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Tidal Data Analysis Based on Season Using Admiralty Method in Lasolo Bay Waters, Southeast Sulawesi

Analisis Data Pasang Surut berdasarkan Musim Menggunakan Metode Admiralty di Perairan Teluk Lasolo, Sulawesi Tenggara

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Abstract

Research on tidal analysis based on seasons has been carried out in Lasolo Bay, Southeast Sulawesi, using secondary data, namely tidal data in 2021 in January representing the western season, April representing the transition season I, July representing the eastern season and October representing the transition season II. This study aims to determine the type of tides formed and the value of sea level elevation in each season at the research site. Tidal data processing uses the admiralty method, producing amplitudes and phase differences from 9 main harmonic components. The analysis results of the calculation of formzhal numbers show that the type of tides formed in Lasolo Bay is a mixed type of double daily inclined with a formzhal number value of 0.5618-0.7059. In addition, based on the calculation of sea level elevation, the maximum average sea level (MSL) occurs in the second transition season (October), which is 532 cm, and the western season (January) is 460 cm. For the other two seasons, the first transitional season (April) and the eastern season (July) have an average sea level of 101 cm and 130 cm.

Keywords: Admiralty method, Formzhal number, Sea level elevation.

Abstrak

Penelitian mengenai analisis pasang surut berdasarkan musim telah dilakukan di Teluk Lasolo, Sulawesi Tenggara dengan menggunakan data sekunder yaitu data pasang surut tahun 2021 pada bulan Januari yang mewakili musim barat, bulan April yang mewakili musim peralihan I, bulan Juli yang mewakili musim timur dan bulan Oktober yang mewakili musim peralihan II. Tujuan dari penelitian ini yaitu untuk mengetahui tipe pasang surut yang terbentuk dan nilai elevasi muka air laut pada setiap musim di lokasi penelitian. Pengolahan data pasang surut dilakukan dengan menggunakan metode *admiralty* yang menghasilkan amplitudo dan beda fase dari 9 komponen harmonik utama. Hasil analisis perhitungan bilangan *formzhal* diketahui bahwa tipe pasang surut yang terbentuk di Teluk Lasolo yaitu tipe campuran condong harian ganda dengan nilai bilangan *formzhal* sebesar 0,5618-0,7059. Selain itu, berdasarkan hasil perhitungan elevasi muka air laut, tinggi rata-rata muka air laut (MSL) maksimum terjadi pada musim peralihan II (Oktober) yaitu 532 cm dan musim barat (Januari) sebesar 460 cm. Untuk kedua musim lainnya, musim peralihan I (April) dan musim timur (Juli) tinggi rata-rata muka air laut sebesar 101 cm dan 130 cm.

Kata kunci: Metode Admiralty, Bilangan formzhal, Elevasi muka air laut.

1. Introduction

Lasolo Bay is located in North Konawe Regency, Southeast Sulawesi Province, which has varying depths, with the deepest part reaching 15 m. This bay has various types of marine life, including corals, fish, and turtles, so it has the potential to be developed as a marine tourism object and has the potential to be in development and development in the marine sector. Coastal areas in Lasolo Bay are used for various human activities such as settlements, ports, transportation, fishing and fish farming (Kusmiana, 2020). In carrying out these activities, oceanographic information is needed, one of which is tidal data. Tidal data is necessary for navigation, coastal areas, port development, and fisheries (Jayanti & Tarigan, 2016).

One of the phenomena that often occur in marine waters is tides. Tidal is the movement of the rise and fall of sea level caused by the force of gravity between celestial bodies, especially the sun, earth and moon (Amalina et al., 2019). In addition to gravitational forces, coastlines and seabed topography affect tidal characteristics, especially in semi-closed waters (bays), so that in various locations, they have different types of tides (Hamunal et al., 2018). Multiple methods, including the admiralty method, can determine the kind of tides in a water area. The admiralty method is a method that can describe the characteristics of the water table, including information about tidal harmonic constants, water table elevation and tidal type. This method has advantages such as having high accuracy, producing nine tidal components using tidal observation data in a short time series and the results of determining formzhal values close to or matching reference values (Khairunnisa et al., 2021).

