Estimation of Seiche tide parameters in the Bohai Sea on October 20

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Abstract

On October 20, 2024, a relatively large-scale seawater inflow occurred in the Bohai Sea region of China. This paper argues that this large-scale influx is mainly caused by the relatively large number of super typhoons that have generated over the entire Pacific Ocean this year. The energy accumulated by several super typhoons caused very long Seiche standing waves throughout the Pacific Ocean. Although the amplitude of the standing wave is not large, about 0.3m, such an amplitude of Seiche may cause the existence of a secondary Seiche phenomenon with a higher amplitude after passing through a relatively narrow bay on the west coast of the Pacific Ocean. In some narrow bays, the amplitude of this Seiche standing wave may reach more than 1m, resulting in a more serious seawater inflow problem in the coastal areas of the west coast of the Pacific Ocean. Therefore, in this paper, we should consider the changes in sea level throughout the Pacific Ocean caused by the accumulation of energy from multiple super typhoons over a relatively long period of time, in addition to the disasters caused by a single typhoon when disasters such as seawater inflow occur.

1 Introduction

On October 21, 2024, cities along the Bohai Sea saw an increase in sea water of up to 1 meter

to 1.6 meters. The increase in seawater at this magnitude is relatively large, and it has also caused a relatively serious disaster of seawater inflow. According to some news descriptions [1], this phenomenon is unprecedented and has not been reported abroad. There is a lot of speculation about the cause of this backflow. Some experts say that the large-scale influx of seawater is related to the strong gravitational pull of the moon, hence the astronomical tides. In addition, some experts say that the inflow of seawater is related to global warming and overall sea level rise. Other experts believe that the inflow may be closely related to the phenomenon of tidal wave resonance. The exact cause of this sudden inflow has not yet been determined, but it is believed that this incident in the Bohai Sea should provide us with a very good opportunity to study and more accurately understand the impact of natural disasters caused by sea level rise on human society. In this paper, we suggest that the Seiche standing wave phenomenon [2] can be used to explain the cause of this seawater inflow.

2 Situation in Bohai Bay

Figure 1. Situation in Bohai Bay

From Figure 1, we can see that Bohai Bay is a very narrow bay area, and it is very shallow. It is only about 346 km wide and 550 km long. Therefore, as long as there is enough energy input, it is easy to generate Seiche standing waves in this relatively narrow bay area. The greater the input energy, the greater the amplitude of the Seiche standing wave. Judging from the depth of Bohai Bay, Seiche should be able to produce an average of about 15m to 18m of seawater inflow after the energy input. Therefore, the harm to the coastal cities in the Bohai Sea region is still very large.

In Figure 1, we can also see that there are some narrower bays along the coast of Bohai Bay. These bays are represented by Laizhou Bay, Tianjin Bay and Yingkou Bay. The width of these three bays is narrower, so even with a small amount of energy input, it can cause relatively high tides. In

this way, the danger of coastal erosion is even more serious. Judging from the situation of seawater inflow along the coast of the Bohai Sea area this time, the seawater inflow in these three bays is even more serious.

3 Energy estimation of the Bohai Seiche

The average water depth of the Bohai Sea is 15 meters, and according to the formula for calculating the wave velocity of shallow water waves, the propagation velocity of water waves here can be calculated as $v = \sqrt{gd} \approx 12(m/s)$. Therefore, if Seiche produces enough energy, this area should be able to produce flooding at depths of more than 15 meters. However, in the current Bohai Seiche phenomenon, the Bohai coastal areas only experienced an average depth of about 1 meter, and the duration was about 20 hours. It shows that the energy carried by Seiche this time is not large. Judging from the situation on the spot [1], the wavelength of Seiche will also be longer this time. If the wave length is the width of the Bohai Sea, then it is about 346 kilometers, the energy will be smaller. If it is the north-south length of the Bohai Sea, then the wave length of the Seiche standing wave is 550 kilometers, the energy will be higher.

Calculated according to the wavelength $\lambda = 3.46 \times 10^5 m$, then the period of this Seiche standing wave will be

$$T = \lambda/v = \frac{3.46 \times 10^5}{12} = 2.88 \times 10^4\ (s) \approx 8(h)$$

And if calculated according to the wavelength $\lambda = 5.5 \times 10^5 m$, then the period of this Seiche standing wave will be

$$T = \lambda/v = \frac{5.5 \times 10^5}{13} = 4.58 \times 10^4 (s) \approx 12.7(h)$$

According to relevant reports [1], the duration of the storm surge warning was 7 days. The

Yellow Sea and Bohai Sea areas have a water infill of 1 to 1.6 meters. The water filling process lasts up to 20 hours. Taking into account the influence of various other factors, the duration of this flood increase is basically consistent with the theoretical calculations, and it can be confirmed that the seawater intrusion event is caused by the Seiche phenomenon caused by the narrow environment in the Bohai Bay and other areas.

In this way, we can roughly estimate the energy carried by the Seiche standing wave in the Bohai Sea this time. The amplitude of the Seiche standing wave in the Bohai Sea is calculated according to 1.5 meters, considering that the Seiche standing wave is mainly composed of gravitational waves, it can be calculated directly using the energy formula of shallow water waves, then the energy is

$$E = 3.46 \times 10^5 \times \frac{1}{8}\rho g h^2 \lambda = \frac{1}{8} \times 3.46 \times 10^5 \times 1000 \times 9.8 \times 1.5^2 \times 5.5 \times 10^5$$

$$\approx 5.22 \times 10^{14}(J)$$

This energy is not very large. A moderately strong typhoon releases $10^{19}J$ of energy per day, and it can be seen that if there is a moderately strong storm near the Bohai Sea area, and 1/100,000 of the energy enters the Bohai Sea area, it can cause the Bohai Seiche standing wave of this scale.

