Development of an automated processing system for potential fishing zone forecast

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Abstract. The Institute for Marine Research and Observation (IMRO) - Ministry of Marine Affairs and Fisheries Republic of Indonesia (MMAF) has developed a potential fishing zone (PFZ) forecast using satellite data, called Peta Prakiraan Daerah Penangkapan Ikan (PPDPI). Since 2005, IMRO disseminates everyday PPDPI maps for fisheries marine ports and 3 days average for national areas. The accuracy in determining the PFZ and processing time of maps depend much on the experience of the operators creating them. This paper presents our research in developing an automated processing system for PPDPI in order to increase the accuracy and shorten processing time. PFZ are identified by combining MODIS sea surface temperature (SST) and chlorophyll-a (CHL) data in order to detect the presence of upwelling, thermal fronts and biological productivity enhancement, where the integration of these phenomena generally representing the PFZ. The whole process involves data download, map geo-process as well as layout that are carried out automatically by Python and ArcPy. The results showed that the automated processing system could be used to reduce the operator’s dependence on determining PFZ and speed up processing time.

1. Introduction
Since its first-established in 2005, the Institute for Marine Research and Observation (IMRO) has had routinely produce map of fishing ground for Indonesian waters based on sea surface temperature (SST) and chlorophyll-a (Chl-a) data from satellite. At the beginning, the map was produced manually and based only on very simple methods, i.e. identifying areas with low SST and high concentration of chlorophyll-a as a fishing zone. Afterwards, from time to time IMRO tried to improve its potential fishing zone (PFZ) map by implementing Python-based scripts that automatically estimate the potential area of fishing zone to reduce the operator’s dependence and speed up the processing time.

The method applied to develop the automated processing system was edge-detection [1]. This method was used to identify the thermal fronts as an indication for some oceanographic phenomena such as upwelling fronts, frontal eddies, and fronts associated to geomorphic features [2] where some of those phenomena were occurred in the Indonesian waters. For example, upwelling along the Java-Sumatra Indian Ocean coasts that usually occurred during the southeast monsoon (June to October) [3-5], persistent upwelling and front over the Sulu Ridge [6], and front in the southern Banda Sea, shelf front north of Java in the Java Sea, shelf front west of Dolak Island, New Guinea in the northern Arafura Sea [7]. The utilization of satellite-retrieved SST data to estimate the ocean fronts have been started since 1970s, including some parts of Indonesian waters [7]. Since the upwelling regions usually nutrient-rich and the primary productivity tends to increase and can be represented by the increase of
chlorophyll-a concentration, the utilization of remotely-sensed SST and concentration of chlorophyll-a were widely used to estimate the PFZ for pelagic fishes, making use of simple relationship of marine food webs [5, 8, 9].

2. Methods

2.1. Study Area
Currently, IMRO has produced several types of PFZ maps based on their spatial resolution (from national to fishing port scales) as well species of fishes (small and big pelagic fishes). In this paper, the automated system discussed was applied to only national scale fishing zone map, covering the whole area of Indonesian waters (figure 1). For our dissemination purposes, the PFZ maps were divided into 5 main regions afterward, i.e. Java-Bali-Nusa Tenggara, Kalimantan, Maluku-Papua, Sumatra, and Sulawesi (figure 2).

![Figure 1. The study area](image)

2.2. Satellite Data
Two types of dataset were used in this study, i.e. 3-days composite of Level 3 Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) of sea surface temperature (SST) and chlorophyll-a concentration (Chl-a). These dataset are processed and distributed by the Ocean Biology Processing Group (OBPG) at http://oceancolor.gsfc.nasa.gov. These images were Level 3 Standard Mapped Image (SMI) products that are created from corresponding Level 3 binned products and have spatial resolution of 4.6 km at the equator [10].

2.3. Modules of Automated Processing System
The Python-based scripts developed in this study were divided into 3 modules, namely pre-processing, processing, and post-processing. In the pre-processing module, the script will handle automatically the process on cropping the global image into Indonesian region, masking the image with land and cloud, and compositing the raster. In the processing module, images obtained by the first module were processed automatically to detect the thermal fronts as well as regions with high primary productivity. Afterwards, results produced by second module were processed to produce a PFZ map.
Detection of Thermal Fronts

SST is usually used in predicting PFZ [5, 8, 9, 11]. Two water masses with temperature gradient known as thermal front were usually occur on sea boundary between two horizontal masses of seawater with different densities [12]. A thermal front zone usually nutrients rich and has an effect to stimulate primary production [13] indicated by the abundance of phytoplankton as producer in the marine food webs. Since in the thermal front zone, temperature gradient exists, an edge detection method could be used to identify this phenomenon [1]. As already mentioned previously, there are some areas within the Indonesian waters that have thermal fronts due to upwelling, eddies, and geomorphic features. Although in some cases the temperature gradient is not big enough, for example around 0.025°C/km over the Sulu Ridge [6], but the evidence showed that this phenomenon could increase the concentration of chlorophyll-a by 5 to 15 times greater [5, 6]. Therefore, thermal fronts are important and could be used as indicator to predict the PFZ. Previous study used temperature gradient of 0.5°C for every 3 pixels [9] while in this study, the value chosen for threshold is equal to 0.45°C. Before this value was chosen, an experiment making use of monthly SST data that shows upwelling in the Indian Ocean south of Java was done. Within this experiment several values of threshold were used in edge detection method in order to detect the thermal fronts and we found that 0.45°C gives reasonable result.