Research on tidal analysis in waters using the admiralty method has been carried out by (Supriyadi et al., 2019) in the waters of Pameungpeuk, Belitung, and Sarmi. In the study, it was known that the tidal type for Pameungpeuk and Sarmi waters had a double daily leaning mixed tidal type and for Belitung waters had a single everyday tidal type. In addition, the kind of tidal phenomena vary from one region to another. This can be caused by differences in geographical location, sea depth, seabed topography, strait width, bay shape, and differences in the response of each region to tidal generating forces that affect the frequency of tides and tides every day. Generally, the tidal type of a body of water is determined by the ratio between the amplitude (wave height) of the main single tidal element and the main double tidal element using the formzhal number.

Tidal data analysis aims to determine the characteristics of tides in water. Understanding the characteristics of waters, especially those related to tides, is very necessary for humans to carry out various activities. Tidal characteristics in harmonic components, water level elevation and tidal type can provide information for predicting water levels, planning shipping activities, port management, and marine tourism (Khairunnisa et al., 2021).

2. Material and Method

2.1. Time and Place

This research was conducted in Lasolo Bay, North Konawe Regency, Southeast Sulawesi, located at coordinates 3°38'45.27" S and 122°22'37.71" E, as seen in Figure 1. This quantitative research method uses secondary data obtained from BMKG Maritim Kendari. The data is in the form of tidal data of Lasolo Bay within 15 days in January, April, July and October 2021.

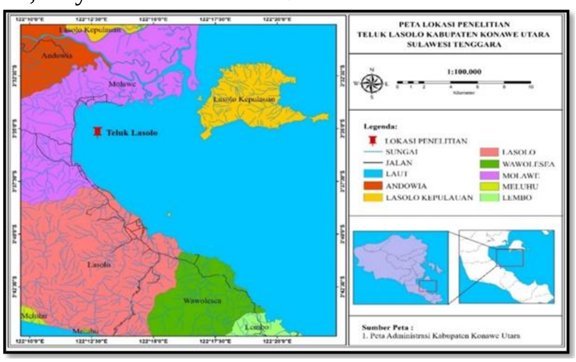


Figure 1. Research location

2.2. Procedure

2.2.1. Data Processing

The Secondary data obtained from BMKG Maritim Kendari was processed using the admiralty method in Microsoft Excel to obtain the value of tidal harmonic components. Calculating tides by the admiralty method requires a supporting table containing calculation constants and a scheme consisting of eight groups of schemes, where each scheme is a form of the final result of the calculation of the previous scheme. The stages of tidal data processing consist of arranging data in the schema, adding and subtracting schema data, multiplying the schema data by the multiplier constant, calculating the formzhal value, and analyzing the data to find the water level elevation value (Octaferina & Prasetya, 2021).

2.3. Data Analysis

The data analysis stage is a stage to analyze the results of data processing that has been carried out. The output produced from the admiralty method is amplitude (A) and phase difference (go) obtained from nine main tidal components: M2, S2, N2, K1, O1, P1, M4, MS4, and K2. Furthermore, the amplitude value can be used to calculate formzhal values to determine the type of tides in the study area based on equation 1 and the determination of sea level elevation shown in Table 1.

$$F = \frac{AO_1 + AK_1}{AM_2 + AS_2}$$

Formzhal numbers have a specific range of values to determine the type of tide in a body of water. The classification is: If $F \leq 0.25$, double daily tides; If mixed tides (double lean) $0.25 < F \leq 1.5$; If mixed tides (single daily skew) $1.5 < F \leq 3$; If a single daily ebb and flow $F > 3$.

Table 1. Tidal elevation calculation

Elevation	Symbol	Formula
Highest high water level	HHWL	$S_0+(M_2+S_2+K_2+K_1+O_1+P_1)$
Mean high water level.	MHWL	$S_0+(M_2+K_1+O_1)$
Mean low water level.	MLWL	$S_0-(M_2+K_1+O_1)$
Lowest low water level	LLWL	$S_0-(M_2+S_2+K_2+K_1+O_1+P_1)$
Mean sea level	MSL	S_0

3. Result and Discussion

3.1. Analysis of Tidal Components in Lasolo Bay

Processing tidal data by the admiralty method produces amplitude values (A) and phase differences (go), as shown in Tables 2 to 5. The amplitude value indicates the wave height of each component, and the resulting phase difference indicates the time and direction of wave propagation of harmonic constants. The variation in the value and direction of propagation illustrates the difference in response to tidal generating forces at each location.

