INVESTIGATION OF THE WAVE ENERGY POTENTIAL IN BLACK SEA BY MEANS OF SATELLITE DATA

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KEYWORDS: Wave energy, Black Sea, Satellite data

ABSTRACT: In this study, the sources renewable and clean energy sources were discussed. Due to these energy sources are accepted as clean energy, they have limited negative effects on environment. Wave energy is comparatively new but requires expensive technique to operate, contrary to other countries there is no production activity on wave energy in Turkey. Although in the studies related to determine the wave energy potential required before the production activity, in general, these process are carried out by using models rather than in situ measurements of the wave height, which is the basic parameter of the wave energy. The main reason for this is that the wave size measurement due to sea conditions can be very costly and technically difficult. Additionally, these equipment is not produced in Turkey and are provided from other countries. In this study, the possibility of using satellite imageries to obtained wave height is considered. In order to determine the accuracy of satellite data, wave meters and satellites receiving data from the same region were taken was compared. Satellite data is downloaded from aviso+ web site for comparison. Due to the lack of satellite data formats, the conversion process has been performed so that the downloaded data will be read in Excel format. In order to determine the results, wave energy conversion systems and the wave power values of the seas in the region of these systems have been investigated. With this comparison, the wave power potential of the Black Sea and the wave energy that can be provided for Istanbul was determined. With all these evaluations and investigations, it has been concluded that wave energy could be an important energy source for Turkey in the near future. Although the amount of wave energy is relatively small compared to fossil fuels, there is a source of energy that can be used in wave power in the Turkish seas.

1. INTRODUCTION

Nowadays, Energy has become one of the basic needs of individual and society. One of the most important conditions of being economically powerful is that the demand for energy can be met by the state's own means. In this context, states have entered into a competition with each other. Fossil fuels, which are abundant in nature, have been used in meeting the need for energy for a long time throughout the world, and almost all energy needs infrastructure is based

on the use of fossil fuels. Due to increased environmental problems and concern, significant search for alternative energy sources has been started.

Due to three sides of Turkey covered by seas of Black Sea, Aegean Sea and Mediterranean Sea, wave energy potential should be considered as an alternative renewable energy source for Turkey. In addition to these three seas, the Marmara Sea, which is an economic and strategically important inland sea between Istanbul and the Straits. Due to geographical location of Turkey, it seems that the interaction with sea is quite large but in fact it is not that much. In general, seas are used for generally for fishing and tourism activities. Apart from these, as an important issue, Turkey may get the energy from the sea (Saglam et al., 2010).

Developing countries like Turkey, industry and growing population requires more energy. Another issue of Turkey is not homogeneous distribution of industry and population. Much of industries are located around the Istanbul and the Marmara Region. Thus, energy requirement is constantly increased.

Along with the evolving technology and industry in the world as well as in Turkey, the economy and social development in terms of energy resources has become the first requirement of the communities. Although the need for energy has always been present throughout human history, the demand for energy resources has increased after the Industrial Revolution and this increase continues nowadays. For a long time, most of the energy requirement in the world was supplied from fossil sources (coal, oil and natural gas). In Figure 1, energy production sources in percentage of OECD countries in the years of 1973 and 2016. It can be seen in the figure, total percentage of fossil fuels has sharply decreased which is considered as a positive development but this level is not yet at the desired level (IAE, 2017).

