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DISTRIBUTION OF TIDE TYPE IN INDONESIAN WATERS BASED ON 7 DAYS DATA MEASUREMENT OF IPASOET-BIG STATION

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ABSTRACT

Tidal data is needed in the field of energy, marine navigation, coastal construction and other activities related to the oceans. Tidal phenomena occur due to the interaction of the earth with space objects. The sea level rise in coastal waters can be modeled by a harmonic function containing tidal constant numbers. From the constants formed can be calculated a Formzahl number that shows the type of tides that occur at the observation station. This paper tries to describe the distribution pattern of tidal types that exist in Indonesian waters based on data observation collected at station belong to the Geospatial Information Agency. The result is that there are 4 types of tides in Indonesian waters, with the most dominant distribution are mixed tide, prevailing semi diurnal typel.

Keywords: Formzahl number, interpoplation, tide, distribution type.

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INTRODUCTION

Tides is a natural phenomenon in the form of rising and falling sea levels on the earth due to the gravitational influence of space objects, especially the sun and moon (Fitirana et al. 2019) [try to find the original article that defines what tide is?. Tidal energy can be used for energy fulfillment purposes (Cocks, 2009). In addition to energy, Pugh (1996) states that the tide of sea water is one of the vital considerations and influences the success of navigation, surveying and construction work located on the coast and / or at the sea.

The tidal forces are generated by the attractive forces of the earth, moon and sun (Fadilah et al., 2014) (try looking for original articles about tide generating forces). The attractive force between the earth and the moon causes the earth-moon system to become a unitary system circulating together around the common axis of revolution. The formation of tides is strongly influenced by the main movements of the sun and moon, namely:

- The revolution of the moon against the earth, where the orbit is elliptical and requires a period to complete the revolution for 29.5 days.
- Earth's revolution against the sun with an elliptical orbit, the required period is 365.25 days.
- Earth's rotation about its own axis, the period required for this movement is 24 hours.

The tidal driving force can be described as the result of the combination of a number of tidal harmonic components. The data components can be grouped into 3 (three) parts, namely: semi-diurnal, diurnal (daily), and long-period. Some important harmonic components and their relative strength comparisons can be seen in Table 1.

According to Triatmodjo (1999) (This statement was first made by Wyrtki in 1961 , in his book The Physical Oceanography of South East Asia), tides in Indonesia are divided into 4 types (Figure 1), namely:

- 1. Double daily tides (Semi Diurnal Tide). It is a tide that occurs two times the tide and two ebbs which are almost the same in one day, this is in the Strait of Malacca to the Andaman Sea.
- 2. Mixed Tide, Prevailing SemiDiurnal. This is a tide that occurs twice and twice a day but sometimes occurs once and once. At low tide, it has a different height and time, it is found on the South Coast of Java and Eastern Indonesia
- 3. Mixed Tide, Prevailing Diurnal, mixed tides. It is a tide which occurs one tide every day and one ebb, but sometimes with two tides and two ebbs which are very different in height and time.
- 4. Single daily tide (Diurnal Tide). It is a tide that only occurs once and one ebb in a day, this is located in the Karimata Strait.

The movement pattern of the tide water level in the territory of Indonesia is dominated by the double daily type. In general, this pattern can be seen in Figure 2.

Formzahl is an index commonly used to determine the type of tide. The Formzahl index has a certain range to determine the tidal type of a region (Fadilah et al. 2014) this statement is also written in Wyrtki 1961. This paper conducts an experiment to describe the distribution pattern of tidal types in Indonesia based on the Formzahl index calculated from the tide station data (Ipasoet) - Geospatial Information Agency (BIG). (source: http://ina-sealevelmonitoring.big.go.id/ipasoet/

Table 1. Important tidal harmonic components (Pond & Pickard, 1981)

Components	Symbol	Period (sun hours)	Ratio (relatif)
Semi-diurnal			
- Principal lunar	M2	12,4	100
- Principal solar	S2	12,0	47
- Larger lunar elliptic	N2	12,7	19
- Luni-solar semi-diurnal	K2	11,97	13
Diurnal			
- Luni-solar diurnal	K1	23,9	58
- Principal lunar diurnal	O1	25,8	42
- Principal solar diurnal	P1	24,1	19
- Larger lunar elliptic	Q1	26,9	8
Long-period			
- lunar fortnightly	Mf	238,0	17
- lunar monthly	Mm	661,0	9
- solar semi-annual	Ssa	2191,0	8