Based on the calculation of the amplitude of the tidal component, it was found that the dominant component of tidal plants for each season was strongly influenced by the M2 component, which is a double daily component affected by lunar gravity with a value range of 58-65 cm. In contrast, the influence of the lowest tidal components is found in M4 and MS4, with values of 0 cm to 3 cm and 1 cm, respectively. This shows that the response of shallow water components does not significantly influence tidal conditions in the waters of Lasolo Bay.

Table 2. Tidal components in the Western season

	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	460	58	22	16	34	17	2	1	6	11
g°	-	125	209	75	184	144	97	165	209	184

Table 3. Tidal components in the transition season I

	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	101	61	24	12	35	25	2	1	7	12
g°	-	127	202	89	212	138	313	165	202	212

Table 4. Tidal components in the Eastern season

	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	130	65	24	13	32	28	0	1	6	11
g°	-	127	205	90	182	134	251	143	205	182

Table 5. Tidal components in transition season II

	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	532	64	25	15	30	20	3	1	7	10
g°	-	125	217	96	196	142	5	108	217	196

The components of single tidal plants, namely K1 and O1, have a reasonably high amplitude value, which ranges from 30-35 cm for K1 and 17-28 cm for O1. So, it can be known that a single tidal plant is quite influential. In addition, the S2 component, which is a double daily component influenced by the Sun's gravitational force, has a smaller amplitude value when compared to M2, which is 22-25 cm. This follows the theory that the influence of the Sun's gravitational force on the Earth is smaller when compared to the Moon's gravitational force on the Earth.

3.2. Tidal Types in Lasolo Bay

Tidal movements can be well characterized and predicted in the future because planetary orbital motions tend to be stable and predictable. Nonetheless, scientists and engineers have long observed that tidal rates in many locations change significantly due to nonastronomical factors over seasonal, decade, and secular time scales (Haigh et al., 2020). Humans have widely used the ebb and flow of seawater since ancient times. Tidal benefits include navigation, fishing and water tourism. The difference in sea level at certain intervals can also be used for power generation. In addition, tides can help remove pollutants and circulate nutrients that marine plants and animals need to survive. Areas with mixed tidal types tend to have a high level of vulnerability to pollution hazards because if there is input of pollution materials (pollutants), then pollutants will not immediately slip out (Yulius et al., 2017). The determination of tidal types is carried out in 4 seasons, namely during the western season, an intermediate season I, an Eastern season and transition season II, using formzhal numbers. The formzhal value results from dividing the single daily tidal components (O1 and K1) by the double everyday tidal components (M2 and S2).

3.2.1. Western Season

Calculating the tidal component using equation 1 yields a Formzhal value of 0.6375. Based on the classification, the resulting F value belongs to the double daily skewed mixed tidal type shown in Figure 2. Tides with this type are tides that occur twice and twice a day with different heights and times, but sometimes also occur once and again a day.

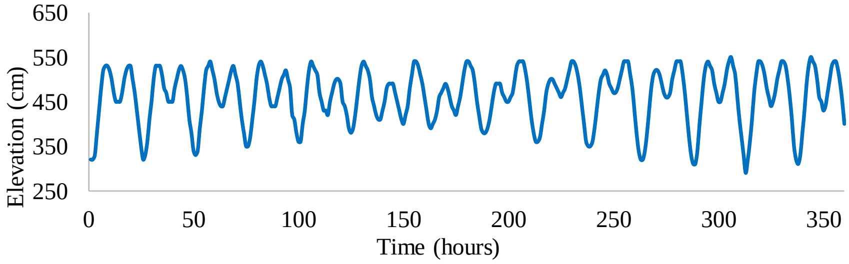


Figure 2. Tidal time series chart in the Western Season (January 2021)

3.2.2. Transition Season I, Eastern Season and Transition Season II

Calculating the tidal component using equation 1 yields a Formzhal value of 0.7059. Based on the classification, the resulting F value belongs to the double daily skewed mixed tidal type seen in Figure 3. Tides with this type occur twice a day with different heights and times, but sometimes also occur once and again a day.

