account of one voyage are discussed.

A. Weather Forecasts

The most important forecasts from a sailing viewpoint and the kind and quality of the information available to the forecaster when the forecasts were made are reviewed first. The discussion closes with several complementary suggestions about changing the forecast content and format.

The two critical National Weather Service forecasts were those for the coastal area that were made at 0200 PST 10 April, six hours before the race, and at 0800 PST, just as the race started. Both these forecasts covered the area "Pt. Arena to Pt. Pinos out 60 miles." The parts of the forecasts that cover Saturday, 10 April are cited below.

. . . Forecast issued at 0200 PST 10 April.

"Begin small craft advisory. Wind southeasterly, increasing to 15 to 30 knots this afternoon. Waves building to 3 to 6 ft late today. Swell northwest 3 to 5 ft, becoming southwesterly 4 to 8 ft by tonight. Rain today and tonight with a chance of thundershowers this afternoon and evening."

. . . Forecast issued at 0800 PST 10 April.

"Change small craft to gale warning. Wind southeasterly, increasing to 20 to 35 knots and waves 4 to 7 ft later today. Swell northwest 3 to 5 ft, becoming southwesterly 4 to 8 ft tonight. Periods of rain with chance of thundershowers."

The upper air charts available to the forecaster before the 0200 PST (10th) coastal forecast was released, were those

5. L. Warren; Concord, CA 94521.

for 1600 PST 9 April. The nature of these charts can be seen in Figs. 4–7. On the NMC surface charts (as discussed in section 3), there was a problem with the continuity of the low center and the frontal system on the surface synoptic charts from about 1600 PST (8th) to 0400 PST 10 April. Hence, there was little, if any, indication on the 1600 PST chart for the 9th that the storm was intensifying. (There was also little, if any, indication of rapid development given in the various numerical weather prediction model outputs.) Information from the 2200 PST 9 April surface chart was available by forecast time but showed no major change from the 1600 PST chart. On that chart, the low center continued near its earlier position and showed little evidence of cyclogenesis. The attendant, weak cold front showed little movement or development. From a retrospective standpoint, the surface situation appeared unclear, and the lack of observational data in the vicinity of the low center continued to be a problem.

The upper air charts available to the forecaster who issued the 0800 PST coastal forecast were those for 0400 PST 10 April. The nature of those charts can be seen in Figs. 4–7. At 850 mb, the intensification and initial northward motion of the low center at 850 mb is evident in Fig. 7. Information from the 0400 PST surface synoptic chart was also available to the forecaster. The one prepared by NMC showed that little change in the longitude of the cold front had occurred during the previous 24 h, i.e., the front extended from about 32°N–130°W to 25°N–133°W on both maps. However, an intensification of the low center and a major weakening of the ridge in the Gulf of Alaska were evident in the axis of the − 12 mb isallobar (0400 PST 9th to 0400 PST 10th) which extended from 32°N–135°W northward past 45°N.

In summary, the initial cyclogenesis and movement of the low took place after the low center had shown an uneventful history and a meandering path for six days (NODC, 1982). The analysis in Fig. 6 shows significant baroclinicity with the surface low to the east of the 500-mb trough in a favored place for development. However, the cyclogenesis which took place was difficult to anticipate due to the fact that the incipient storm was located in an ocean area characterized by a lack of surface and upper-air observations. The resulting problem was a loss of frontal continuity on the surface chart and little, if any, indication of storm occurrence from the model outputs. A review of the satellite imagery from the archives at San Jose State University and discussion with the NWS staff on duty 10 April indicates the satellite data provided the most useful information in the preparation of the above two forecasts.