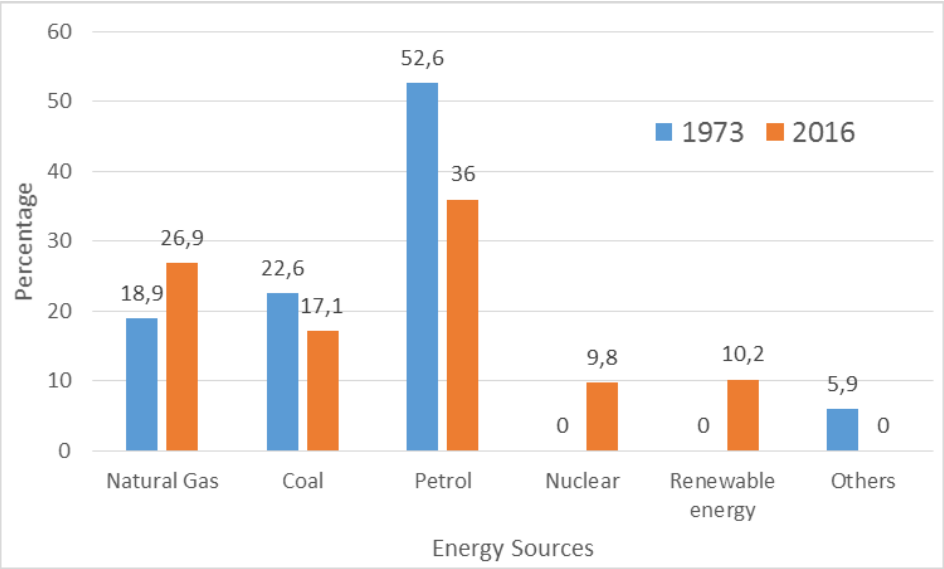

Figure 1. Distribution of the energy sources of OECD countries.

Although fossil energy resources are currently being used at a high rate, it is foreseen that this rate will not be sustainable in the future. The main reason for this is the limited amount of fossil fuel resources in the world. When the reserves of the world are examined, it is predicted that oil reserves will be exhausted in a 51 years, natural gas reserves in a 53 years and coal reserves in a 114 years (Aktas, 2019). In addition to energy production, fossil fuel resources are used extensively by people in daily life. The world has used fossil fuels extensively to meet its energy requirement for a long time. Therefore, fossil fuels are used in many processes such as transportation, heating and cooking. This intensity use cause also environmental problems. In spite of all these, with the increasing awareness about the environment, manufacturers develop more environmentally friendly and electrically operated transportation vehicles and heating systems. In this way, it is aimed to reduce environmental impacts of fossil fuels.

Due to the negative effects of fossil fuels, investments in sectors such as extraction, transmission, processing and utilization of these resources are expected to decrease in the future. According to the International Energy Agency, it is estimated that a total of 66.5 trillion USD will be invested in the energy sector between 2016 and 2040 on a global scale. It is observed that, usage of renewable clean energy sources in European Union (EU) region is significantly increased.

Actually, the renewable energy sources, which have been known and used for many years but cannot compete with fossil fuels. They are gaining importance again. In particular, EU countries that are not rich in fossil resource reserves, industrialized Far East countries and the United States (USA), whose energy consumption is very large, are the pioneers in the development and dissemination of renewable energy resources. Although renewable energy sources still have a small share in proportion but this ratio is gradually increasing.

According to the scenarios, although the shares of fossil fuels have decreased relatively by 2040, they still will be the dominant sources. The usage of nuclear energy in primary energy resources is expected to increase. In general it is expected that usage of renewable energy resources in 2040 will be 16.1%. According to the current policy scenario, global electricity demand is expected to increase by 80% by 2040, an average of 2.3% per year. Renewables are expected to be the fastest growing energy source with an average annual growth rate of 9.8%. Nuclear power will have an average annual growth rate of 2.3% and growth in hydroelectric is 1.8% on average. The expected growth rate of these three sources is greater than the growth rate of total primary energy sources. The source with the highest growth rate among fossil fuels is natural gas with an average annual growth rate of 1.5%. Natural gas will be followed by oil and coal with an average annual growth rate of 0.4% and 0.2%, respectively (Aktas, 2019). When the New Policies Scenario is taken into account in 2016-2040, investments for energy supply infrastructure by resources is given in Figure 2.

