Discovering the river outlet current by using simple field measurement (case study of Kendal Coastal Area)

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Abstract. Theoretically, in the natural condition the wind is main energy induce wave and sea surface current. The measurements related to the wind patterns may indirectly reflect the condition of waves and the sea surface current. Other theory stated that in some cases, sea surface current has different direction depending on the bathimetry condition or other local factors. This research aimed to discover the correlation between wind and sea surface current direction in Kendal Coastal Area, focusing on nearshore zone nearby Bodri Rivermouth. The research was conducted by a simple measuring instrument for detecting sea surface current direction. The background of this research was the occurrences of the lost people drowned in the research area and being related to the mystical phenomena by the coastal community. The results showed that the correlation values of the wind and sea surface direction up to 0.40 and 0.09, each for point 1 and point 2, respectively. Those differences between wind and sea surface current direction imply that the results against the first wind direction theory. However, the results revealed that the existence of river mouth is the main factor that influences the different pattern of the sea surface current and wind direction. It is proof that the outlet current exists in the research area.

1. Introduction
Study of the physical aspects in the coastal area has become an important issue as it is involved in the regional development program in Indonesia [8]. This urgency was considered to the correlation of the high productivity in the coastal area [16]. On the other hand, high productivity in line with population growth. This condition reveals two possibilities; 1) the population growth harms the coastal environment, 2) the high population is followed with the high-risk exposure induced by the coastal agent dynamic [17].

Central Java is a province with intensive coastal dynamics compared to the other province in Java Island, Indonesia, related to its dense population [34] [13] as a consequence traversing by the densest road in Indonesia [11]. Considering these facts, the coastal area in Central Java was chosen as the main research area, with the focus area of Kendal Regency.

Based on its complexity and risk exposure, the land occupation in the coastal area particularly in Kendal Regency has become an important issue [10] [18] [28]. Besides as the defense strategy from a
natural disaster is a consequence of the coastal dynamic, the land occupation management highly required to maintain the ecological functions in the coastal area [4] [17] [27]. That understanding can be increased through the studies conducted holistically on the aspects that influence the coastal area, especially for the study of the physical aspects.

Two physical aspects that are highlighted in this research are wind and sea surface current. The identification of hydrodynamics information related to wind patterns and sea surface current will be studied more deeply as the main purpose of this research. Wind and sea surface current normally analyzed by using high technology, i.e. buoy. But then, the high-tech tool is not that easy to be utilized in term of the legal document’s procurement and its availability. Considering those facts this research was conducted by simple measurement to analyze the sea surface current direction. This measurement was conducted by several occurrences of lost people in the research area drowned by the stream, especially occur in Kendal Coastal Area. However, these occurrences are always being related to mystical issues as a consequence of traditional system that still exist widely in Java Island, namely Kejawen system [23].

2. Study Area
Kendal Regency is the regency in northern Central Java with high coastal dynamics and complexity [33]. The high coastal dynamics and complexity are driven by the intensiveness of human activity [14]. This condition is triggered by the existence of Jalan Pantai Utara or North Coast Line as the densest road in Indonesia. Moreover, as had been regulated on the Regency Act. Number 20 2011 [7] explains that the coastal area of Kendal Regency is prioritized to accelerate the industrial activities. So that all the facilities related to the industrial activities in Kendal Regency will be developed, i.e. the settlement, legally or illegally. Other complexity showed on the intensiveness of natural disasters in the research area, i.e. flood, inundation, and erosion [15] [22] [30].

3. Materials and Methods
The methodology that was conducted in this study was a direct measurement in the field followed by pearson correlation analysis. The analysis was conducted to determine the correlation between wind and sea surface current direction. This analysis put the direction of sea surface current as an independent variable and wind direction as the dependent variable. This research was conducted by using primary data, i.e. the sea surface current, and wind direction were taken for 15 days in the two points of the sample area of the nearshore zone nearby the Bodri Rivermouth. The research data acquisition is shown in Table 1. The time span of 15 days was considered as half period of tidal fluctuation by the Moon orbital [24] [32] [25]. The measurement of the direction of sea surface current using a simple measuring device shown in Figure 1, consists of 3 m pipe with 3-5 cm of the width, 6 m fishing rope, one floating ball with 5 cm of width, and one ballast. To measure the sea surface direction, the prototype needs to be placed 2 m under the water vertically with the floating ball and ballast are placed in the front knotted by the fishing rope as showed in Figure 1. By drowning the prototype, the measurement is started by paying attention to the floating ball to its velocity and direction. While the wind direction measurement was conducted by using an anemometer. Data were collected on the west season that tends to frequent rains and also considered as the frequent period of lost drowned people.