The critical satellite imagery leading to the gale warning forecast was that taken at 0515 PST 10 April 1982 (Fig. 13). That forecast played a key role in mitigating the storm's impact and is discussed below. The satellite data is an enhanced infrared image. The dark area west of the California coast may be due to cirrus cloud blowing off the tops of large convective cells. The grey spots inside the darker area may indicate thunderstorm areas. The location of the convective area relative to the comma cloud to the north suggests the intense storm was preceded by an old weak system that had passed northward without leaving much rain or other evidence of its passing. It is noteworthy that the mass of clouds just ahead of the turbulent area depicted in Fig. 13 was associated with the warm front, which brought considerable precipitation and low wind speeds to the area from 0100–1200 PST. The character of the precipitation, which arrived with the cold front (heavy rainshowers and thunderstorms), was quite different. It occurred from 1700–2300 PST on the 10th along with very high wind speeds.

After the storm had subsided, there was a serious question raised about the lack of communication between the Bay Area Multihull Association's (BAMA) race committee and the NWS. Various aspects of the problem were highlighted in news accounts and in meetings between NWS staff, members of the St. Francis Yacht Club and BAMA, the race sponsor. Topics included: the process and difficulties of making forecasts; the development of a better understanding of forecasts and the uses to which they can be applied; and ways to improve liaison between the NWS and the users of its forecasts. All of these topics have merit. However, interviews with the people personally involved in the storm forecast process and those who were users of the forecast indicated they were primarily concerned with the forecast content. In essence, they seemed to be asking for a forecast that contained information about the likelihood of serious wind, weather and wave conditions. This appears to warrant further consideration, and it may be that some additions to the coastal marine forecast or changes in emphasis are feasible. For example, it would be helpful to the user if the forecast contained an estimate of wind speed gusts and emphasis was given to any wind warning by placing its predicted direction as well as speed at the very start of the VHF marine broadcast. In terms of broadcast effectiveness, it would be helpful to repeat any warning (e.g., "southeast gale warning, southeast gale warning") and to delete any non-essential information.

B. Weather Broadcast on VHF Radio

A VHF radio capability was part of the required list of gear for this race, and each boat had to check in by radio at the start of the race, according to Caswell (1982). Since each boat had a radio, it was generally assumed each crew was able to receive the weather broadcasts. The 0800 PST 10 April broadcast, which contained the gale warning, turned out to be very important. The forecast available prior to the race start was the small craft advisory for southeast winds 15–30 kt, waves 3–6 ft, and chance of thundershowers that was issued at 0200 PST. With this forecast on hand, and rain actually occurring since midnight, the outlook was not particularly good at starting time, but most of the hardy sailors from the San Francisco area did not think either the weather or forecast was unusual at the 0800 PST starting time.

A number of sailors reported that they picked up the southeast wind gale warning during the morning hours on the VHF radio. Many were influenced by this broadcast to take extra precautions, change course, turn back, etc. According to Dellaria (1982), 70 boats had dropped out of the race by midday. However, as the day progressed, many boat crews had difficulty using their radios because they were fully occupied with sailing. In some cases, the radios were not securely installed and came loose in the rough seas. In many cases, they became soaked as the sea water and rain penetrated around the edges of the closed hatch covers or through the cabin hatchway. At race end, soaked radios were "a dime a dozen." Electrical failures, due to batteries coming loose or becoming soaked, compounded the whole safety problem. Radio "capability" obviously means more than the ability to talk to the race committee as one passes the starting line.

Racing sailors are an independent lot and, as expected, their reactions to the weather advice were quite varied. One sailor picked up the southeast gale warning on a 0930 PST

