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Technical Note

Ocean Spectra Climatology in the Gulf of Mexico[†].

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Abstract

A climatology of ocean wave spectra has been developed for the nearshore waters of the Gulf of Mexico. Long term records from 7 National Data Buoy Center (NDBC) buoys were used for this study. Supplement information on wave direction was obtained from a relatively shorter hindcast database that was developed using the third generation wave spectral model WAVEWATCH III^{TM}.

Acknowledgments. The data used in this study is from the National Data Buoy Center (NDBC) archives. The authors would like to thank Bruce Wooden from the NOAA Office of Marine and Aviation Operations (OMAO) who is spear-heading the design work that motivated this study. This report is available as a pdf file from

http://polar.ncep.noaa.gov/waves

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1 Introduction

The NOAA office of Marine and Aviation Operations (OMAO) is in the conceptual design phase of a Fisheries survey vessel (FS5) that will operate in shallow waters (water depth $\approx$ 6 fathoms). Due to design constraints for the ship, OMAO wants to obtain a good estimate of the ocean conditions (particularly the ocean spectra) in the waters in which this ship will operate. The ocean spectra data will be used in a Ship Motion Program to predict the ship motion. These predictions are necessary to ensure that the ship will be able to complete the shallow water surveys. In the event of excessive motion, some hull modifications may be necessary.

The Marine Modeling and Analysis Branch (MMAB) at NCEP was approached to provide some guidance on the wave conditions in the regions where the survey vessel is expected to operate. With this in mind a wave climatology based on long term observations has been developed and is the subject of this report. The ship is expected to operate in the Gulf of Mexico and along the Florida coast in the Atlantic Ocean. The main concern were the shorter waves which could have significant impact on the roll characteristics of the vessel. Since the longer swells that impact the Atlantic coast are not critical, this study has been limited to the nearshore waters of the Gulf of Mexico.

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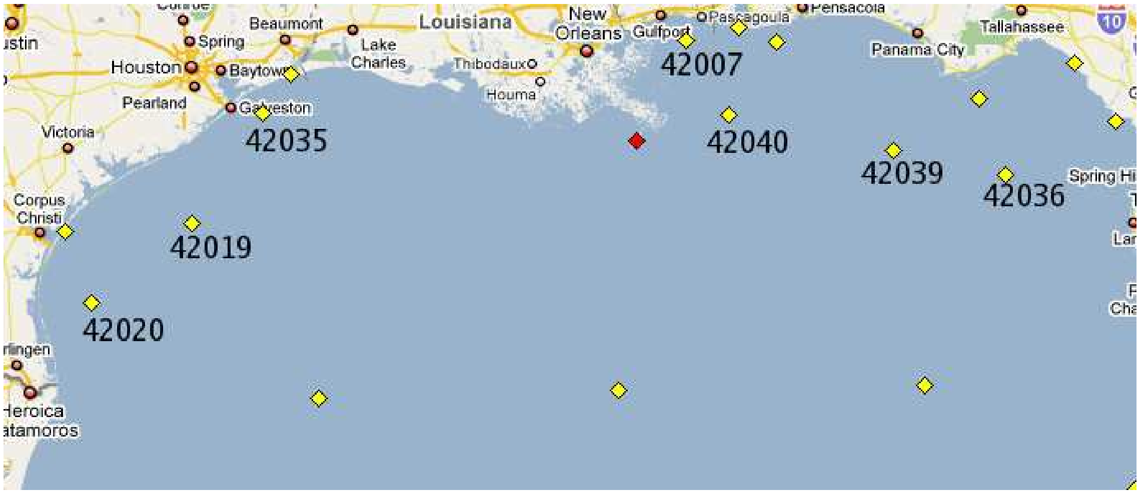

Fig. 2.1 : NDBC buoys for climatology study. The NDBC met/ocean buoys are identified by yellow diamonds and the stations used in this study are labeled by their unique 5 character long ID numbers

2 Methodology

There are two separate sources from which a climatology of the ocean spectra can be developed. First, is the data archive from the National Data Buoy Center (NDBC) which provides long term field observations from a number of moored buoys in this region. Second, is an archive of wave hindcast simulations of a third generation wind wave model called WAVEWATCH III$^{\text{TM}}$(Tolman, 2002, 2008). The wave model has been providing wave forecast guidance to the National Weather Service for over a decade.

NDBC has a fairly large network of ocean buoys in the Gulf of Mexico that have been recording ocean wave spectra for more than a decade. Due to the availability of this extensive record, buoy data are the primary source of our climatology study. However, wave directional data are only available at some select locations. Thus, where applicable, wave directional data have been obtained from the wave hindcast simulation archive. This archive is not long enough to develop a climatology, but does provide a reasonable distribution of wave direction.