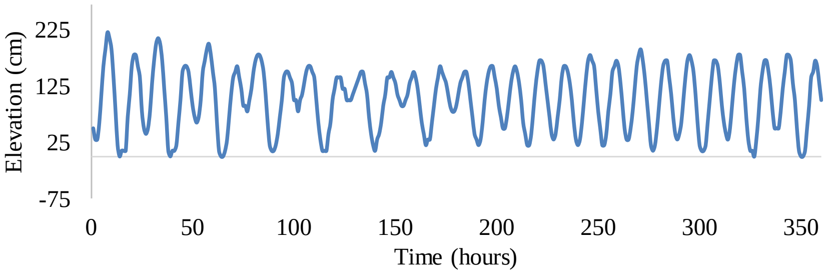


Figure 3. Tidal time series chart in the transition season I (April 2021)

Calculating the tidal component using equation 1 yields a Formzhal value of 0.6742. Based on the classification, the resulting F value belongs to the double daily skewed mixed tidal type seen in Figure 4. Tides with this type occur twice a day with different heights and times, but sometimes also occur once again a day (Figure 4). Calculating the tidal component using equation 1 yields a Formzhal value of 0.5818. Based on the classification, the resulting F value belongs to the double daily skewed mixed tidal type seen in Figure 5. Tides with this type are tides that occur twice and twice a day with different heights and times, but sometimes also occur once and again a day.

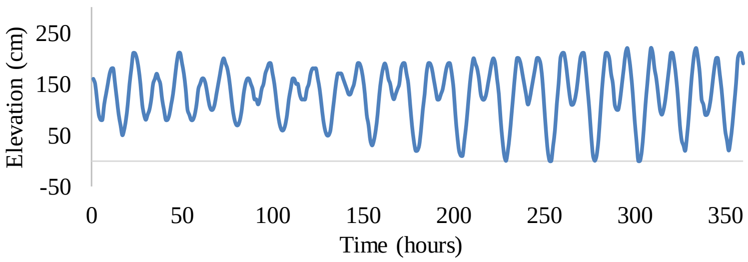


Figure 4. Tidal time series chart in Eastern season (July 2021)