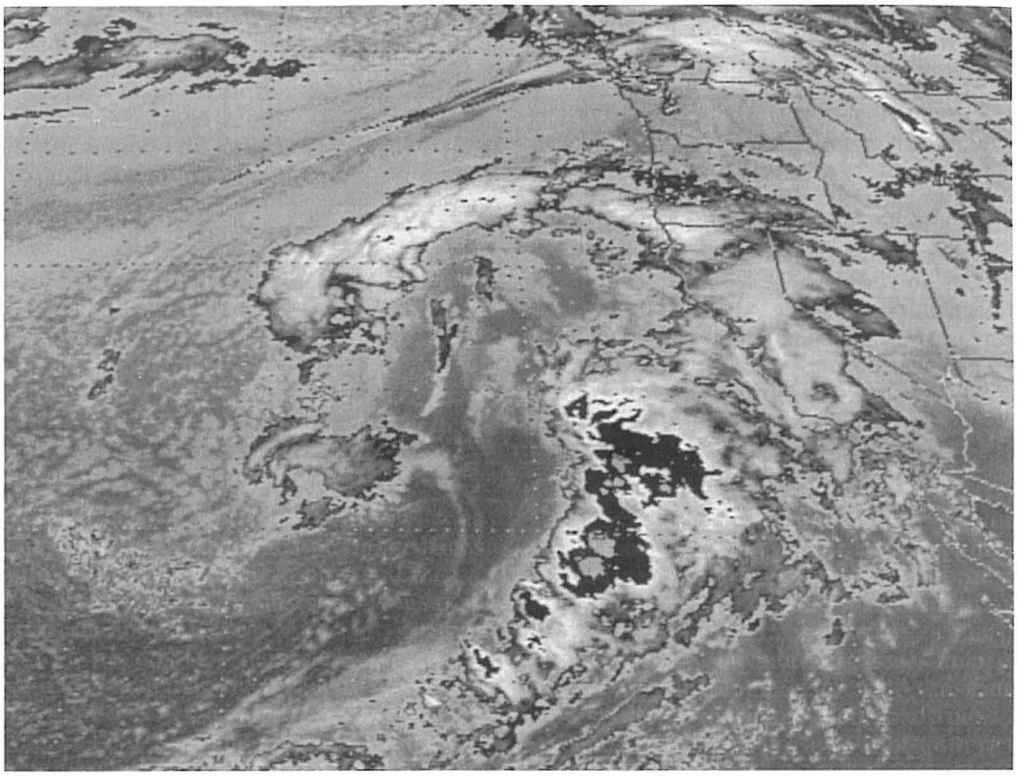

Fig. 13. Enhanced infrared NOAA satellite imagery for 0515 PST 10 April 1982. Figure is a printed copy of a photo from the original facsimile transmission.

radio check; he sensed the problem forthcoming with the wind and the northerly current and headed south. Another said he heard the warning at 1000 PST and "chickened out." Another non-racer said, "I was three miles from the Farallones when I heard the 35–50 kt warnings. (This was apparently the storm warning issued at 1600 PST.) I decided to stay at sea until the storm eased." On the other hand, one sailor said, "We brought a radio to the boat on the morning of the race; never had a chance to get it adequately installed." Another said, "I race regardless of the weather." One ("big boat") skipper said, "I didn't have any trouble out there."

Following the race, the issue of adequate weather information was a major topic in the media. The race committee was criticized for not obtaining up-to-date information from the NWS before and during the race. Since it was assumed each sailing vessel could receive the latest VHF broadcast directly, the issue boiled down to the question: was the race committee responsible to advise racers of forecast conditions or to recognize the possibility of a sailing disaster and cancel the race? The race committee did not cancel the event, possibly for legal reasons that might have made them liable for the disaster. It is, according to experts, a tenuous distinction between running a race and being responsible for it, a distinction that makes many racing committees nervous. According to Caswell (1982), "every vessel must be self-sufficient and should not need the race committee to advise it whether it is safe to sail or not." This is a common view held by many ocean-going sailors. "Self-sufficiency," according to Rousmaniere (1989), "deals with times when sailors are entirely on their own." Anchoring, heavy-weather sailing, emergencies, and boat maintenance, are covered in separate chapters in the part of his book on self-sufficiency. A more encompassing requirement might be the possession of the knowledge and skill necessary to be a good seaman. "Seamanship in its widest context includes everything involved in the safe voyaging of a boat from its departure port to its intended destination," according to Knox-Johnston (1987). Interestingly enough, an entire chapter in his book is devoted to meteorology.