We have chosen 7 stations in the Gulf to develop our climatology (see Fig 2.1). Two of the stations (42007 and 42035) are in relatively shallow water (where the design climatology is desired) while the remaining are further offshore and in much deeper water (see Table 2.1). The stations have been chosen because they record spectral data, have a long data archive (greater than 10 years) and cover a significant portion of the nearshore gulf region.

At each of these stations the buoys record hourly wave spectral information. The spectra is derived from a 20 minute sample of the buoy tilt and heave sensors.

Table 2.1: Gulf of Mexico buoy particulars.

Buoy ID	Longitude	Latitude	Water Depth (m)
42007	88.77 W	30.09 N	14.7
42035	94.41 W	29.23 N	13.7
42020	96.69 W	26.97 N	88.1
42019	95.36 W	27.91 N	83
42040	88.21 W	29.21 N	274
42039	86.01 W	28.79 N	307
42036	84.52 W	28.5 N	54.5

Detailed information on the sampling strategy can be found at the NDBC website (http://www.ndbc.noaa.gov/measdes.shtml). We used a ten year archive (1997 - 2007) of hourly wave spectral data to construct our climatology at the different stations and the results are explained in the next section.

3 Results

The climatology was constructed on a month by month basis. Since the frequency bins over which the wave spectra are defined remain unchanged across the extent of the archive, it was possible to compute statistics on the wave spectra on a bin by bin basis, for a particular month across all the years.

Figs. 3.1 to 3.7 show the wave spectra climatology at all the buoys for the different months of the year. In each subplot the x axis refers to frequency (in s^{-1}) and the y axis refers to the energy spectra (in m^2s). Plotted on the figures are the average spectra for the month (with the spread indicated by the 95 per cent confidence interval), as well as the different percentiles of wave energy. The X percentile line, where X is a number between 0 and 100, indicates that X per cent of the wave spectra is below this line. The different percentile lines show how often the energy is below a particular limit, and thus provide guidance on expected operational conditions.

At all the buoys we find that the peak of the spectra is around 0.15 Hz, which translates to a wave period of $\approx$ 7 sec. The energy tends to be higher during the winter months, with the summer months being relatively calm. The influence of hurricanes during the hurricane season (July - Sep) can also be seen in the spectral climatology. During this time we see the development of longer swells in the average spectra, as well as an increase in the spread due to the limited occurrence of these events. The infrequent nature of these events preclude their signature patterns being observed in the different percentile lines. The hurricane driven swell patterns are particularly obvious in buoys 42007 (Fig 3.1) and 42040 (Fig 3.5) which were along the path of hurricane Katrina as it made landfall. It should be pointed out that the confidence interval spreads have been computed assuming a Gaussian distribution, which is valid for most region of the spectra (as shown by the average spectra lying between the 90^{th} and 25^{th} percentile curves. However, in the hurricane driven swell portion of the spectra, the Guassian distribution is not a valid assumption, thus underestimating the actual spread.

The offshore energy spectra in the western part of the Gulf (buoys 42019 and 42020) is greater than the offshore energy spectra in the eastern part of the Gulf (buoys 42040, 42039 and 42036) by approximately 30 percent. This translates into a roughly 15 percent difference in wave heights in these two regions. The most probable cause of this apparent difference is the longer fetches for waves propagating across the Gulf.

Comparing offshore wave climate with the shallow water nearshore wave climate (where the design vessel is expected to operate) we find that the wave conditions are comparatively weaker in the shallow waters. The lower energy in the shallow waters is likely due to the relative closeness of the buoys to the coast. This would not have much of an impact if the waves were driven onshore, but