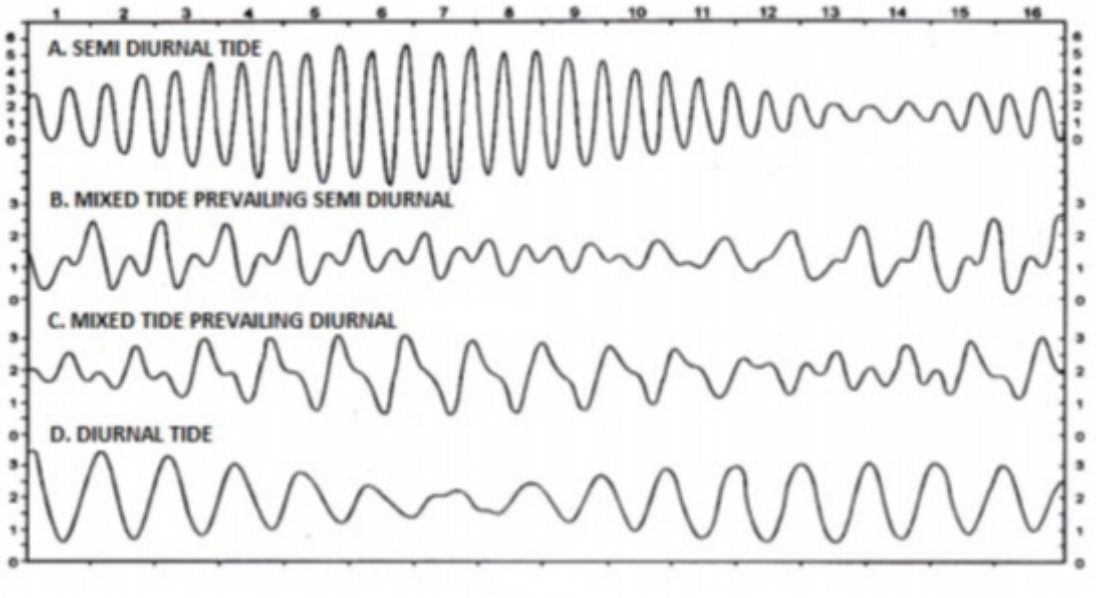

Figure 1. Type of tide that can be found in Indonesia (source: Hendri et al. 2019).

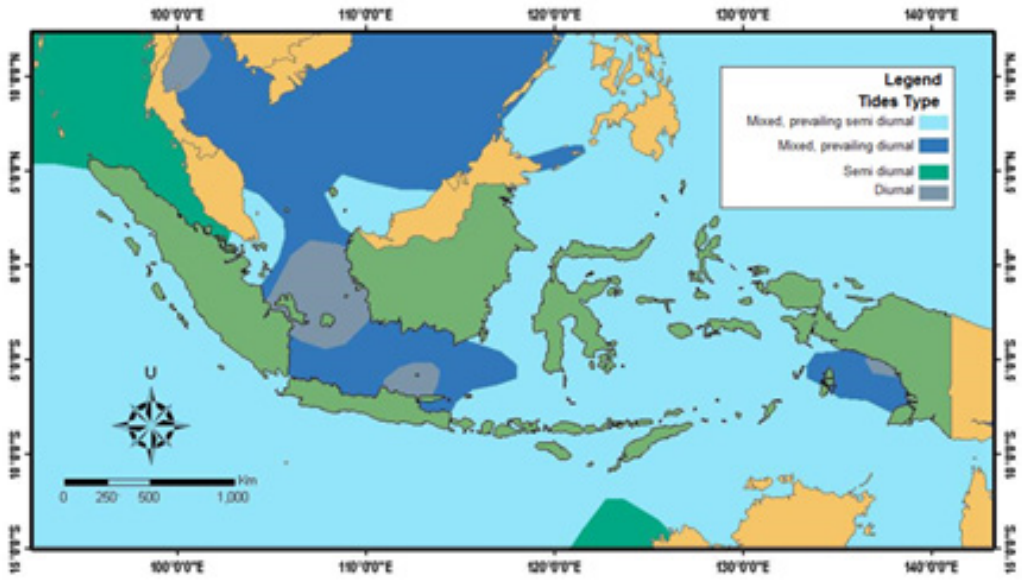

Figure 2. The distribution pattern of tide types in Indonesia (Wyrtki 1961, Anugerah 1987 and Ramdhan 2011).

