MARINERS WEATHER Log

MESOSCALE WIND STORMS AT SEA; WHAT THE WEATHER MAPS DON'T SHOW

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The ocean racer is a particular kind of marine weather observer. Unlike the merchant mariner, he does not venture from Atlantic ports during the winter when the exposure to gales caused by extratropical cyclones is greatest, and during late summer and early autumn the threat of tropical cyclones confines him to contests near shore where sheltered water is never more than a few hours away. Even during the favorable months of early summer, however, when the long-distance events typically occur, his relatively frail craft is often beset by storms of great intensity, though of such short duration that they pose little problem to commercial ocean-going craft and (presumably for this reason) are seldom reported by them in detail.

This contribution describes a series of mesoscale[1] storms as observed by the contestants in the June 1970 Bermuda Race, and as seen in the broadscale synoptic analyses of the National Meteorological Center (NMC) and in detailed analyses (after the fact) of hourly surface observations over land and of all available observations at sea. These storms disabled seven of the racing craft because of spar or rigging failure, including mine. Consequently my interest was not solely scientific.

The rhumb-line course for the 1970 race is shown in figure 1. Note that the course intercepts the mean June position of the Gulf Stream near 38° N. There is some evidence (Sanders, 1972) that at the time of the race the Stream was north of its usual position, or that a warm eddy had formed, but the squalls on the night of June 21-22 were not in any event produced by the Stream, as we shall see.

The NMC surface analysis for 0000 GMT June 22 is shown in figure 2. The area of the racing fleet lay northeast of an analyzed warm front, in a region of weak southeasterly flow, to judge from the isobars, while a weak wave cyclone along the front was indicated near 38° N., 74° W. In fact, the fleet at this time was experiencing fresh southwesterlies; violent thundersqualls had struck about 1 1/2 hr earlier, and would again 9 hr later.

To find the origin of these storms, I made a series

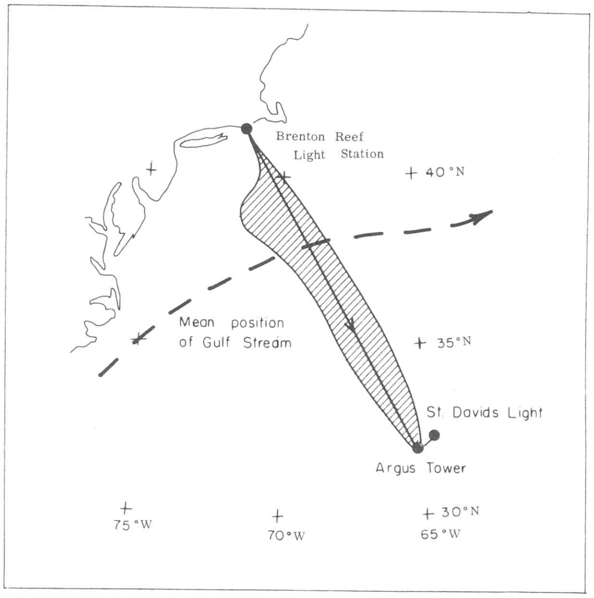

Figure 1.--Course of the 1970 Newport-Bermuda Race. The start is at the Brenton Reef Light Station near Newport, R.I., and the finish is off St. Davids Light, Bermuda. The Argus Tower on Plantagenet Bank southwest of Bermuda is a mark of the course and must be left to port. The hatched area represents approximately an envelope of the tracks of individual yachts.

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[1] Mesoscale refers to that portion of the science of meteorology concerned with the study of atmospheric phenomena smaller than the scale of the migratory high- and low-pressure systems but larger than the scale confined to the surface boundary layer of a small area of the atmosphere (microscale). Thus, this scale is concerned with the detection and analysis of the state of the atmosphere as it exists between the meteorological stations, or at least well beyond the range of normal observation from a single point.

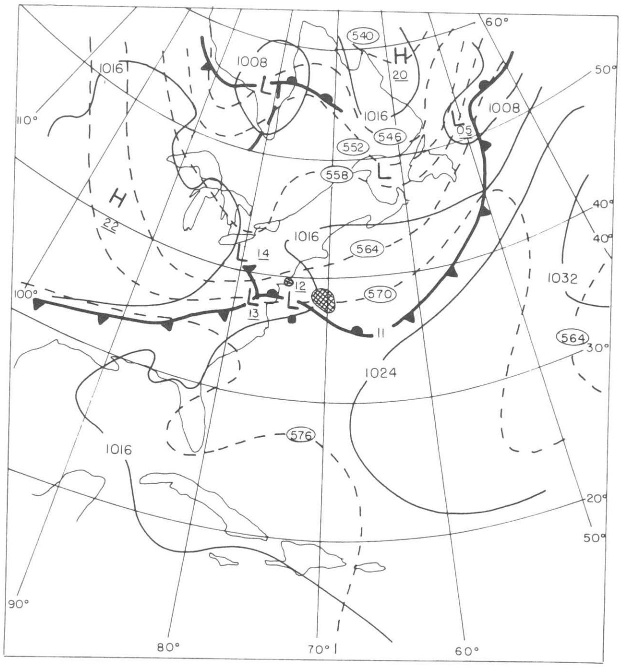


Figure 2. --National Meteorological Center analysis for 0000 GMT June 22, 1970. The solid lines are sea-level isobars at intervals of 8 mb and the dashed lines are isopleths of thickness of the layer from 1000 mb to 500 mb, at intervals of 60 m. The large solid dot indicates the location of the XERB-1 buoy. The hatched area represents the approximate envelope of the racing fleet at this time. The circled X denotes the location of Atlantic City (ACY).