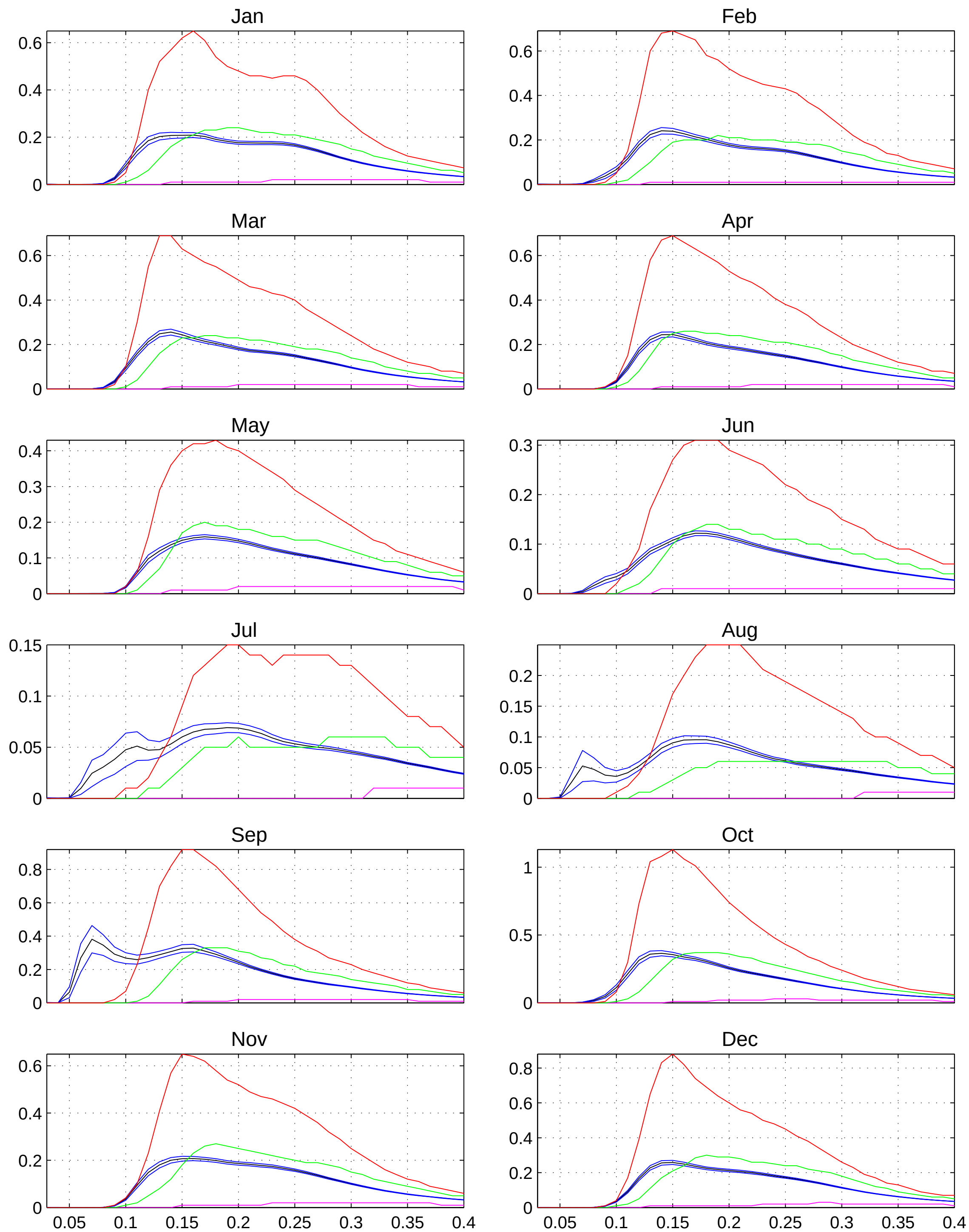

Fig. 3.1 : Wave spectra climatology for buoy 42007. ('Black' is the mean spectra; 'Blue' is the 95 percent confidence interval; 'Red', 'Green' and 'Blue' lines are the 90^{th}, 75^{th} and 25^{th} percentile of wave energy, respectively)