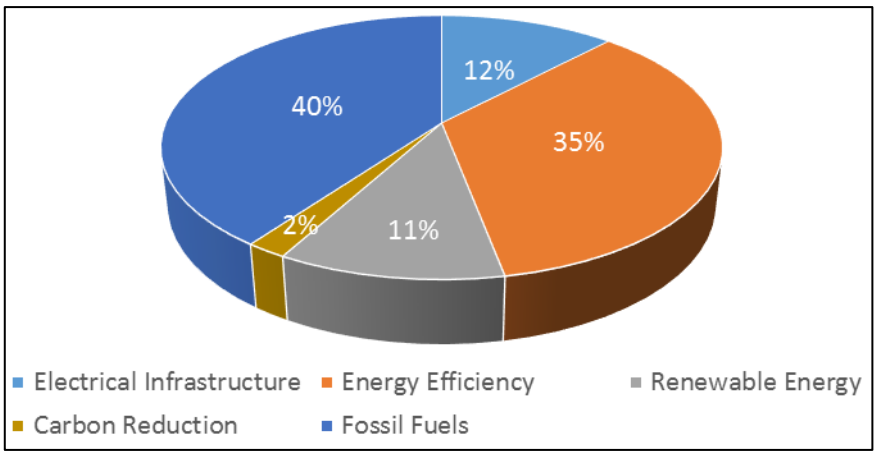

Figure 2. Investments for energy supply infrastructure by resources for 2016-2040.

136.23 Million Tons of Oil Equivalent in Turkey in 2016 annual supply of energy that reaches the value compared to the previous year showed an increase of approximately 5.5%. According to 2016 data, crude oil and petroleum products rose to the first place with 32.7% in energy supply, coal remained at second place with a slight difference and natural gas decreased to third place. The remaining 13.4% was supplied from electricity from renewable sources, including hydraulics. When the 2014-2016 period is compared, it is seen that the share of petroleum and petroleum products, geothermal and wind in the primary energy supply continuously increases and the share of natural gas and bioenergy and wastes decreases continuously (EUAS, 2017). The two main characteristics of Turkish energy markets are the ever increasing demand and dependence on foreign sources in the supply of energy resources.

In recent years, it is particularly important developments and breakthroughs in the use of renewable energy sources observed, though, that Turkey is surrounded by seas on three sides, is seen as lagging behind in obtaining energy from the sea. In this context, the aim of this study is to determine the wave power potential of the Black Sea. The main source of data during this investigation is the data collected by satellites. In this way, both the ease of data collection was tried to be shown and the potential of wave height and wave power was determined. In this study, Jason, SARAL and HY 2 Satellites data were used. This data can be accessed over the internet and thus, the desired analysis can be carried out without the need for an additional data collection tool.

2. DATA AND METHODOLOGY USED

Wave height measurement can be made using buoys or satellites data in all over the world. In particular, the Jason Satellites have been rotating around the world for nearly 20 years and collecting various meteorological and oceanographic data. Apart from Jason satellites, there are many different satellites which collect the similar data. These satellites are given in Table 1.

Table 1. Satellites collecting meteorological and oceanographic data around the world

Satellite	Revisit Cycle	Launched Year
GEOSAT	17	1985
ERS-1	35	1991
Topex/Poseidon	10	1992
ERS-2	35	1995
GFO	17	1998
Jason-1	10	2001
ENVISAT	30–35	2002
Jason-2	10	2008
CryoSat-2	30	2010
HY-2	14/168	2011
SARAL	35	2013
Sentinel-3	27	2016
Jason-3	10	2016

In this study, the satellite wave data were compared with the buoy data and then the wave height data and wave power potential were determined. Satellite data were obtained from AVISO + website and float data from National Data Buoy Center website. In the study 3 different buoys were selected to compare the accuracy of the satellite data. Selected buoys and routes of Jason2 are given in Figure 3.

Figure 3. Location of selected buoys and routes of Jason2 satellite.

