Monthly Mean Wind Fields for the South Atlantic Bight

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ABSTRACT
A total of 339,389 marine weather observations have been analyzed to produce monthly mean wind fields for the South Atlantic Bight. The results of plotting wind vectors on a $1^\circ$ latitude by $1^\circ$ longitude grid yields four traditional seasonal flow regimes (winter, spring, summer and fall) and an additional regime designated as mariners' fall. These seasonal wind regimes are discussed and related to the monthly mean ocean circulation in the Bight.

1. Introduction
Interest in the meteorology and climatology of the South Atlantic Bight (SAB) has increased recently because of shipping, offshore oil exploration and drilling, and other energy or defense related activities. Possible environmental consequences of planned or unplanned releases of materials into the ocean or atmosphere demand a better understanding of physical transport processes. Equally important is verification of physical models of shallow-water and atmospheric boundary-layer flow.

A relatively recent studies have led to useful data summaries on the climatology and circulation of the SAB. The U.S. Naval Weather Detachment has published the Climatic Study of the Near Coastal Zone—East Coast of the United States (1976). The Navy study was based on tabulation of surface marine data analyzed on a $1^\circ$ latitude by $1^\circ$ longitude grid. Among other data, surface wind roses and surface currents are presented. Jacobson (1974) and Ruzek (1974) conveniently summarized the climatology and physical oceanography of the SAB for the Bureau of Land Management (BLM). Recent studies of the SAB (Pietrafesa and Lee, 1979) supported by the BLM used the available experimental data and mathematical models to provide an up-to-date summary of knowledge about the SAB's circulation.

The present study relates the mean monthly wind fields to the shelf circulation on a grid of $1/2^\circ$ latitude by $1/2^\circ$ longitude. It compliments and extends the U.S. Navy study mentioned above.

2. Data source
Marine weather observations are made routinely at 3 h intervals (0000, 0300, 0600, 0900, 1200, 1500, 1800 and 2100 GMT) by most commercial and government ships, and are individually compiled and sent monthly to the National Climatic Center in Asheville, North Carolina. The data contained in the reports are keypunched and placed on magnetic tape data files. One such major tape file is known as the Tape Data Family-11 (TDF-11), which represents the coded weather observations from ships of opportunity. These data are subgrouped into card deck categories which represent the major agency or nation compiling the reports. The publication, TDF-11 Surface Marine Observations, lists 17 such card decks contained on the tapes. The TDF-11 tapes are the data source for this report.

3. Sorting and editing
Two periods of study were chosen: 1) 1945—63 (Card Deck 116), and 2) 1963—73 (Card Deck 128). Data from the TDF-11 set were first sorted to include only those observations within a bounded zone of a sphere covering the North Atlantic Ocean from Cape Hatteras, North Carolina, to Miami, Florida, and 80°—74°W longitude. This preliminary sort resulted in 1,056,716 weather observations. Another sort of the data retained only the observations within an irregular grid covering the SAB region including the continental shelf and part of the Gulf Stream (see

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Fig. 1. A total of 368,900 observations for the 24-year span is included in this region.

Thirty-nine percent of the total (143,802) observations in the SAB came from the more recent Card Deck 128. Presumably, with more modern instrumentation aboard the ships involved, these observations would tend to be the most accurate. The number of observations on a monthly basis for the total region was fairly constant, varying by only \( \sim 10\% \). A total of 194,087 observations were derived from Card Deck 116, i.e., 53% of the total for the SAB. Ninety-two percent of the observations are included in Card Decks 116 and 128. The remaining 15 card decks accumulated are almost inconsequential and were not included in the final data sets.

Fig. 2 shows the monthly averaged spatial distribution of data for Card Deck 116. Each number in Fig. 2 was computed by summing the number of observations for a grid cell for the 19-year period, then summing over the 12 months, (January–December) and dividing the result by 12.

Elimination of observations from the data set was done whenever the following occurred:

- The ship’s position was reported by whole degrees latitude and longitude rather than degrees and tenths.
- The wind direction was reported as calm or variable.
- The grid cell contained less than 20 observations for a given card deck and month.

We felt that the first criterion would eliminate faulty or imprecise navigation, the second, ambiguous wind observations, and the third, statistically insignificant sample sizes.

**Wind Fields**

Observations of wind speed and direction are taken at selected 3 h intervals. The shipboard observer is required to subtract out the motion of the ship by using a nomograph. After storing the wind observations belonging to a particular grid cell, wind velocity vectors are computed and a vector-averaged wind is determined for each individual cell. When this operation is completed for all the cells, the results are plotted on a monthly basis.

Despite the many possibilities for errors in observing, recording and collating the data, a fairly organized monthly flow pattern emerged. Figs. 3–14
Fig. 3. Mean monthly wind vectors for November (1945–63).