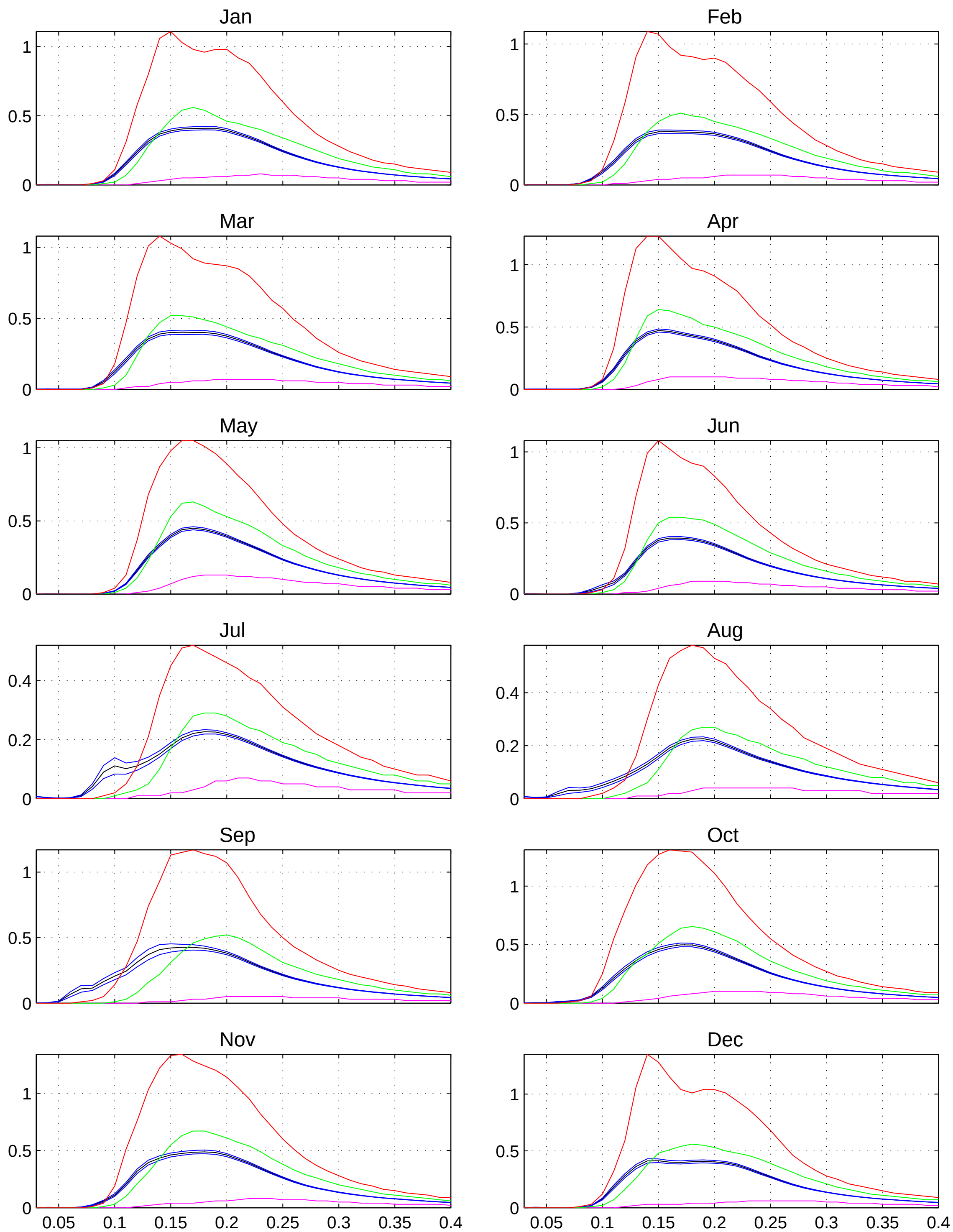

Fig. 3.2 : Wave spectra climatology for buoy 42035. (Caption similar to Fig. 3.1)