C. Nautical Situation

Given the rapidly worsening weather, the sailing problem faced by crews on the return trip from the Southeast Farallon Island on 10 April can be visualized if one first draws a line on Fig. 1 from the Island through the main channel to the GG Bridge. To make good a deep water passage through the main channel, one would have had to maintain an average "return course" of about 250°, i.e., along the above line. For sailing vessels that ended up to the north of this line, it became ever more difficult to get south against the rapidly increasing southerly winds and the northward moving current set.

At least seven types of crises developed. They included: (1) capsizing, (2) failing to clear Pt. Bonita, (3) encountering large commercial ships, (4) being driven onto the lee shore (coastline from Pt. Reyes to Pt. Bonita in Fig. 1), (5) dealing with equipment failure, crew injury, losing crew overboard, inability to make headway, radio failure, etc., (6) risking a deliberate beaching, and (7) staying at sea until the storm abated.

D. Log of One Voyage

The following quotations were selected from a more comprehensive group given in an exceptional article by Mittendorf (1982). Mittendorf gives a candid and sequential presentation of conditions during his voyage from San Francisco to the Southeast Farallon Island and back to Pt. Bonita on the morning and afternoon of 10 April. The buoys and geographical features he refers to are identified in Fig. 1.

Outbound	0815	"Raining steadily." "The wind is dying, and the fleet is bunching at the bridge. Yuk. Where is the predicted SE 15–25?" "As we pass Pt. Bonita, it starts to rain hard and visibility drops to 1 mile."
	0930	"As we come up on buoys 7 and 8, Keith turns on radio for a weather check." "Coastal forecast for Pt. Arena to Pt. Sur and out 60 mi. Change small craft advisory to gale warnings. SE winds 25–35 knots." "We quickly head up the boat to a tight spinnaker reach and go south. We want to be on right side of shift." "Where we are, it's still blowing from the east at about 6 (knots)."
	1015	"We are south of the channel buoy #2 and observe a substantial northwest current flowing on the buoy."
	1030	"The wind has clocked 50° and is rising. We are glad it has stopped raining." "We are making 6½ knots." "The seas are mostly southerly but confused and about 5 ft. We see two big boats with blown-out jibs." "A bearing check on the Island confirms that there is still a strong northerly current."
	1215	"We round the northeast corner of the island.
Inbound	1300	"We are around and in the clear. Wind seems to be at 25 kt, and the seas are starting to build." "Still a strong northerly current."
After	1300	"One by one, all the boats that have rounded with us are dropping below us."
	1500	"Midway between separation buoys B and C on the rhumb line."
After	1500	"We pass the temporary Lightbucket (buoy SF) on course." "The seas are squaring up and becoming a problem, since they are hitting us right on the beam. Its gusting to 35 kt. Boat takes occasional 50° rolls." "We begin rounding up and going sideways. We are being blown below our course."
	1600	"Inside the Bar Channel." "We can see some boats coming in (on a course) to the north (of us) and rounding Pt. Bonita. The boats along the south shore appear to be carrying a lot of sail and sitting up pretty straight. Let's go for it. The main goes back up with three reefs. We bear off and head for Bonita Cove (just E of Pt. Bonita). The boat starts doing 14's and 15's (boat speed in knots)." "As we start to close on Pt. Bonita, we can see the ebb is doing us no good. Keith expresses concern we won't clear Pt. Bonita."
	1705	"We pass the outer rock of Bonita about 40 yds abeam. I hear Keith say, 'This wave looks like it might break. It's about 7–8 ft. The wave is directly on beam and steep and knocks us both overboard'." "I look up and see the boat slowly turn turtle." (The story of their successful survival effort to reach shore is omitted here.)
Estimated	1745	(on a beach near Pt. Bonita.) "A fierce squall line comes up. Visibility drops to zero, and the dividing line between water and air is ambiguous." "Locally, it is blowing at least 60 kt, maybe 70. We cannot face into it."