| No | Point Samples | Coordinate (UTM) | Measurement Time |
|----|---------------|------------------|-----------------|
| 1  | 1             | 407631.226, 9243696.202 | 9.00 am         |
| 2  | 2             | 408282.152, 9244847.839 | 9.00 am         |
Note: the research data were taken at the neap tide period considering to the possibility accessing the channel and the sea. The spring tide period was followed by storm considering to the west monsoon season. However, in the neap tide period, 9.00 am is an early high tide (worldtide.info).

Figure 1. Simple measuring device for sea surface current

4. Result and Discussion
Based on the previous theory [1] [31], wind, wave, and sea surface current is a linear process as the conversion of kinetic energy in a sequence. Related to this theory, sea surface current direction ideally has the same direction with wave and wind [5]; as had explained that there is a certain circulation or movement induced by the existence of the wind as the main energy. The linearity between the wind, wave, and sea surface current was also found in the previous researches [3] [9] [12] [20]. Contrary to the theory, this research showed a different direction of the sea surface current (Figure 2).

Considering the different direction, there were suspected factors that may affect. The factors that could cause the movement of the sea surface current heterogeneously is the influence of the Coriolis force. However, the Coriolis force is more influential on the deeper current in high latitude position, considering the influence of the Coriolis force is more global [26]. On the other hand, this research was conducted in the shallow water of the Java Sea (Figure 3) with the focus area in the nearshore zone with high local influences instead of global influences.

The topographic condition of the seabed is also one of the factors suspected to the sea surface current direction. This was explained in other researches [2] [12] that the sea surface current condition is also determined by the variability of seabed topography. However, the research area indicating the absence of the rugged seabed topography, it was shown in Figure 3 for the bathymetric map of the research area. The last factor that most affecting the condition of the heterogeneity of the direction of the sea surface current in the research area are the position of the large river estuary, namely Bodri River. Hence, the current of the river
provides a major influence on the current condition of the sea surface at the location of measurement.

**Figure 2.** Comparison charts of the wind and sea surface current direction located in point Kendal Regency. Point 1 and point 2 reflected to the measurement at 9.00 am (Trihatmoko, 2017 and modification)

**Figure 3.** Sampling location of research area (two red dots) and seabed condition on the research area detailed by red box. The map shows that seabed topography of the research area has the smooth and gradual elevation, mainly in the nearshore zone (source: Marine Affairs and Fisheries Agency of Central Java and modification)

The graphs in Figure 2 show that there is a deviation direction of the sea surface current significantly from the wind direction. It is also confirmed by the correlation between wind and sea surface current direction direction up to 0.40 and 0.09, each for point 1 and point 2, respectively. Those mean that the correlation of the wind and sea surface current direction has no significant correlation by pearson correlation analysis. The results of measurements and data analysis of wind and sea surface current direction in Kendal Regency indicate that factors
influencing the direction of the sea surface current is not only the direction of the wind but also the existence of river mouth on the research area that had a substantial role in determining sea surface current as a form of outlet current. Outlet current defines as the river currents flowing toward the sea and possibly become dangerous when it comes with higher energy [21] [29]. It was important information that has to be understood for the coastal community to avoid the incident that could harm the community. It was proved by the disappearance of some people in the river mouth due to the lack of understanding to the stream strength of the river, even if it's not too heavy on the surface, but could force the sea surface current contrary to the wind force direction, as mentioned in the result.

5. Conclusion and Recommendation
The findings reveal that the wind and sea surface current have different direction about 0.40 and 0.09 for each correlation in point 1 and point 2 respectively. So that the theory of linear-direction of wind and sea surface current on the research area is not in line. Seabed topography in the research area is also shown as homogenous. The most suspected condition is the river mouth existence in the research areas. As conclusion, the current strength of the river is the most suspected aspect that possible to give an effect for the sea surface current direction close to the river mouth. Scientifically, this research proves that the loss of drowned people was caused by river outlet current that highly controls the current in the surrounding area. For further research it is recommended to conduct a review of the Bodri River discharge itself so that it can find out how influential the river debit is with the direction and speed of the current.

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