Identification of Chlorophyll-a for Ocean Productivity.

Chlorophyll-a is one of important oceanographic parameter to detect skipjack tuna habitat in tropical region [15]. The migration route and feeding habitat for albacore tuna in the central and eastern North Pacific Ocean have been detected using chlorophyll-a about > 0.2 mg/m³ [16]. On the other hand, the distribution and migration of skipjack tuna are strongly influenced by oceanographic factors such as
distribution of SST and chlorophyll-a [14]. In the present study, it was observed that the favourable ranges of chlorophyll-a and SST for various pelagic species that can be used to find out the potential fishing ground are 0.2-0.5 mg/m$^3$ and 15-27ºC, respectively [17]. But since for tropical region such as Indonesia the SST difference is not as high as sub-tropical regions, therefore, concentration of chlorophyll-a was used also as indicator to estimate the PFZ. Before the chlorophyll-a data were used, in order to reduce high and low pixel in the data, smoothing process using median and Wiener filters were applied [18].

2.3.3. PFZ Map Generation. After successfully identifying the thermal fronts as well as favourable range of chlorophyll-a concentration for various pelagic fishes species, the PFZ was generated in the post-processing step. There are two conditions for PFZ define in the map, i.e. based on thermal front and chlorophyll-a concentration, which is defined as PFZ with highest probability, and based only on thermal front, which is defined as PFZ with moderate to low probability (table 1). These conditions were defined in order to inform the fishers which areas should be chosen as priority.

### Table 1. The PFZ conditions.

| Dataset                                    | PFZ Condition               |
|--------------------------------------------|-----------------------------|
| Thermal front + favourable range of chlorophyll-a for various pelagic species | Highest probability         |
| Thermal front only                         | Moderate to low probability |

3. Results

Figures 3 and 4 show the example of 3-day composite of SST and concentration of chlorophyll-a data obtained by pre-processing module. These data are for 1-3 January 2016. By implementing this module, processing time to provide images to be used in the processing module was decreased by 30 minutes. Anyhow, from these figures we found that some area were covered by cloud and therefore cannot be included in the next process. Normally for tropical areas such as Indonesia, especially during the rainy season, cloud cover is one of crucial issue that sometime reduces the area can be analyzed. Method such as Data Interpolating Empirical Orthogonal Function (DINEOF) [19] could be a good alternative to be used in order to fill the area covered by cloud.

![Figure 3. Sea surface temperature derived from MODIS Level 3.](image-url)
Figure 4. Chlorophyll-a concentration derived from MODIS Level 3

Figure 5 shows the example result after edge detection method was applied to the SST data where thermal fronts are found in some areas around the South China, Java, and Sulawesi Seas, Sulu Ridge, Makassar Strait, as well as the western part of Pacific Ocean.

Figure 5. Thermal front detected by the edge detection method

Figure 6 shows favorable range of chlorophyll-a concentration after filtering. Overlaying this result with thermal front map, we found that in general, in the area where thermal front exists the concentration of chlorophyll-a is significantly high (see Figure 7).
Figure 6. Favorable range of chlorophyll-a concentration for various pelagic species

After all processes to identify the thermal front and favorable range of chlorophyll-a concentration were finished, and based on classification given by table 1, the forecasting process to obtain PFZ was performed. The result obtained by this process was given in figure 8. In order to evaluate the overall improvement obtained by applying automated processing system, results obtained by this method were compared to results produced manually by operators. Two aspects were taken into account in the evaluation, i.e. the accuracy and processing time. It was found that by applying edge detection method on estimating the thermal front, the process was faster. Furthermore, since for tropical region such as Indonesia, thermal gradient is usually small and in some cases difficult to recognize manually, the edge detection significantly improve the accuracy.

In average, time needs to produce fishing zone map manually is approximately 1 to 2 hours, depend on the experience of operator. By applying the automation system, time needed to produce the fishing zone map is only 5 minutes, and this improvement of course very significant. The machine used to perform the process is personal computer Intel i5 with 8GB RAM.
Figure 7. Overlay of thermal front and favorable range of chlorophyll-a for various pelagic species

Figure 8. Map of PFZ obtained by the automated processing system

4. Conclusion
From this study, we found that the automation processes on producing fishing ground map have some advantages. In the pre-processing step, automation processes could decrease the processing time significantly, from 2 hours to only 5 minutes. In the processing step, besides decreasing the processing time, misinterpretation by operators could also be minimized, and therefore, results from this automation system could increase the accuracy. Similar advantages also found in the post-processing step, where the production of fishing ground could be done faster and easier.

However, in this study, issue related to cloud cover did not handle yet during pre-processing step, while this issue was very significant, particularly for tropical region such as Indonesia. We planned to apply method such as Data Interpolating Empirical Orthogonal Function (DINEOF) in our next generation of automated processing system.

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