data/map#)

METHODOLOGY

TThe data that used was downloaded from the list of tidal stations on the Ipasoet website (Figure 3) from 6 February 2020 - 13 February 2020. There are 159 tidal stations on the Ipasoet website, this website is managed by the Geospatial Information Agency (BIG). On the website there are 145 stations that are actively sending data, 14 stations are not sending data. The data processing can be seen in Figure 4.

Tidal data from Ipasoet were downloaded, processed using NumXL and visualized using ArcGIS software. Seven days of data, then the complete day was selected to extract the harmonic numbers.

The calculation of the constant value of tidal harmonic numbers is carried out using the Fourier transform method as used by Ramdhan et al (2018), namely by using the following formula:

$$X_k = \sum_{j=0}^{N-1} x_j e^{-2\pi \frac{i}{N} jk} \quad \text{..... 1)}$$

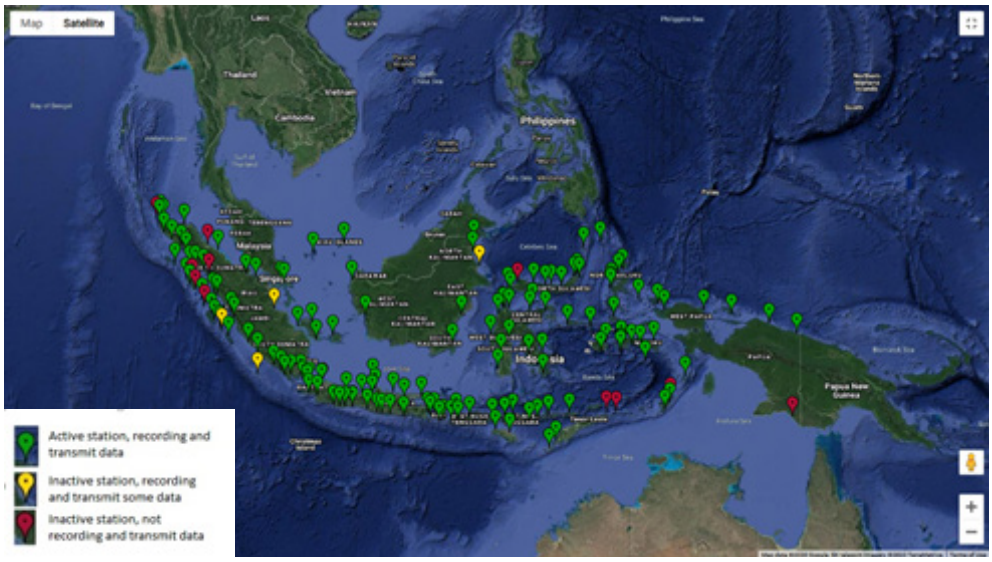

Figure 3. Distribution of Installing Stations of Ipasoet-BIG.