of detailed hourly analyses over the Middle Atlantic States, where weather radar observations from Atlantic City showed the initial thunderstorm echoes. A few of these maps, at 3-hr intervals, are shown in figure 3. The first group of thunderstorms formed in the trough of low pressure in central Virginia just after 1500 GMT while the second group formed in another trough in the same region at about 0000 GMT. Each of these storm groups moved eastward and out to sea at a speed of about 50 kt, producing brief but strong wind gusts at land stations, some of which produced the deaths, injuries, and damage reported in Storm Data (Environmental Science Services Administration, 1970). Tornadoes were observed over land in Virginia, and waterspouts were seen on Chesapeake Bay during the passage of the first line of storms.

Analysis over the ocean was restricted to the 6-hr intervals at which ship observations are routinely made. Hourly data are transmitted automatically, however, from the XERB-1 research buoy, anchored at the edge of the Gulf Stream east of the Virginia capes. A plot of the series of observations from this buoy, shown in figure 4, provides evidence of the passage of two squalls separated by 10 hr, as was observed over land. The series of oceanic maps covering the period of activity is shown in figure 5, with pertinent portions transcribed from the detailed analysis over land. Except at 0600 GMT, the ship observations (the actual names of all the vessels listed appear in table 1) give a fair idea of what was going on. However, there is no hint of the violent gusts reported by the racers. Note, however, the rapid eastward motion of the squall lines over the sea, lending credibility to the numerous sailboat estimates of 50 kt and more.

Errors in the 0000 GMT NMC analysis are apparent in figure 5(b). The ship reports indicate the southwesterlies that the racing fleet was experiencing, while the observation from the GYPSUM EMPRESS (GHZF) places the small low center near 40° N., 72° W., or more than 100 mi northeast of the NMC position. On this map, it is difficult to reconcile the observation from the WOLTERSUM (PIRL) with those from other ships, unless it is assumed that the observation was made perhaps 3 hr before the nominal time of the map. Similar problems are found with the observation from the Nantucket Light Vessel (NLV) (40.5° N., 69.5° W.). The southwest wind reported by the MELVIN H. BAKER (5LBU) seems excessive on this and on the other maps. If, however, the ship's speed of about 10 kt toward the southwest is subtracted vectorially from the reported wind, the result is in excellent agreement with neighboring observations; thus it seems almost certain that the apparent wind, rather than the true wind, was being reported. There are reports of severe convective weather either present or past on this map from the MELVIN H. BAKER (5LBU), the GYPSUM EMPRESS (GHZF), and the GYPSUM PRINCE (GHYX). The analysis would have been greatly aided had the time, direction, and speed of the peak wind gusts been transmitted as additional remarks.

It is interesting to note that the analyses show no clear indication of fronts in the conventional sense, except perhaps for a warm front extending southeastward in figure 5(a) through 35° N., 70° W. The hourly temperature record from XERB-1 (fig. 4) shows that the squalls came near the beginning and end of a period when the air was warmer than the sea locally, thus suggesting a warm sector; but there was no systematic change of wind direction accompanying the beginning and end of the warm interlude, as there is in the classical textbook description. Note that both squalls at XERB-1 cooled the air temperature quickly and at least temporarily to values lower than the sea-surface temperature, a behavior characteristic of organized squall lines but not of warm fronts. Despite all this activity, there was a tendency for a weak pressure trough to persist (after the first map) more or less parallel to the Gulf Stream but located between it and the shore rather than directly over the warmest water as one might intuitively have guessed. This feature further confounded efforts to interpret the situation in terms of conventional fronts, but may have provided a favorable environment for continued severity of the second group of thunderstorms after they passed offshore. The vigor of the first group indicates, however, that such help was hardly necessary.

The times and speeds of the peak gusts reported by the racers are mapped in figures 6 and 7. One might expect exaggeration born of inexperience except for three considerations: only experienced crews are accepted in the race; the reports make consistent patterns while exaggeration surely varies from individual to individual; the extraordinary speed of advance of the squall through the fleet is physically and quantitatively consistent with the peak speeds reported. Besides, my mast doesn't fall down every day!