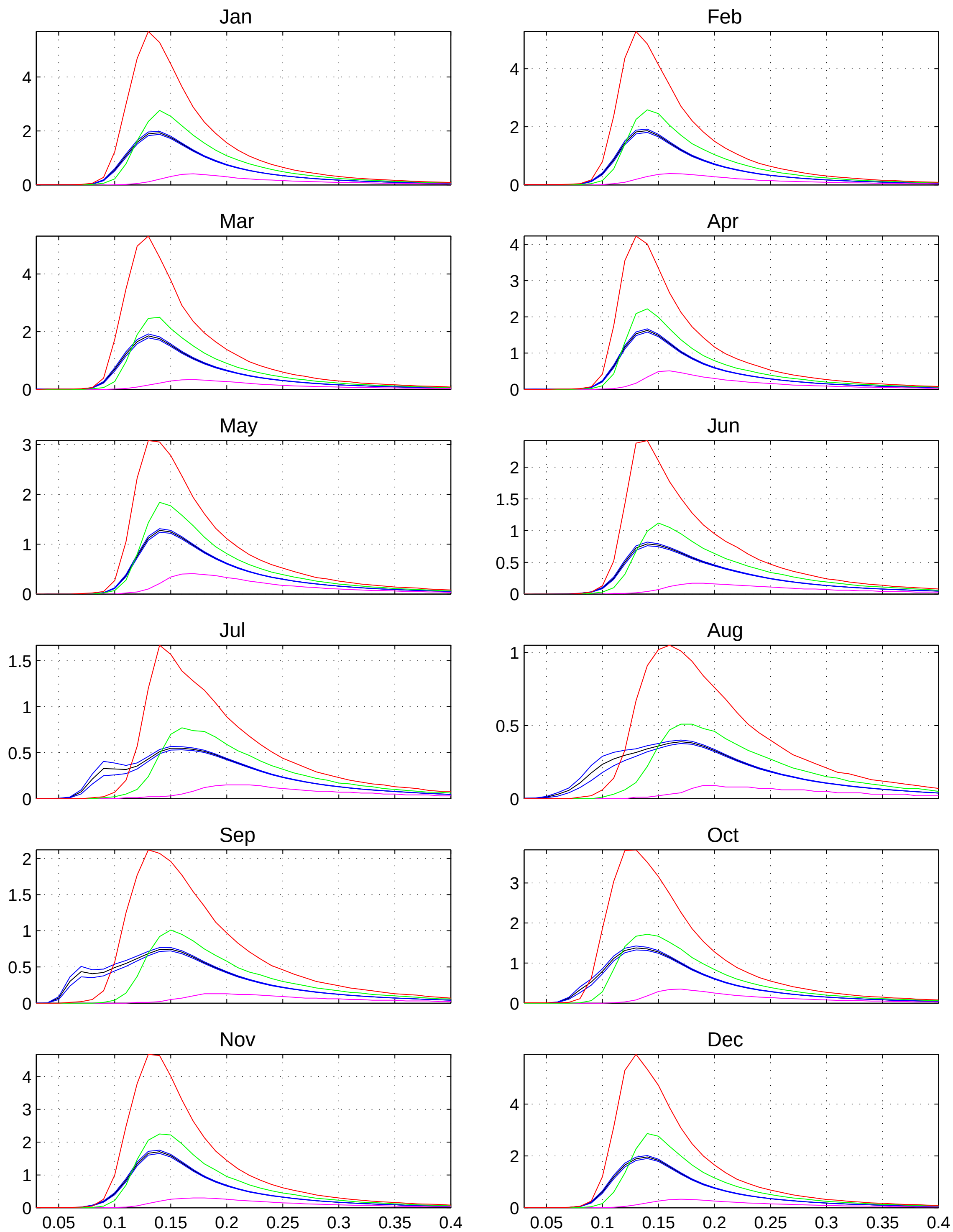

Fig. 3.3 : Wave spectra climatology for buoy 42020. (Caption similar to Fig. 3.1)