6. Summary of Incidents

In evaluating this disaster, the term "incident" describes a situation in which either people or vessels were lost or rescued. The term "incident" is also used to describe a few unusual cases where people in extremis saved themselves. These cases involved three people who successfully "swam for it" after losing their boats, and six people who deliberately or otherwise beached their boats. The list of incidents is given in Table 7. The primary source of incident information is Jones (personal communication 1988). This information includes U.S. Coast Guard documents such as Search and Rescue (SAR) Incident Summaries, Heavy Weather SAR Summaries and Distress Situation Reports for 10–18 April 1982. The list in Table 7 comprises most of the known official cases referred to in the search and rescue record. It does not, however, provide an accounting of the boats and lives saved by the crews which brought their boats in on their own. Based on interviews with some of these people, it is noted here that each crew had a story of outstanding sailing in extremely difficult circumstances and a survival set, despite the hardships encountered. As one said to me during an interview, "I never had the idea, it's all over."

A tally of the individual entries in Table 7 shows that there was a total of 32 people incidents and 17 vessel incidents. Seven vessels and six people were lost. The six people were on the vessels given reference #1, #2 and #3 in Table 7. There is little known detail about the loss of vessels #1 and #2, since there were no survivors and no known emergency radio traffic of record. One body was recovered and some identifiable pieces of wreckage were found from each vessel, along with a scattering of identifiable gear.

Vessel #3 was not racing but had departed San Francisco for Los Angeles on Friday morning 9 April. The vessel reached Pigeon Pt. (Fig. 2) before the wind turned southerly and a decision was made to return to San Francisco. By Saturday afternoon, the crew was uncertain of their position. The nautical situation that evolved brought the sailboat close to a freighter anchored some 3 n mi south of Duxbury Pt. (Fig. 1). In order that the freighter crew might throw the sailboat crew a line, the sailboat was maneuvered alongside of the freighter. In the process, the sailboat was thrown against the freighter by the storm, breaking her mast and puncturing her hull. The master of the freighter saw that the sailboat had been partially dismasted, but he did not realize that she had also been holed. Shortly after the accident, the sailboat took on water and began to sink. The boat subsequently capsized, and the three sailors attempted to swim to shore. Only the skipper made it to shore successfully. The details of this event and a published opinion with regard to the litigation which followed is given in Huber (1988).

The nature and extent of the disaster can be seen in the individual entries in Table 7 and in the meanings of the words

Table 7

Summary of Vessel Incidents, 10-11 April 1982

Ref No.	Vessel hull & LOA (ft)*	Comments**	Outcome*** Vessel	People
1	M 22	Piece of hull found onshore about 5 n mi NW of Duxbury Pt.	Lost	2 Lost
2	M 24	Piece of hull found onshore N of Potatopatch Shoal	Lost	2 Lost
3	M 31 (NR)	Thrown against a freighter by wave action about 3 nm S of Duxbury Pt.	Lost	2 Lost, 1 saved himself
4	M 30	Capsized by wave action near Pt. Bonita	Lost	2 saved themselves
5	C 31	Capsized by wave action over Potatopatch Shoal	Lost	2 Rescued by sailboat crew
6	M 30	Wrecked on Duxbury Pt.	Lost	2 Rescued by helicopter
7	C 30	Deliberately beached west shore of Bolinas Bay	Lost	2 saved themselves
8	M 21 (NR)	Endangered near Head Rock vicinity of Half Moon Bay	Rescued	1 Rescued
9	C 20	Deliberately beached on west side of Drakes Bay	Saved by crew	2 saved themselves
10	M 40 (NR	Beached near eastern end of Pt. Reyes	Salvaged	2 Crew saved themselves
11	M 24	Endangered about 5 n mi NW of Pt. Bonita	Rescued	2 Rescued
12	M 26	Endangered about 5 n mi S of Pt. Reyes	Rescued	2 Rescued
13	T 26	Endangered between Pt. Bonita and Golden Gate	Rescued	2 Rescued
14	M 27	Endangered about 5 n mi SE of Pt. Reyes	Rescued	2 Rescued
15	M 27	Unable to make way in S.F. Bay	Rescued	2 Rescued
16	M 25	Needed assistance in S.F. Bay	Rescued	2 Rescued
17	M 35	Escorted from position just E of Duxbury Pt.	Escorted	2 Assisted