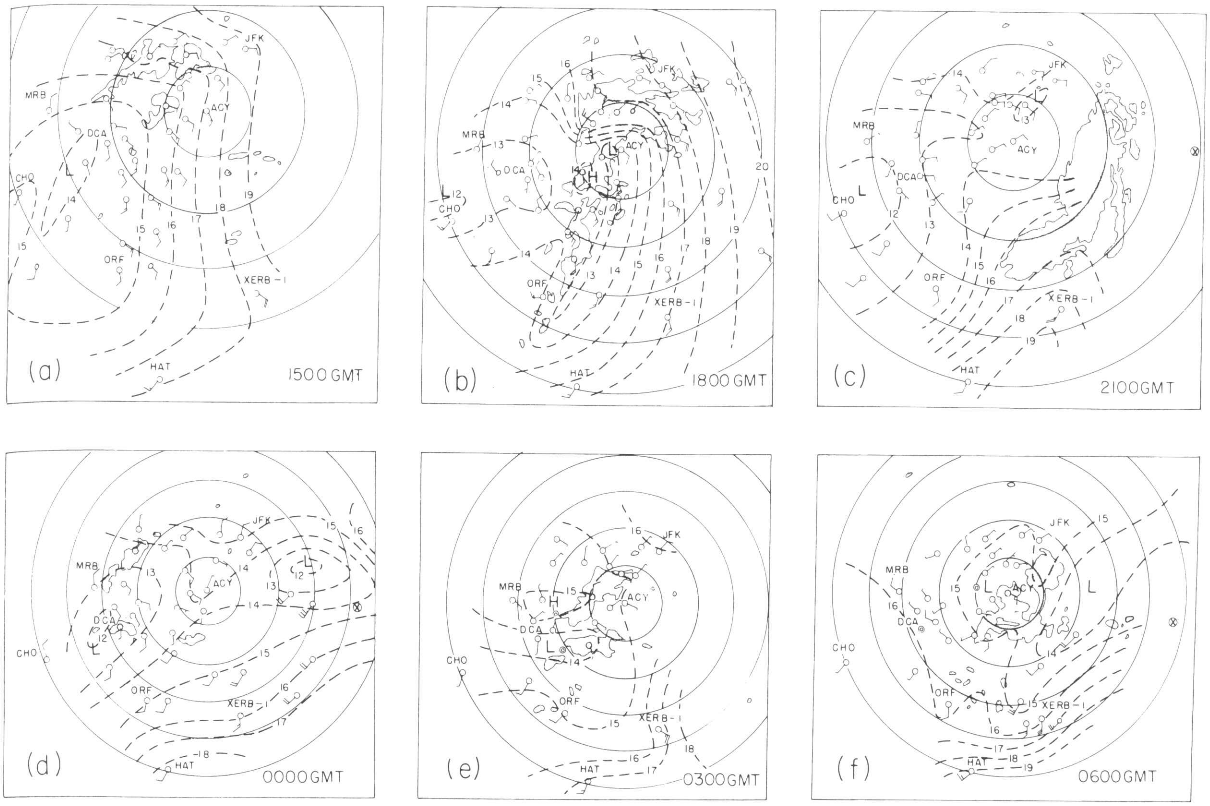


Figure 3. --Mesoanalyses of sea-level pressure at 3-hr intervals June 21-22, 1970, superimposed on echoes observed by the WSR-57 radar at Atlantic City (ACY). The photograph nearest the nominal time of the 3-hr surface observations was used. Thin solid lines are range circles at intervals of 50 mi. Dashed lines are sea-level isobars at intervals of 1 mb. Locations shown for orientation are: J. F. K. Airport, N. Y. (JFK); the XERB-1 buoy; Hatteras, N. C. (HAT); Norfolk (ORF) and Charlottesville (CHO), Va.; Martinsburg, W. Va. (MRB); and Washington National Airport,D.C. (DCA). Circled X's show approximate centroid positions of yachts reporting squalls.

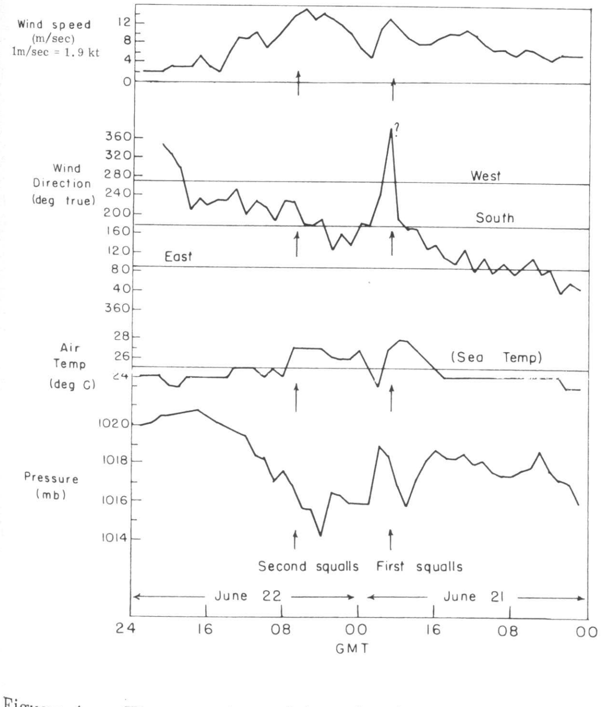


Figure 4. --Time series of hourly observations from the XERB-1 buoy at 36.5° N., 73.5° W., June 21-22, 1970.

The second episode of severe weather during the race befell the smaller survivors who were still beating their way toward the Argus Tower on June 25 long after the larger craft had crossed the finish line. The NMC analysis for 1200 GMT, in figure 8, shows an old frontal system through the fleet area with waves, one of which was associated with a weak cyclone center near 35° N., 67° W. Few ship observations were available to support this analysis, but satellite pictures did indeed show an impressive band of cloudiness approximately along the analyzed position of the front. During the day, some but not all of the fleet were lashed by a sustained gale of small scale but with speeds as high as 50 kt!