3. RESULTS

In the study, overlapping data for the buoys and satellite data were used. After the data is prepared they were compared. Buoys named as 41044, 42055 and 46026 were used these comparison. In Figure 4, the comparison of wave height measurement results of 41044 buoy

and Jason2 satellite for the same region in January 2015 – December 2015 period was presented. In Figure 5, buoy 42055 and Jason2 satellite data was compared for the same period. In Figure 6, comparison of 46026 buoy and Jason2 satellite for the October 2016 - March 2017 period is displayed.

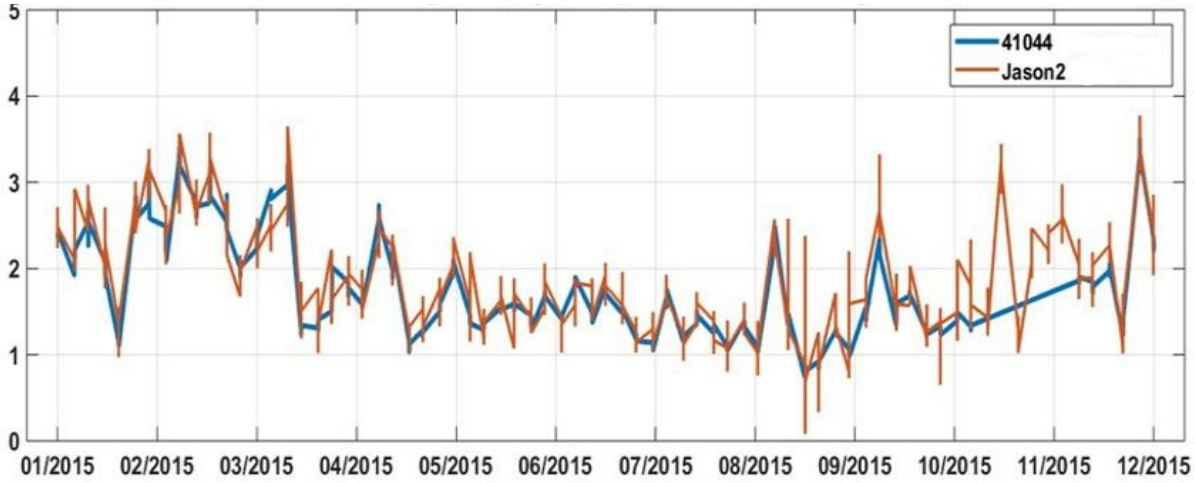

Figure 4. Comparison of the wave height data obtained from buoy 41044 and Jason2 Satellite data for the year of 2015.