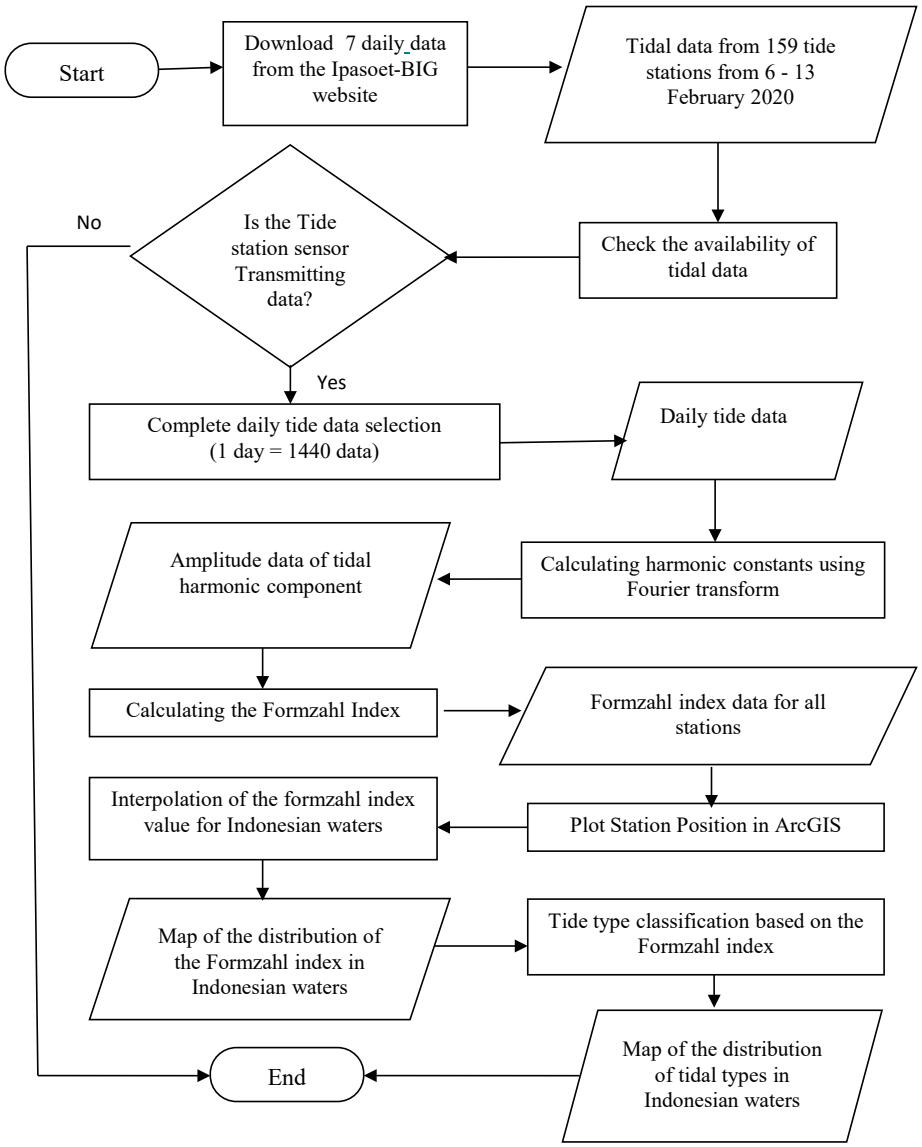

Figure 4. Research flow chart.

where,
k : frequency of the component
x0, ..., xN-1 : the input data tide values.
N : original number as the total input for the time series to be calculated

The software used to produce this tidal component is the 14-day NumXL trial version plug-in with serial number: 79F7-C8-A6-01-7767, for Microsoft Excel 2010. The number of tidal components generated is 7 components, namely: M2, S2 , K1, O1, N2, P1, K2 AND Q1. Furthermore, the Formzahl index is calculated using the following formula:

$$F = \frac{A_{O1} + A_{K1}}{A_{M2} + A_{S2}} \quad \text{..... 2)}$$

where,
F : Formzahl index
AK1 : amplitude of the single main tidal component caused by the attraction of the moon & sun (Meter),
AO1 : the amplitude of the single main tidal component caused by the lunar tensile force (Meter),
AM2 : amplitude of the main double tidal component caused by the moon's tensile force (Meter),
A S2 : amplitude of the main double tidal component caused by the gravitational force of the sun (Meter).

RESULTS AND DISCUSSION

The Formzahl number value of each station is classified into four classes. The double daily type has a smaller formzahl number (consistent please) (equal to 0.25. For the mixed type, the double daily tilt has a formzahl index range between 0.25 and 1.5. The single daily tilt mixture type is in the formzahl number range from 1.5 to 3. Whereas for the Formzahl number value of more than 3, it is classified as a single daily tide type. (For terms that are already commonly used in the field of oceanography, it is better to refer to the book Physical Oceanography of South East Asia, written by Wyrtki, 1961)