From the observations provided by the contestants, it was possible to piece together a picture of what had happened. A series of maps at 3-hr intervals based on the yacht data is shown in figure 9. As with the earlier case, it was not possible to find a front in the usual sense, but a small vortex clearly moved through the fleet from southwest to northeast, producing gale-force winds only on its southeast side and those of such limited extent that at Bermuda, only 80 mi away, peak gusts were observed no higher than 27 kt. Elsewhere (Sanders, 1972), I have argued, from the estimated speed of advance of the vortex and from the difference in wind speeds across it, that this small cyclone was dynamically similar to a tropical storm, despite its initial formation in an old frontal cloud band. This storm evidently moved on to the northeast and dissipated before reaching the major Atlantic

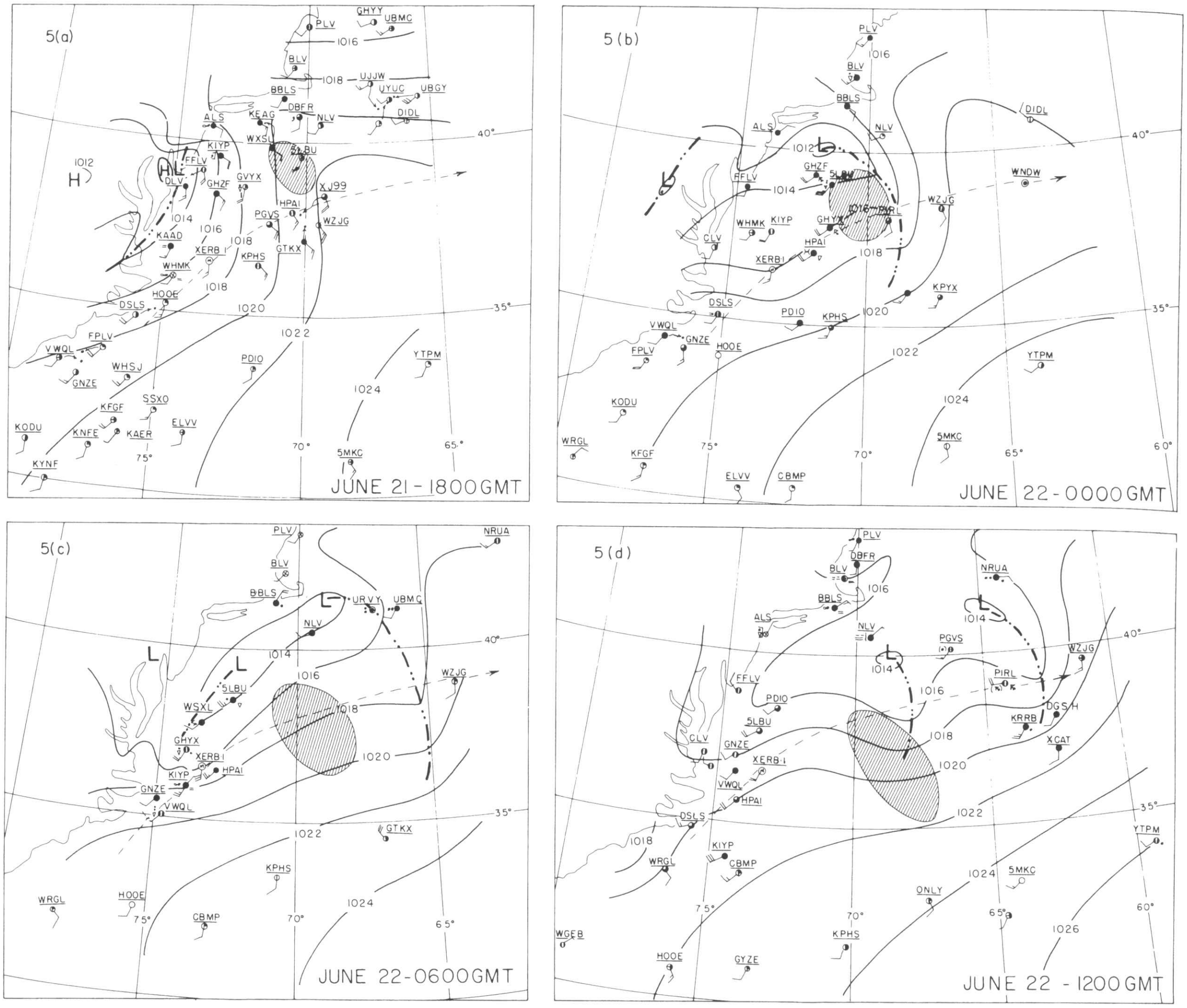


Figure 5.--Surface analyses over the west-central Atlantic Ocean, June 21-22, 1970. Solid lines are isobars and are labeled in millibars. The dot-dashed lines represent the leading edges of squall lines. The thin dashed line is the mean June position of maximum current in the Gulf Stream. Ships are identified by radio call sign (see table 1 for actual names), and winds, present, and past weather are plotted in the conventional manner. The hatched area represents the approximate position of the racing fleet.