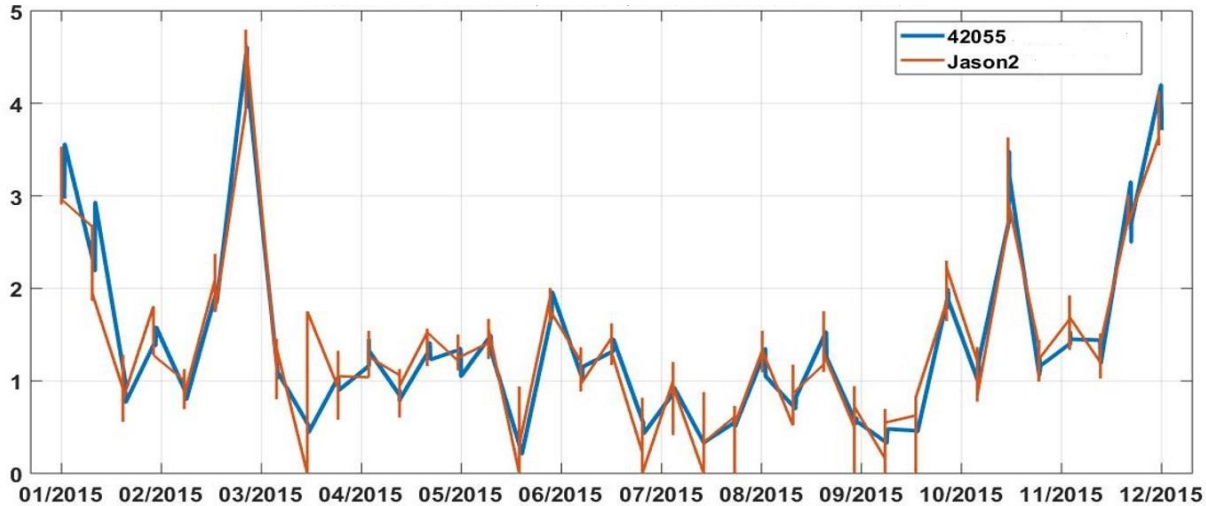

Figure 5. Comparison of wave height data obtained from buoy 42055 and Jason2 Satellite data for the year of 2015.

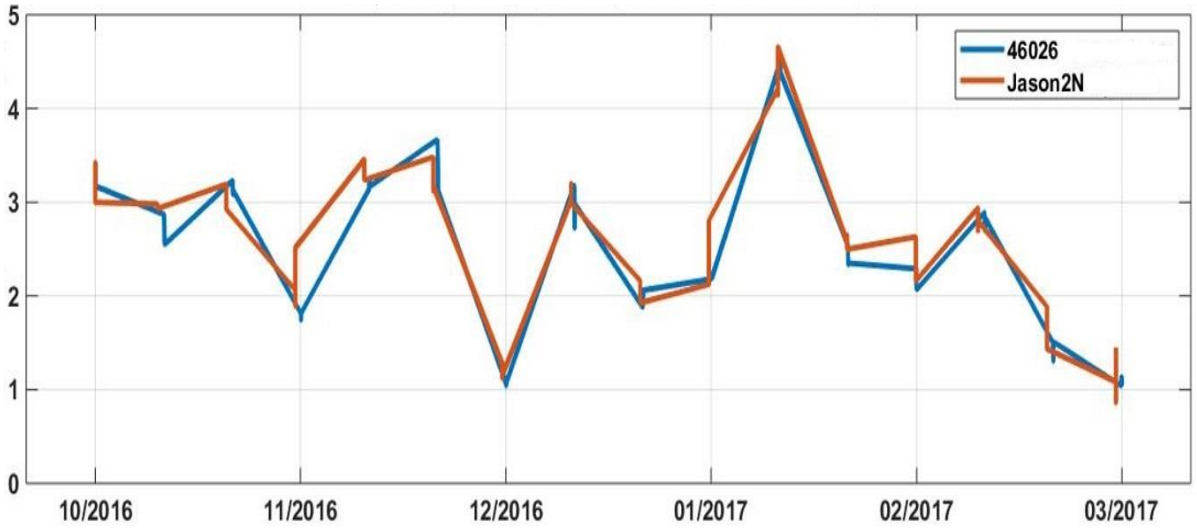

Figure 6. Comparison of wave height measurement results of 46026 buoy and Jason2N satellite for the same region in October 2016 - March 2017 period.

Figures 4, 5 and 6 indicates that there is a significant similarities between buoy and satellite data. It is seen in the figures, the buoys and satellite data have similar values. This similarity indicates that the measurement of wave height with satellite data is suitable Thus, it can be seen that wave height values, which are a difficult measurement, can be measured easily and accurately by means of satellites.

When the satellite trajectories were examined for the region identified as the study area, the results given in Table 2 were obtained. Considering the satellite routes and data collection periods, it is concluded that the most suitable satellite is SARAL for the study area which given in Figure 7.