Of course, it can also be seen from the above calculations that if the width of the bay is narrower, the less energy is required to produce Seiche standing waves of the same amplitude.

Considering that the inflow of seawater in the Bohai Sea region may also be related to the sea level oscillation of the entire Pacific Ocean, we will also calculate here how much energy is required if the seawater in the entire Pacific Ocean fluctuates by tens of centimeters.

The current data of the Pacific Ocean is basically about 15,900 km wide from north to south, and about 19,000 km long from east to west, so the energy will be

$$E = 1.59 \times 10^7 \times \frac{1}{8}\rho g h^2 \lambda = \frac{1}{8} \times 1.59 \times 10^7 \times 1000 \times 9.8 \times 0.3^2 \times 1.9 \times 10^7$$

$$\approx 3.33 \times 10^{16}(J)$$

It can be seen that even the energy of such a standing wave that crosses the entire Pacific Ocean is not large, even less than the energy of a storm. However, since storms are generated in the ocean, storms in the Pacific Ocean can actually absorb a lot of energy from the ocean, so after a storm occurs, not all of its energy can be absorbed by the sea. Conversely, the presence of less intense storms may mean that most of the energy is absorbed by the ocean, and the storm surge generated by these storms may be larger.

We can also calculate the period of this Seiche standing wave that spans the entire Pacific Ocean.

First of all, according to the average water depth of the Pacific Ocean of 4000 meters, it can be calculated by the formula for calculating the wave velocity of shallow water waves

$$v = \sqrt{gd} \approx 198(m/s)$$

Calculated according to the wavelength $\lambda = 1.9 \times 10^7 m$, then the period of this Seiche standing wave will be

$$T = \frac{\lambda}{v} = \frac{1.9 \times 10^7}{198} = 1 \times 10^5(s) \approx 27(h)$$

It can be seen that a moderately strong storm can produce standing waves on the surface of the Pacific Ocean with a period of up to 27 hours if its energy is adequately absorbed by the seawater. Considering that the loss of oscillating energy in the Pacific Ocean is relatively small, this Seiche standing wave can last for a long time, which can reach several months.

Of course, although the Seiche standing wave period in the Bohai Sea area can also reach more than ten hours, but because the seawater is poured into the land, there is a very large energy loss, so

its duration is not so long.

4 Analysis

As analyzed by some experts, the reasons for the phenomenon of Seiche standing in the Bohai Sea region should be multifaceted. For example, the tidal rise and drop in the Tanggu area of Tianjin usually reaches about 2 meters. That is to say, the tide rise in the Bohai Sea area is usually about 2 meters, but this time there is a tide rise of 1 to 1.5 meters, just because this increases the tide level by 50% to 100% on the basis of the tide rise in the Bohai Sea area, and the corresponding energy is increased by about 50% to 100%.

The main cause of tides in the Bohai Sea is the gravitational pull of the moon, so the rise in tide level caused by the Seiche standing wave can also be partly attributed to the stronger gravitational pull of the moon.

Another important factor is the current rise in global temperatures, which has led to sea level rise, and the average sea level rise in the waters around China is more than 20 to 30 centimeters higher than the average rise in the entire Pacific Ocean, so compared to the previous sea level, the current sea level rise in China's coastal areas may have reached such a large magnitude of more than 0.5 meters, and now combined with the influence of astronomical tides, it is indeed possible to produce deeper sea water inundation.

However, in the current seawater inflow incident in the Bohai Sea area, the authoritative organizations of the relevant departments have also confirmed that the seawater inflow is unprecedented. This also shows that it is a bit reluctant to rely solely on the stronger gravitational pull of the moon to explain.

From the perspective of external factors, during this period, there were 4 typhoons in the western Pacific in October. However, the intensity of these typhoons is actually not large, so the energy carried is not very large, and the energy that can reach the Bohai Sea area is even less. Therefore, it is difficult to say that it was caused by these four typhoons.

Many current studies show that the number and intensity of typhoons have been increasing rapidly in recent years [3,4]. In terms of the typhoons that have occurred in the entire western Pacific region, the intensity of typhoons this year is still relatively large, and the number of typhoons is also higher than in previous years, among which the super typhoon Capricorn that occurred in September caused very serious damage in Vietnam and other places. Therefore, it cannot be ruled out that a combination of multiple strong typhoons caused a larger Seiche standing wave phenomenon throughout the western Pacific region. And on October 20, there was a relatively large sea level rise in the west coast of the Pacific Ocean, and then there was a seawater inflow disaster in the Bohai Sea.

5 Conclusions

From the analysis of this paper, it can be seen that the large-scale seawater inflow in the Bohai Sea is mainly caused by the relatively large intensity and number of typhoons that have occurred in the entire Pacific Ocean this year. The input of a large amount of typhoon energy caused a phenomenon of long-lasting Seiche resonance across the Pacific Ocean. Calculations show that it does not require a lot of energy to cause the entire Pacific Ocean to produce Seiche standing wave amplitude of about 0.3m. Such an amplitude of sea level oscillation can produce Seiche standing waves with large amplitude in the Pacific coast, especially in some narrow bays on the west coast

of the Pacific Ocean. Seiche of this magnitude will cause seawater to intrude into the land, resulting in a more serious seawater inflow flood.

References

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