Table 1.--Appropriate ship, light vessel, and light station names corresponding to the call signs appearing in figure 5

ALS	(Ambrose Light Station)
BBLS	(Buzzards Bay Light Station)
BLV	(Boston Light Vessel)
CBMP	(MAIPO)
CLV	(Chesapeake Light Vessel)
DBFR	(WALTER HERWIG)
DGSH	(WUPPERTAL)
DIDL	(ALSTER EXPRESS)
DLV	(Delaware Light Vessel)
DSLS	(Diamond Shoals Light Station)
ELVV	(EL GAVILAN)
FFLV	(Five Fathom Light Vessel)
VPLV	(Frying Pan Light Vessel)
GHYX	(GYPSUM PRINCE)
GHYY	(GYPSUM QUEEN)
GHZF	(GYPSUM EMPRESS)
GNZE	(WILKAWA)
GTKX	(FRANCONIA)
GVYX	(unidentified)
GYZE	(CARIBBEAN ENTERPRISE)
HOOE	(OCEANIC)
HPAI	(LOUISE)
KAAD	(TEXACO MASSACHUSETTS)
KAER	(AFRICAN PLANET)
KEAG	(ESSO CHESTER)
KFGF	(CARBIDE TEXAS CITY)
KIYP	(ESSO LEXINGTON)
KNFE	(HESS VOYAGER)
KODU	(TEXACO MINNESOTA)
KPHS	(CHARLESTON)
KPYX	(SILVER LARK)
KRRB	(STEEL MAKER)
KYNF	(TEXACO KANSAS)
NLV	(Nantucket Light Vessel)
NRUA	(USCGC OWASCO)
ONLY	(LULUA)
PDIO	(CHEVRON ROTTERDAM)
PGVS	PRINSES MARGRIET)
PIRL	(WOLTERSUM)
PLV	(Portland Light Vessel)
SSXO	(unidentified)
UBGY	(unidentified)
UBMC	(SVYATOGOR)
UJJW	(SEVERODVINSK)
URVY	(DAURIJA)
UYUC	(unidentified)
VWQL	(VISHVA PREM)
WGEB	(MOBIL FUEL)
WHMK	(ESSO BALTIMORE)
WHSJ	(PENNSYLVANIA SUN)
WNDW	(BOSTON)
WRGL	(VALLEY FORGE)
WSXL	(unidentified)
WXSL	(unidentified)
WZJG	(AMERICAN ASTRONAUT)
XCAT	(AZTECA)
XERB1	(Experimental Environmental Reporting Buoy #1)
XJ99	(unidentified)
YTPM	(KAPETAN MARTINVIC)
5LBU	(MELVIN H. BAKER)
5MKC	(SERAFIN TOPIC)

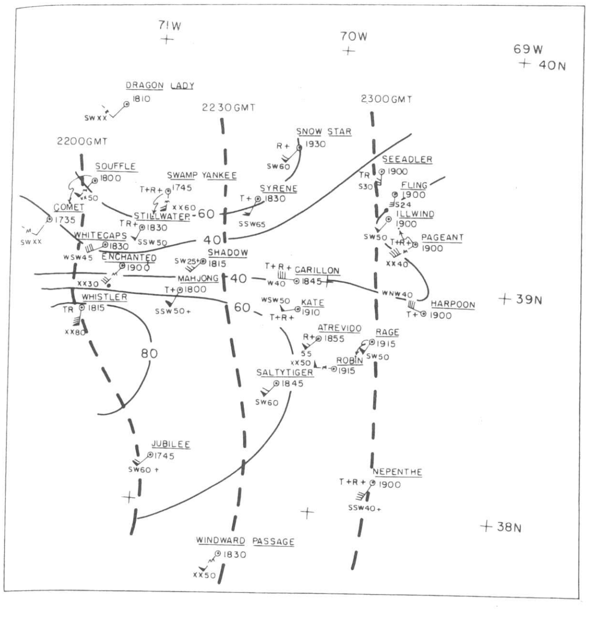


Figure 6. --Peak gust in first series of squalls, June 21. Solid lines are isotachs at intervals of 20 kt. Dashed lines are isochrones of the peak gust at intervals of 30 min. Peak velocities reported by each yacht are plotted in the conventional manner. At the upper right of the station circle is the reported time (EDT) of squalls. Reports of thunder or rain (+ indicating heavy intensity) from each yacht are plotted to the left of the station circle as T or R, respectively.

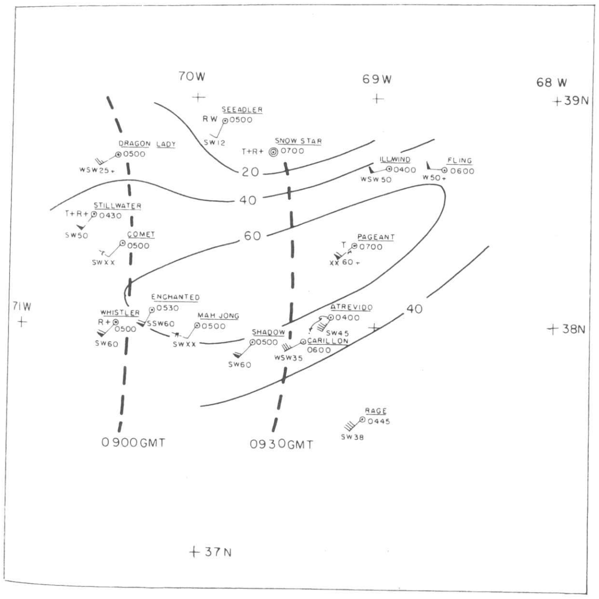


Figure 7. --Peak gust in second series of squalls, June 22. Notation is the same as in figure 6.

shipping lanes, for no ship (so far as I am aware) ever reported a hint of the gale.