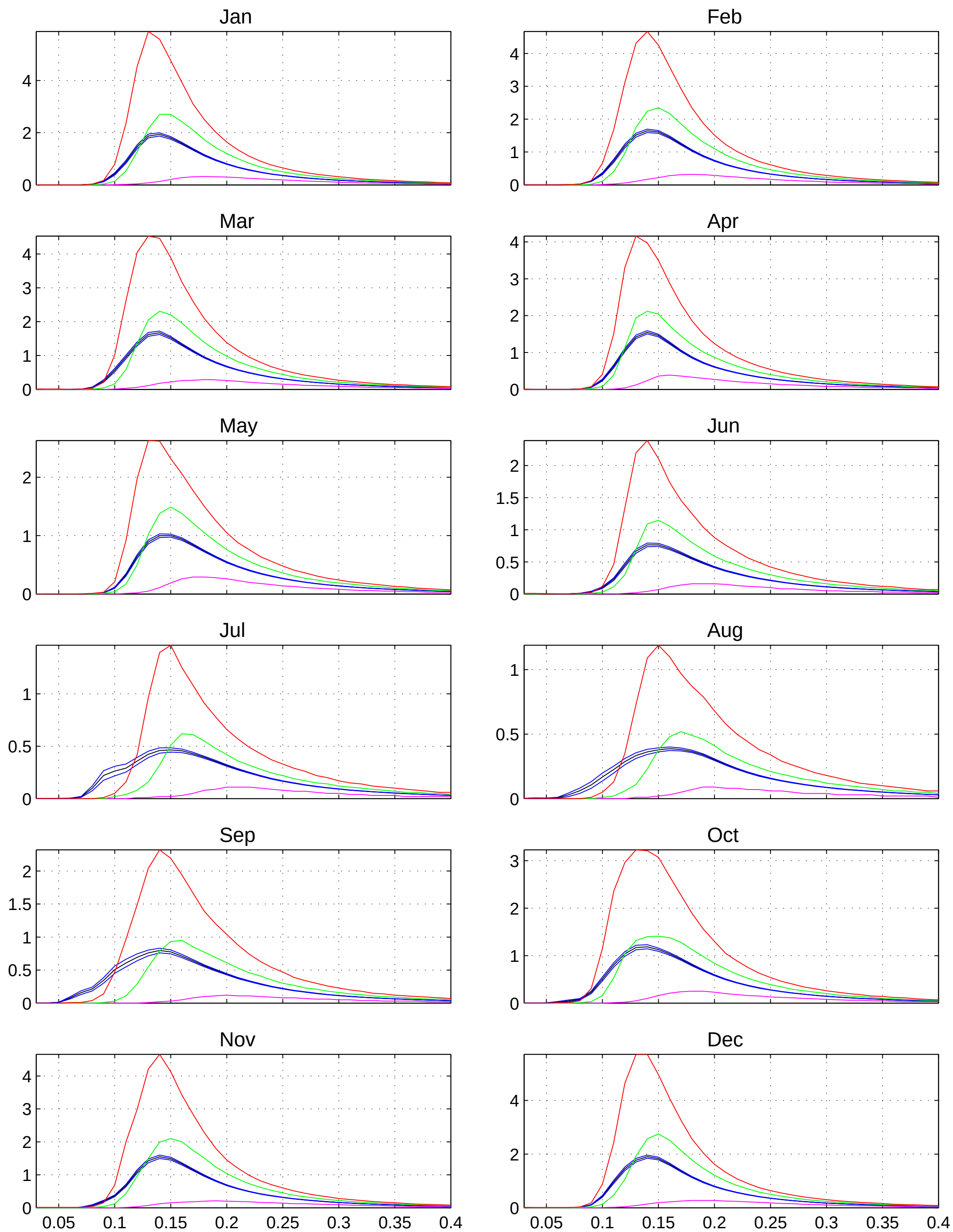

Fig. 3.4 : Wave spectra climatology for buoy 42019. (Caption similar to Fig. 3.1)

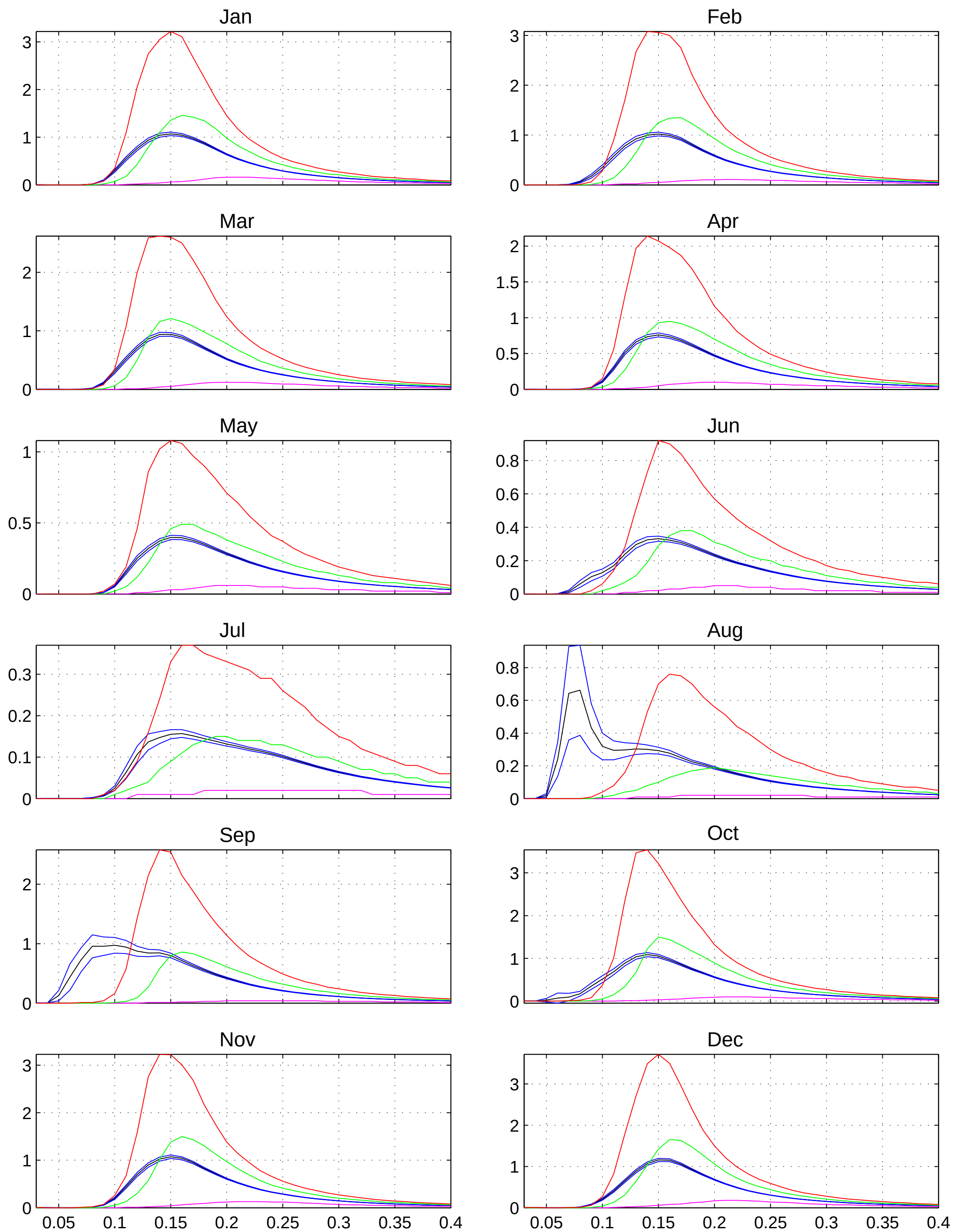

Fig. 3.5 : Wave spectra climatology for buoy 42040. (Caption similar to Fig. 3.1)