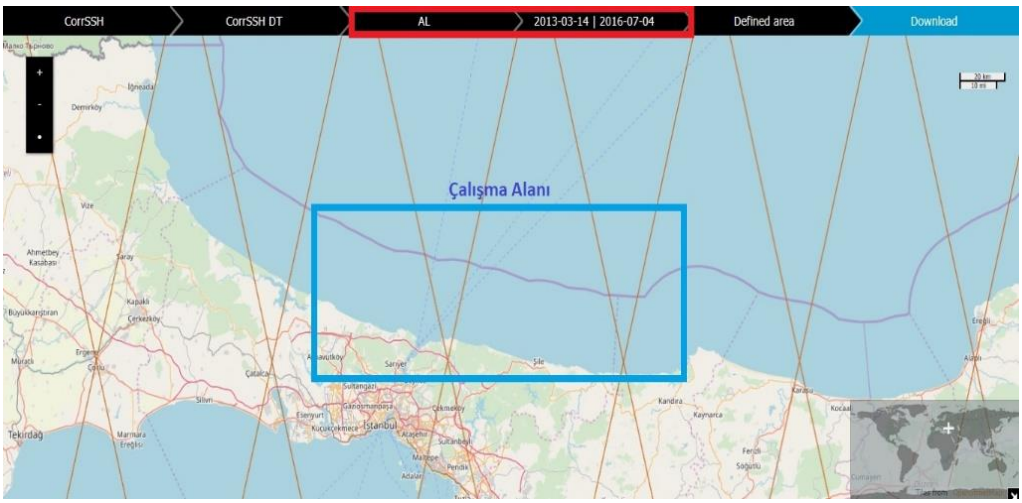

Figure 7. The study area.

Table 2. Wave height values for different satellites of the study area

Satellite	Data Period	Average Hs (m)	Maximum Hs (m)	Minimum Hs (m)
SARAL	2015	1,09	2,95	0,16
HY-2A	2015	1,17	3,58	0,12
Jason 2	2015	1,12	4,80	0,09
Jason 2N	2016 -2017 Winter	1,43	4,65	0,37
SARAL-D	2016 -2017 Winter	1,47	7,35	0,18

The mathematical expression of the sea wave power which is presented in 7th Symposium of the Coastal Engineering as follows;

$$P = (\rho.g2)/(64.\pi)\ Hs2.Te = 0.49\ Hs2.Te\ kW/m$$

As can be seen, the parameters determining wave strength are wave height and wave period. In the same symposium, the wave period for the Black Sea is calculated as;

$$T = 4{,}5125.Hs^{0{,}3235}$$

As a result, the wave height and wave period values required for wave power calculation and wave power values for the working area were also calculated. Table 3 shows the significant wave height values measured by SARAL satellite in 2015 and the wave period and wave power values produced using these values.

Table 3. Example values for the year of 2015.

Date	Hs (m)	T(s)	Power (kW/m)
13.01.2015	1.820	5.477	8.888
17.02.2015	2.952	6.404	27.341
9.04.2015	1.330	4.949	4.290
18.06.2015	0.644	3.914	0.795
23.07.2015	1.976	5.625	10.767
07.09.2015	1.012	4.531	2.275
01.10.2015	2.029	5.674	11.450
02.12.2015	2.473	6.048	18.117

4. CONCLUSIONS

As the intense demand for energy increases day by day, the use of all kinds of energy resources at the highest level has become a necessity rather than a choice. Therefore, to use Turkey's existing resources at the highest level and researches on these issues are very important. Therefore the possibility and necessity of using wave energy sources for Turkey should be kept in mind.

With the continuous increase of technological developments, the utilization rate of wave energy, which has been ignored for a long time, is constantly increasing in the world. In this study, the wave power potential of the Black Sea coasts of Istanbul was determined. In this way, the size of the electrical energy that can be generated by the wave energy converters to be installed in the Black Sea will be determined. In addition, one of the main points of the study is the use of satellites in data measurement. In this way, both the data reliability of the satellites was determined and it was shown that these studies could be done more easily by using data obtained from satellites.

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