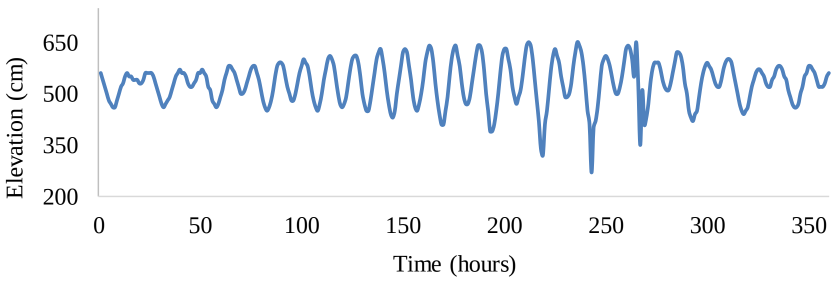
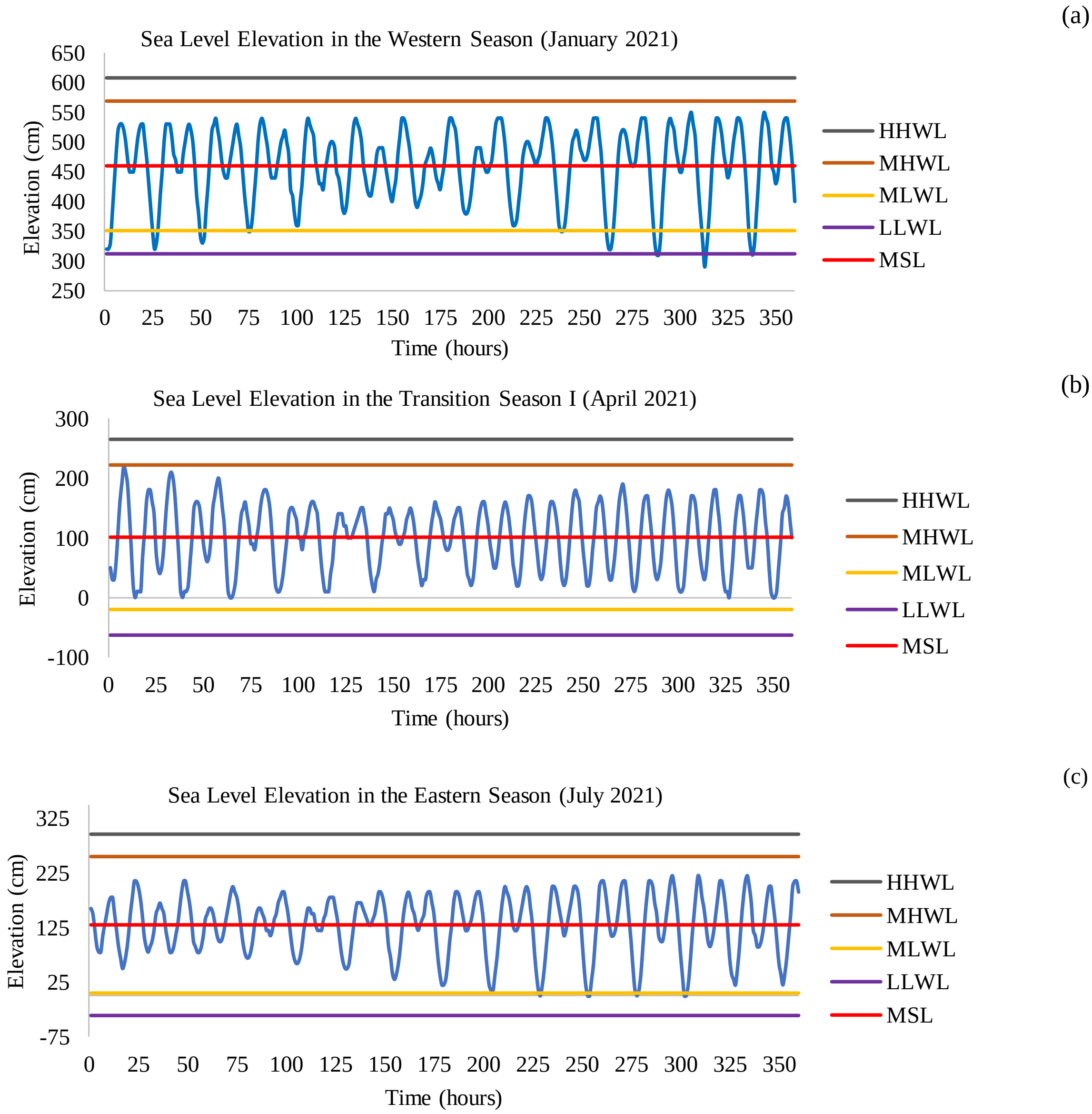


Figure 5. Tidal time series chart in transition season II (October 2021)

3.3. Sea Level Elevation in Lasolo Bay

Information about sea level elevation is very important in constructing coastal and marine buildings. Therefore, sea level elevation data is needed in planning, management, and development. The detailed sea level elevation can be seen in Figure 6 and Table 6. MSL is the average sea level value, where in the western season it is 460 cm, the transition season I is 101 cm, the eastern season is 130 cm, and the transition season II is 532 cm, indicated by a red line. MHWL (the highest average sea level) is 222 – 646 cm, characterised by an orange line. MLWL (lowest average sea level) is -20 – 418 cm, indicated by a yellow line. LLWL (lowest sea level) has a value of -63 – 376 cm, indicated by a purple line. LLWL grades can be used for port construction purposes. HHWL (highest sea level) is 265 – 688 cm, indicated by a grey line. HHWL values are required in coastal engineering planning.