Undoubtedly, mesoscale wind storms occur at sea also at times when sailboats are not racing. One such case came to my attention during analysis of the large

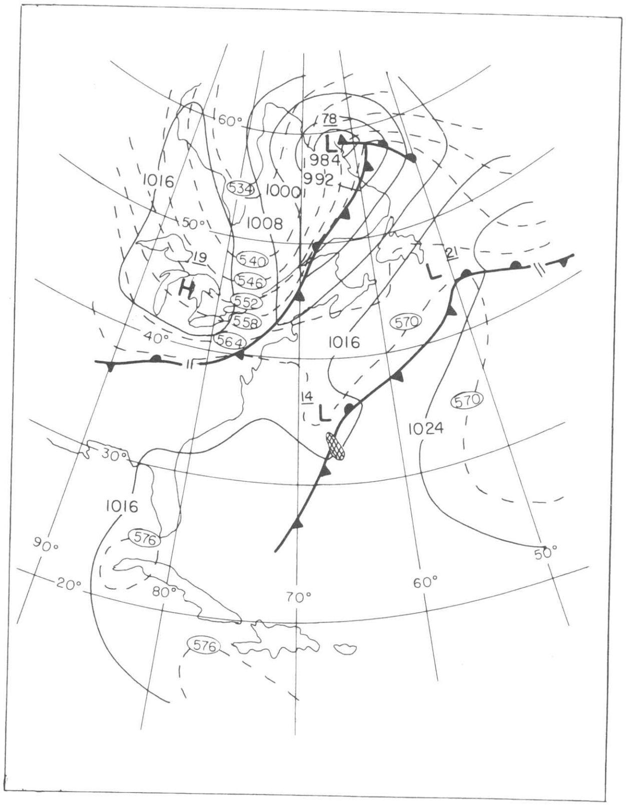


Figure 8. --National Meteorological Center analysis for 1200 GMT June 25, 1970. Format same as in figure 2. The hatched area is the approximate envelope of the racing fleet at this time.

and intense storm along the Atlantic coast of November 11-13, 1968. The low-pressure center first formed as a conventional wave along the Texas Gulf Coast, as shown in figure 10(a). Note on this map, however, the weak cyclonic circulation over the eastern Gulf, off the west coast of Florida. The weak cyclonic circulation was associated with a region of unusually high sea-surface temperature--a physically plausible circumstance.

The maps in figure 10 indicate that this cyclonic circulation was transported toward Florida by the increasing southwesterlies in advance of the cold front, and that it provided the environment for the development of severe convective activity. The resulting squall line produced waterspouts along the west coast of Florida and tornadoes over the peninsula itself, as the cold front itself became obscure and vanished as a significant entity. The line moved with great speed across the northern Bahamas and northeastward into the Atlantic. The remarkable suddenness of onset of gale conditions northeast of Florida between 1800 GMT of the 12th and 0000 GMT of the 13th seems at least partially attributable to the approach of the squall line.

Conditions at the line itself were evidently severe at sea, according to the ships' observations (see table 2 which equates ship call sign with ship name). For example, remarks from the ESSO BANGOR (KEAH) indicate peak gusts to 100 kt at 2230 GMT, while the ESSO JAMESTOWN (KIYO) observed winds gusting to 50 kt, and the CARBIDE TEXAS CITY (KFGF) re-