* M is monohull; C is catamaran; T is trimaran. LOA is length overall. (NR) indicates not racing.

** All vessels experienced a combination of adverse wind, wave and current. The locations are approximate and given with reference to features shown in Fig. 1.

*** Nearly all rescues were made by USCG.

wrecked, capsized, beached, and endangered. Endangered is a condition that may follow a knock-down and dismast, a roll over, crew injury, or an inability to sail away from a lee shore, for example.

In conclusion, it is noteworthy that the disaster was greatly mitigated by the rescue of 17 people and 7 vessels and by the fact that 9 people saved themselves and two vessels as well.

7. Concluding Remarks

Although the April 1982 storm was unusually severe, it should be noted that the Gulf of the Farallones is a place where adverse winds and waves are common. It is not a friendly place for small craft and inexperienced sailors. The lack of a safe anchorage or harbor of refuge reduced the sailors to two options. Either they had to get into San Francisco Bay, or remain at sea overnight. These were both difficult to do in the storm condition which prevailed.

From a meteorological viewpoint, this storm disaster was due to:

- the suddenness and severity of its onset;
- the southerly wind direction;
- the exceptionally adverse combination of wind, weather, current, and wave conditions; and
- the duration of the storm and the advent of darkness during its intense period.

From a sailing viewpoint, this disaster was due to most of the same kinds of events that have plagued ocean racing events for years. These include those alluded to in this article and described in an admirable report by Forbes et al. (1979). The Forbes' report was prepared after the 1979 Fastnet Race (from Cowes, England, to the Fastnet Rock off the south coast of Ireland and then to Plymouth) ended with a tragic loss of life and sailing vessels. The five sections in that report tell the story. They are entitled: Background, Weather, Ability of the Yachts and their Equipment to Withstand the Storm, Ability of Skippers and Crews to Withstand the Storm, and The Search and Rescue Phase.

The April 1982 storm offered up a serious challenge to all those involved. The loss of people and vessels was tragic. The overall experience should remind all that it is serious business to sail off the northern California coast in stormy weather. It is concluded that the losses in the April 1982 storm would have been truly more devastating had it not been for the NWS gale warnings broadcast over the VHF radio, the successful rescues by the USCG, and the outstanding examples of survival sailing and rescues by the sailors exposed.

It is also concluded that the usefulness of the NWS coastal area marine forecast could be enhanced if the forecast statement contained more information about the possible occurrence of extreme wind and wave conditions, and more emphasis was given to those conditions in the VHF radio broadcast.

Acknowledgements

The author appreciates the information and assistance given by the sailors interviewed, the NWS meteorologists, the U.S. Coast Guard Search and Rescue staff, and the San Francisco Bar Pilots. The author particularly appreciates discussions with Richard Lay and Frederick Sanders about the character of this storm. Mr. Lay is a meteorologist and an experienced sailor. In 1982, he was stationed at the NWS San Francisco Forecast Office. Professor Sanders is a professor emeritus from Massachusetts Institute of Technology and an experienced sailor. The author is indebted to Steven Weiss, former editor of the *Digest,* for his patient and skillful editorial help. Thanks are also due to Tim Barker of the NWS Western Region for helpful comments, Marilyn Judson for redrafting the figures and Xavier Lavoipierre for researching the legal reference.

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