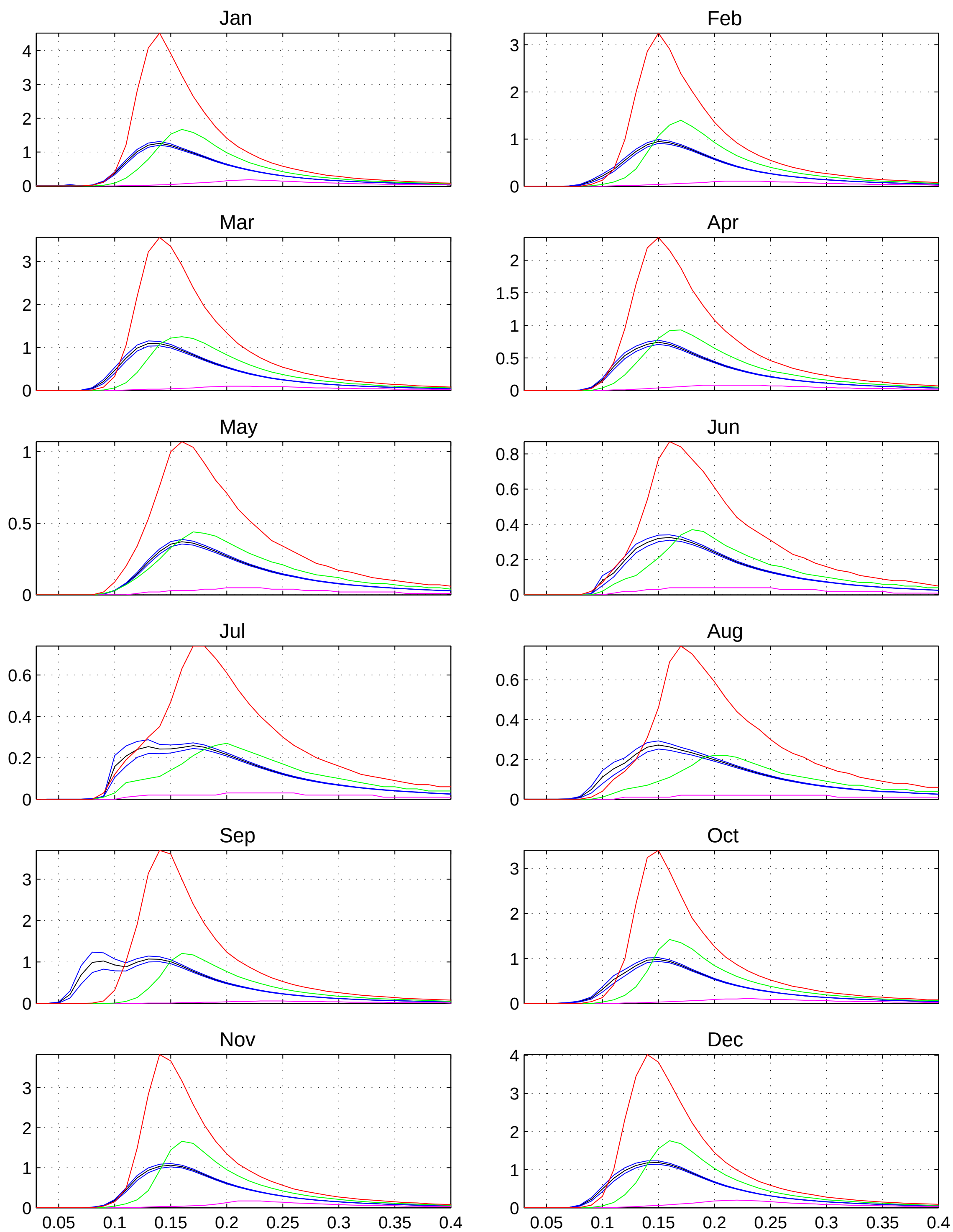

Fig. 3.6 : Wave spectra climatology for buoy 42039. (Caption similar to Fig. 3.1)