Fig. 4. As in Fig. 3 except for December.

Fig. 5. As in Fig. 3 except for January.

Fig. 6. As in Fig. 3 except for February.
show the plotted wind vectors for each month of the year. All vectors have been normalized with respect to the largest average speed at all grid locations for the entire year (8.4 m s\(^{-1}\)). The wind fields derived from Card Decks 116 and 128 are substantially similar. Journal space limitations do not permit inclusion of illustrations for both sets of data; therefore, only Card Deck 116 is discussed and illustrated.

4. The five seasonal wind regimes


This major pattern (Figs. 3–6) persists throughout the months of November, December, January and February, and to some extent, March. In November, the winds are characterized by northwesterlies over the North Carolina continental shelf, and an increasing northeasterly flow over the shelf regions of South Carolina, Georgia and the northern Florida peninsula. The shelf area east of the Southern Florida peninsula is characterized by northeasterly flow. In December, January and February, there is a progression of the northwesterlies toward more southerly latitudes. In addition, the speed of the wind increases in the northern half of the Bight while decreasing in the southern half as winter progresses.

![Figure 3](image_url)

**Fig. 3.** As in Fig. 2 except for April.

b. Spring: Transition regime (March, April, May)

The first changes in the low-level circulation occur in March (Fig. 7) as evidenced by westerlies and southwesterlies nearshore along the Bight from northern Florida to Charleston.

In April (Fig. 8), westerly and southwesterly flow develops off the coast of the two Carolinas. Easterlies begin off southern Florida. The trade winds off southern Florida increase in speed and a center of negative vorticity forms off northern Florida. In other areas the flow tends to be somewhat chaotic.

The May flow pattern (Fig. 9) is easterly off most of Florida and southeasterly off the coast from northern Florida to Georgia. The winds are quite random in other areas of the Bight.

c. Summer: East–south–southeast regime (June, July)

In June (Fig. 10), easterly and southeasterly flows dominate the southern half of the Bight. A region of southerly wind flow is apparent off the coast of South Carolina. A small transition zone from Cape Romain to Cape Lookout is bordered by southwesterly flow off North Carolina.

July (Fig. 11) is clearly dominated by easterlies off southern Florida, southerlies off northern Florida and Georgia, and southwesterlies off the two
Carolinas. From southern Florida to Cape Hatteras, the wind is remarkably coherent over the entire region.

**d. Fall: Transition month (August)**

Breakdown of the summer flow occurs during August (Fig. 12). The flow is generally disorganized except for the seaward side of the band off Florida where northeasterlies have been established. From mid-Florida to the North Carolina-South Carolina border, northeasterlies overcome the southerlies on the seaward side of the zone. [For Card Deck 128 the results showed that the summer (July) flow persisted longer into August, but mean speeds were reduced considerably from July.]

**e. Mariners’ fall: Northeast–east (September, October)**

Mariners’ fall is named because it has not been generally recognized by meteorologists and oceanographers as a major wind regime distinguishable from the winter and summer regimes. The term mariner seems appropriate, because early-day mariners and modern-day oceanographers had to cope with periods of strong winds in September and October.

The wind pattern associated with mariners’ fall
can be detected in some of the published climatologies (Naval Weather Service Detachment, 1976), but the contrast of direction between the summer pattern and mariners' fall is more completely illustrated here. During September (Fig. 13), northeasterly flow occurs over the entire region, gradually changing to easterly flow off southern Florida and over the inner shelf region from northern Florida to Charleston, South Carolina.

In October (Fig. 14), northeasterlies prevail over the entire Bight. Most of the wind vectors shift counterclockwise to become more northerly than those in September. The October winds are the strongest for the entire year.

The existence of mariners' fall in the SAB area was noted rather early (Green, 1944) and used in the circulation discussion of the classic work by Bumpus (1973), but is expanded in time and space detail in the present work. Saunders' (1977) work mentioned the unusual nature of the wind stress during the fall season and referred to it as a regional peculiarity.

5. Discussion

Mean monthly sea level pressure charts are given in the U.S. Navy Marine Climatic Atlas (Naval Weather Service Detachment, 1974). In November and December the Azores high wanes and the Icelandic low begins to affect wind patterns at the
northern parts of the SAB. In January and February, the Icelandic low extends far southward, and the wind fields of the SAB also reflect this. The high pressure system over North America (although much weaker) combines with the Icelandic low to influence the coastal winds in a northwesterly direction as seen from the ship data.

In March, April and May, the Azores high strengthens at the expense of the Icelandic low, but the SAB winds are probably too far distant to be influenced by either of these two semipermanent pressure cells.

By June, however, the Azores high nears its peak of strength and its clockwise circulation brings southerly coastal winds to the SAB in the southern portions. By July the influence of the Azores high is dominant and the result is the summer pattern of winds shown in Fig. 11.