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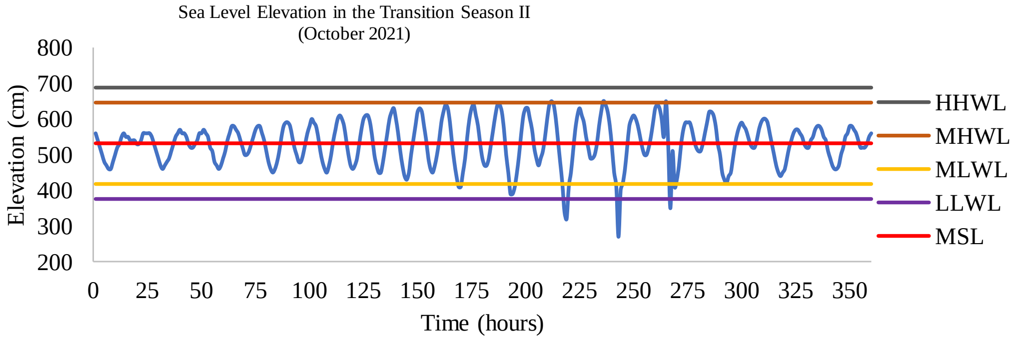

Figure 6. Seawater faces electrification in the Lasolo Bay waters: a. Western Season; b. Transition Season I; c. Eastern Season; d. Transition Season II

Table 6. Sea level elevation in each season

Sea level elevation	Elevation (cm)			
	Western season (January)	Transition season I (April)	Eastern season (July)	Transition season II (October)
HHWL	608	265	296	688
MHWL	569	222	255	646
MLWL	351	-20	5	418
LLWL	312	-63	-36	376
MSL	460	101	130	532

Based on Table 6, it is known that the influence of seasons has an impact on sea level elevation. Sea level elevation in the western season and transition season II tends to be higher. The high sea level elevation in January and October in Lasolo Bay is influenced by the west monsoon gusts and the Indonesian Cross Current (Arlindo), which flows from the Pacific Ocean to the Indian Ocean through the Sulawesi Sea and Makassar Strait. One of the impacts of Arlindo is the occurrence of upwelling and downwelling processes that affect sea levels in an area. During upwelling, there is a void of water masses in the surface layer because water is carried to other places by currents, decreasing sea level height. During downwelling, there is a buildup of water masses on the surface so that it can raise the sea level (Fadlan et al., 2017).

The east monsoon begins to blow during the first transition season (April) and will peak during the eastern season (July), which moves from the southeast to the northwest. The southeast wind in the east season pushes many water masses from the Banda Sea and its surroundings to the west through the Flores Sea and into the Java Sea, creating an upwelling process (Rochmady, 2015). This process is characterized by a significant decrease in sea surface temperature, around 2°C in the tropics and >2°C in the sub-tropics. Sea surface temperatures will increase when the seasons change to the western season. This impacts the density of the water mass, which becomes increasingly tenuous (expansion process). This expansion process affects the volume of seawater that increases, triggering an increase in sea level elevation. Therefore, sea level elevation in the eastern season tends to be lower than in the western season.

Rain can also affect sea level elevation, where increased rainfall causes water discharge in a body characterized by rising water levels. However, it tends to have little effect. The west monsoon (transition season II and west season) tends to contain more water vapour, resulting in increased rainfall than the east monsoon (transition season I and east season). The difference is due to the difference in saturation properties of the two monsoons. In the western monsoon, the wind moves a considerable distance over large waters, while in the eastern monsoon, the wind moves over the sea a short distance. However, the study area tends to experience high rain intensity from mid-May to early July. This is likely due to disturbances in the east monsoon around Kalimantan and Sulawesi, which form wind-meeting areas along the Banda Sea, Sulawesi to Kalimantan, causing the formation of many convective clouds in the region (Qothrunada & Risnayah, 2020).

4. Conclusions

The conclusions of tidal data analysis in Lasolo Bay waters are as follows: 1) the formzhal value obtained in Lasolo Bay in the western season was 0.6375, the first intermediate season was 0.7059, the eastern season was 0.6742 and the second intermediate season was 0.5618. So, based on the classification of numbers, formzhal belongs to the type of double daily inclined mixed tides. This type of tide occurs twice and twice in a day with differences in height and time of occurrence, but sometimes happens once and again once a day. 2) The value of sea level elevation in each season produces different values. In the western season, the MSL elevation value is 460 cm, the first intermediate season is 101 cm, the eastern season is 130 cm, and the second intermediate season is 532 cm. The highest MSL elevation value occurs in the transition season II, while the lowest MSL elevation value occurs in the transition season I. This shows that the season influences sea level elevation.

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