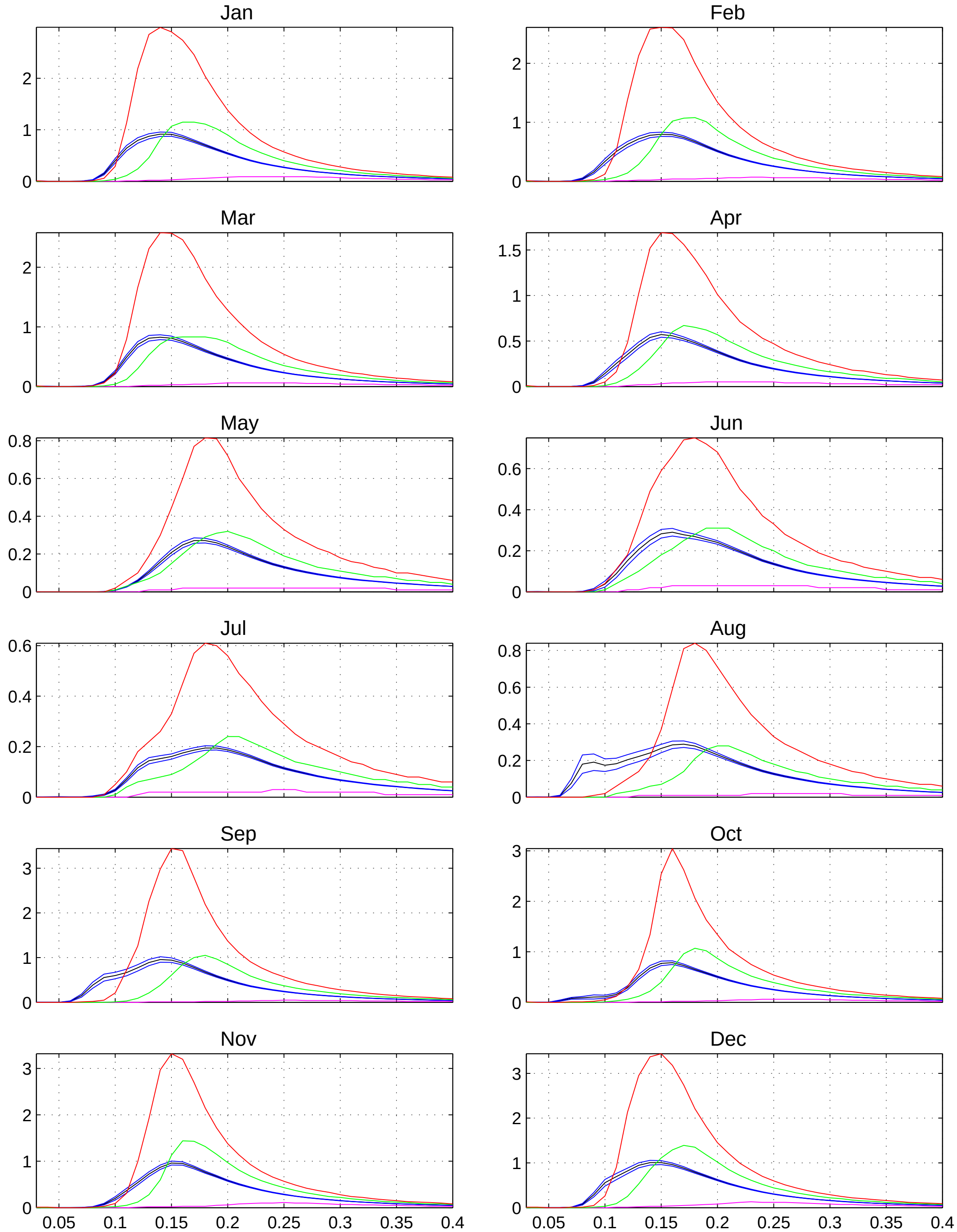

Fig. 3.7 : Wave spectra climatology for buoy 42036. (Caption similar to Fig. 3.1)

have a significant impact for offshore driven waves. We used a hindcast archive (developed using WAVEWATCH III^{TM}) extending from 2005-2009 to obtain a distribution of wave directions for the peak frequency component (component with the highest energy) and found that the distribution was evenly distributed between onshore driven and offshore driven waves (figure not shown).

4 Conclusions

The aim of this report was to deliver design spectra for the Gulf of Mexico nearshore waters which could be used in a Ship Motion Program to test the sea worthiness of a survey vessel being designed by NOAA - OMAO.

With that in mind we used a 10 year archive to construct a year long climatology at seven locations. The climatology included the mean, 90^{th}, 75^{th} and 25^{th} percentile spectra for each buoy. In general we found that the energy spectra tended to be higher in the western part of the Gulf than in the eastern part by $\approx$ 20-30 percent. Also, in general the energy spectra at the offshore buoys tend to be higher than the energy spectra at the nearshore buoys. This because waves in these parts are as likely to be onshore driven as offshore driven. And while not much difference in wave spectra is expected for the onshore riven waves, the offshore driven waves can be very different due to the very small fetch for the nearshore buoys.

References

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