Table 2 is the result of the classification of BIG tide stations on the Ipasoet website. There are 6 stations that are included in the dual daily type, namely: Kuala Tanjung - North Sumatra, Tual - Maluku, Lhokseumawe - Nanggroe Aceh Darusalam, Jembrana - Bali, Belawan - North Sumatra and Enggano - Bengkulu. The majority of tidal stations, a total of 114 stations, have a formzhal number with a mixed category with a double daily tilt. There are 11 stations that are included in the single daily tidal mixed tide type. Namely: Badas - NTB, Ampana - Central Sulawesi, Carik - NTB, Pondok Paddle - DKI, Sheet - NTB, Semarang - Central Java, Natuna - Riau Islands, Karimun Jawa - Central Java, Sanana - North Sumatra, Kolinlamil - DKI and Sunda Kelapa - DKI. 14 stations are included in the single daily type, namely: Laiwui - Malut, Barus - North Sumatra, Jambi - Jambi, Sabang - NAD, Pare-pare - South Sulawesi, Bangka - Babel, Tarempa - Kepri, Kayong - West Kalimantan, Sadai - Babel, Makassar - Sulsel, Mamuju - Sulbar, Tuban - East Java, Sungai Liat - Babel and Belitung - Babel.

The results of data processing which state the existence of 4 types of tides in Indonesia are in accordance with the pattern of tide types issued by Wyrtki (1961), Anugerah (1987) and Ramdhan (2011). However, the resulting distribution pattern, as shown in Figure 5, is different for several water areas.

According to Wyrtki (1961), the Andaman waters north of the province of Nanggroe Aceh Darusalam have a double daily tide type. On the map of the tidal distribution pattern, the results of the interpolation of the Formzahl index, a small part of the area is included in the mixed type with a single daily inclination and most of it is a mixed type with a double daily inclination.

The waters of the Java Sea which according to the results of previous studies have a single dominant daily mixed tide type, in this study it can be seen that in the north of Subang (the border of West Java and Central Java) has a double daily mixed tide type. In the north of Jakarta, the Thousand Islands region, the results of the mixed tide type leaning to a single daily were different from the results of research by Widisanto et.al. (2016)

Table 2. Number of stations by tide type

Tide type	Formzahl Index	Number of Station
Semi diurnal	≤ 0,25	6
Mixed, prevailing semi diurna	0,25 < F ≤ 1,5	114
Mixed, prevailing diurnal	1,5 < F ≤ 3	11
Diurnal	> 3	14
Total		145

who conducted tide measurements on Pari Island in August - September 2011. These measurements provide the results of a single daily tide type in the Pari Island region. Meanwhile, Amalina et.al. (2019) stated that from the results of processing tide data for 253 months in Jakarta Bay, the results of the mixed tide type research were tilted to a single daily, the same thing was obtained from the processing of Ipasoet-BIG data.

The Arafura waters, west of Papua province, also gave different results from the previous reference. In Figure 2, it can be seen that the Arafura waters approaching the coastal area have a single daily tide type, and the mixed type tends to a single daily tide. Whereas in Figure 5, the entire Arafura Sea waters is included in the mixed tide type, which tends to double daily. The same results were obtained from the research of Pranowo and Wirasantosa (2011), which states that the Timor and Arafura Sea areas generally have a mixed tide type, while the Tual Island and Kei Besar Island areas provide single daily tide type results.

This different result is possible because of the influence of the shallow water tidal component (M4) in Indonesian waters (Basith and Prakoso, 2015). This effect was not included in the formzahl number calculation. Another possibility is the influence of beach morphology and the non-uniform distribution of tide station distances (Fitriana et al. 2019).

CONCLUSION

Based on the Formzahl index calculated from tidal station data managed by Ipasoet-BIG, there are 4 types of tides in Indonesia, namely: Double Daily, Double Daily Lean Mix, Single Daily Lean Mix and Single Daily Mix. 6 stations have a dual daily type, 114 stations with a single daily tilt mixed type, 11 stations with a single daily tilt mixed type.

The resulting tidal type distribution pattern is different from previous studies. This may be influenced by the presence of other tidal components which are not taken into account in determining the Formzahl index. It can also be influenced by the influence of the beach morphology where the station is located, as well as the varying distance between Ipasoet stations. For this reason, new research is needed regarding other methods besides the formzahl index in determining the type of tide. Also the addition of tidal stations in Indonesia with a systemic / uniform distribution pattern of station distances.

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