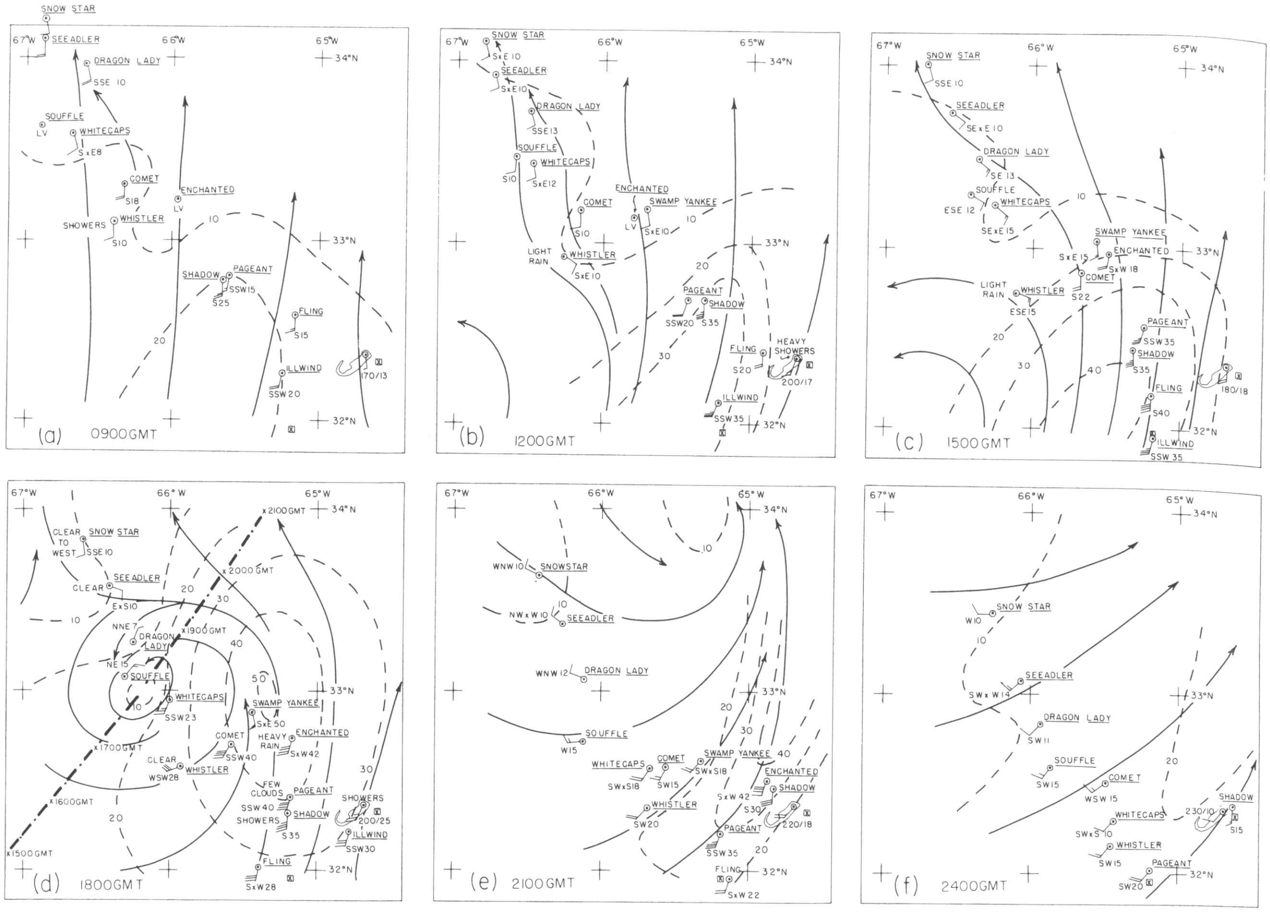
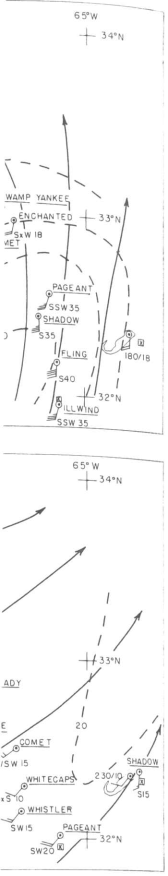


Figure 9.--Detailed surface analyses at 3-hr intervals from 0900 GMT to 2400 GMT, June 25, 1970. Wind is plotted for all yachts and for Kindley Field, Bermuda, with annotations where available concerning sky conditions and precipitation. The solid lines with arrowheads are streamlines of wind flow. The dashed lines are isotachs at intervals of 10 kt. The heavy dot-dash line is the estimated track of the cyclone with hourly positions indicated.

Table 2. --Appropriate ship, light vessel, and light station names corresponding to the call signs appearing in figure 10

CLV	(Chesapeake Light Vessel)	KALC	(ATLANTIC ENTERPRISE)	NOMAD	(Naval Oceanographic Meteorological Automatic Device)
DANP	(ASSEBURG)	KALD	(ATLANTIC ENDEAVOR)	PGBE	(MOORDRECHT)
DDQH	(EUROPA)	KCAO	(EXPORT BUYER)	PHAR	(RIA)
DHMF	(BRANDENBURG)	KEAH	(ESSO BANGOR)	PIGQ	(VIVIPARA)
DSLS	(Diamond Shoals Light Station)	KEAJ	(ESSO HUNTINGTON)	PJLG	(ESSO AMSTERDAM)
EDISTO	(USCGC EDISTO)	KEAK	(ESSO FLORENCE)	PMML	(unidentified)
ELLS	(ORE TRANSPORT)	KEHJ	(WESTERN SUN)	PZAS	(SURINAME)
ELXJ	(CAVALA)	KFBE	(CHERRY VALLEY)	SPQL	(JAN ZIZKA)
FPLV	(Frying Pan Light Vessel)	KFBN	(ATLANTIC COMMUNICATOR)	URTM	(KIMOVSK)
GPVP	(LAOMEDON)	KFBT	(EASTERN SUN)	UUKC	(ISSAKOGORKA)
GPZH	(DUHALLOW)	KFGF	(CARBIDE TEXAS CITY)	WHMK	(ESSO BALTIMORE)
GRPA	(TONGARIRO)	KGKV	(TEXACO NEW YORK)	WIEO	(TEXAS SUN)
HOCX	(ESSO COLOMBIA)	KHVY	(PETROCHEM)	WLDG	(OCONO STOTA)
HOOE	(OCEANIC)	KIBF	(KEYTANKER)	WLDU	(ATLANTIC PRESTIGE)
HYRS	(unidentified)	KIYO	(ESSO JAMESTOWN)	WLGR	(SANTA ELENA)
JWTZ	(BAUMARE)	KIYP	(ESSO LEXINGTON)	WNDM	(ESSO NEW ORLEANS)
JWWG	(JANNETTA)	KPBU	(MAIDEN CREEK)	WNDO	(NEWARK)
JXVS	(BAKKE REEFER)	KPIY	(MARINE TRANSPORT)	WNDW	(BOSTON)
KAAD	(TEXACO MASSACHUSETTS)	KPSI	(MORMACFIR)	WRRS	(CARROLL VICTORY)
KAAH	(SANTA MAGDALENA)	KYTB	(GATEWAY CITY)	WSIQ	(MARYLAND SUN)
KABJ	(ESSO DALLAS)	LJYT	(BAGRU)	5LWR	(CUYAMA VALLEY)
KAHA	(ATLANTIC HERITAGE)	NCCV	(unidentified)	5MGC	(J. LOUIS)
KAHM	(TEXACO OKLAHOMA)	NDTS	(USCGC DAUNTLESS)	5MIR	(ATLANTIC CHALLENGER)
KAIB	(AFRICAN MOON)	NJPT	(unidentified)	6ZYY	(SENTINEL)