The August sea level pressure map seems to indicate that the summer pattern of winds ought to continue in the SAB, but we have seen from the marine observations that it does not. The circulation along the coast breaks down rapidly in August. The Azores high is well into its waning stage and does not seem to influence SAB winds in September and October. The September and October regime denoted as mariners' fall is possibly related to the formation of a weak high pressure system centered at 36°N, 70°W in the pressure charts for the month of October. However, the wind flow in the SAB is stronger and the effect more dramatic than the average pressure charts seem to indicate. So it is possible that storms or other factors are a dominant influence during October.

6. SAB circulation

The seasonal wind fields should influence to some extent the surface drift of currents in the SAB. The surface drift study conducted by Bumpus (1973) summarized the known features of circulation utilizing the returns from surface and bottom drifters. The wind fields shown in this paper are consistent with many of the features of the current maps shown by Bumpus (1973). One must use great caution when comparing the drifter fields with the wind fields in this paper. Drifters released in one month may be driven by winds in a following month before the drifter is recovered. Thus, maps for drifters released late in a given month could very well reflect circulation patterns for the following month, as will be seen later.

During winter (November, December, January and February), few surface drifters were recovered north of 32°N latitude. This may have been the result of strong northwesterly winds blowing the drifters out to the Gulf Stream. South of 32°N, the trend of the shoreline becomes north to northwest with the winds blowing more out of the north. These conditions would induce surface drift toward shore. The data reported by Bumpus (1973) reflect this by a greater number of returns from Florida, along with surface maps indicating southward drift off Florida.

The transition period (March, April and May) is defined by an evolution toward southwesterly winds off the Carolinas, Georgia and northern Florida. Drift currents in March and April reflect this with only minor inconsistencies. Drift currents in May are onshore and predominantly out of the northeast. The band of easterly wind off the central and south Florida coast is too narrow and poorly defined to account for the observation.

The summer winds (June, July) are generally southeasterly off Florida, southerly off northern Florida and Georgia, and southwesterly off the Carolinas. The surface drift maps by Bumpus (1973) do not clearly reflect this because returns were relatively few compared to those later in the fall. The eastward drift induced by northward wind stress probably accounts for the low number of returns.

August is a transition month, after which the winds blow strongly and coherently from the northeast for September and October. The drift data for August show coherent vectors throughout the SAB reflecting strong southwestward flow of 5–10 n mi day⁻¹ (Bumpus, 1973). The same is true for drift in September, which better agrees with the wind field for September. We suspect that the drifter map for August in reality reflects the wind regime for September. Drifters released off North Carolina during August would require a minimum of 30 days to reach Florida if they traveled up to 10 n mi day⁻¹. Thus, much of their journey could occur during September, if they were released after the middle of August. The southwestward drift displayed in the August, September and October maps of Bumpus (1973) might more appropriately reflect the currents for September, October and November. The northeast winds would tend to send drifters southward and shoreward. Relatively high drifter returns would be expected under those conditions, and this seems to be the case when Bumpus' data are incremented by one month. Thus the map for October depicting southward flow off Georgia and Florida has few vectors off the Carolinas because drifters released there were eventually swept offshore by the November winds before they could be found.

During northeasterly winds in fall, drifters are transported toward the coast due to Ekman transport. The orientation of the shoreline strengthens the shelf flow southward (Csanady, 1975) producing the well-defined surface circulation shown by Bumpus (1973). If one takes into account the time lag that occurs from time of release to time of recovery,
the strong late autumn shelf circulation regime compares quite well with the late autumn wind fields depicted here.

7. Conclusions

The wind direction patterns seem to have three distinctly different regimes: winter (northwesterly), summer (southeasterly) and mariners' fall (northeasterly). The transition between winter and summer occurs slowly over the months of March, April and May. The transition in wind pattern occurs rapidly during August between summer and the newly-named mariners' fall. The transition between mariners' fall and winter occurs too rapidly to be resolved in these monthly data sets.

Drifter data presented by Bumpus (1973) are consistent with the monthly mean wind fields during winter. The lack of drifter returns during June and July is consistent with the coastal winds of the same months. Also, the drifter data of September and October agree with the wind fields during mariners' fall. Our study indicates that users of drifter data by Bumpus (1973) must allow for the likelihood that the drifter maps for a given month may more accurately reflect the wind regime one month later. One could expect a transit time of 30 days or more before a drifter is found.

The transition period of spring (March, April and May) and fall (August) have consistent mean wind and drifter data only if one is willing to allow the eddies or other physical factors which overshadow the wind effect. The fall (August) transition period can be explained by the influence of the September–October wind regime late in the drifter's lifetime. This effect tends to bias the Bumpus data toward circulation imposed in the early part of mariners' fall.

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