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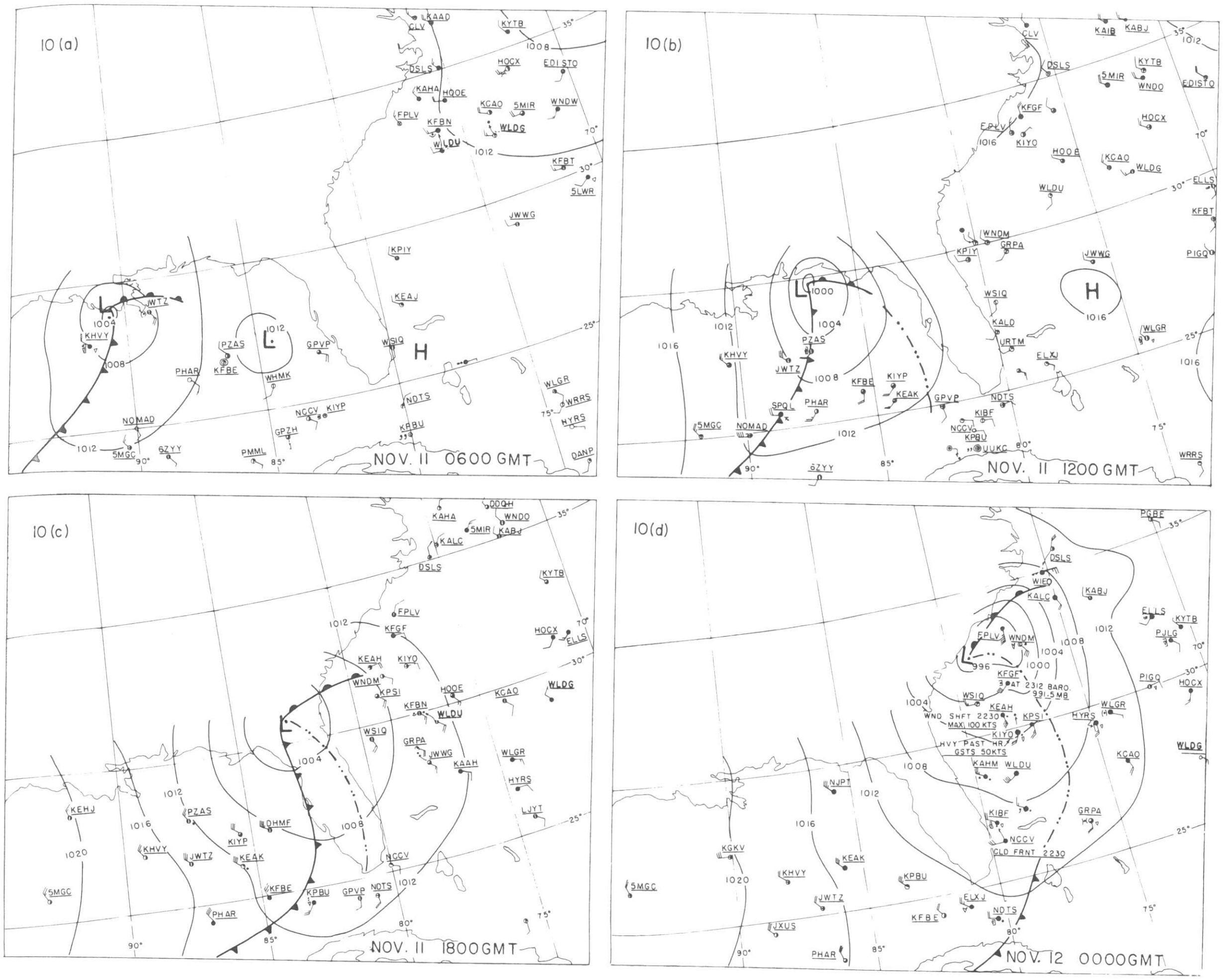

Figure 10.--Surface analyses over the Gulf of Mexico and part of the western Atlantic Ocean, Nov. 11-12, 1968. Format similar to that in figure 5 except see table 2 for the names of vessels identified by call sign.

ported a pronounced minimum on the barograph trace from which a substantial pressure jump (characteristic of squall lines) could be inferred. The squall line lost its identity soon afterwards as it was absorbed by the development of a very extensive and severe gale.

Mesoscale events of the type described here are most interesting, practically important (since they must endanger or damage even fairly large ships from time to time), and poorly documented. Only through study of reliable ship observations can we begin to develop some skill in forecasting these small but violent storms.

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