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Monitoring and Surveillance of Algal Bloom Using IoT Technology

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Abstract

Algal blooms have negatively affected people in terms of economy, society, and environment. This research was focus on the using of Internet of Things (IoT) to determine chlorophyll A and sea surface temperature at the Gulf of Thailand. The IoT used in this study was related to the Aqua MODIS (Moderate-Resolution Imaging Spectroradiometer) imagery and SeaDAS (SeaWiFS Data Analysis System) program. This program showed the results of the Satellite data with chlorophyll A and sea surface temperature during Jan 7-13, 2023. The results showed that chlorophyll A concentrations were found in the study area with the range of 2.31-4.35 mg/m^{-3} while the sea surface temperature were determined with the range of 28- 29^{o}C. However, this study was limited by using the only data from the Aqua MODIS satellite. Therefore, it will be better to study the data comparison from satellite photos with field measurements of sea surface temperature and chlorophyll A content in the appropriate locations.

Keywords : Algal bloom; IoT technology; Chlorophyll-A; Sea surface temperature

Introduction

The Internet of Things (IoT) connects people and machines across various domains and applications by integrating data from sensor devices into the Internet [1]. In recent years, the IoT has advanced significantly. It can be applied to many industries and environments. IoT devices can establish connectivity with the Internet, thereby enabling the extraction and utilization of gathered data to augment workplace productivity, facilitate informed decision-making, and even predict variables that may exert influence. Moreover, the potential for real-time data applications is evident. The adoption of IoT technology holds the promise of expeditiously resolving operational challenges. For example, it allows for real-time monitoring of work environments, fostering continuous learning from job experiences, environmental tracking, and similar applications. The future portends the emergence of a multitude of novel IoT technologies, driven by the distinctive traits and advantages they offer, a trend underscored by the extensive global research engagement. The ubiquity of IoT is further exemplified by the deployment of 27 billion IoT devices worldwide in 2018, a figure projected to surge to an astounding 75 billion by 2025 [2].

The Thailand Digital Technology Forecast 2035, published through a collaboration between Frost & Sullivan and the Digital Economy Promotion Agency (depa) [3], has expounded upon the IoT technology landscape in Thailand. This technological facet significantly permeates the public, corporate, and private sectors, yielding substantial implications. The forecast, underpinned by an average annual growth rate, has anticipated the escalation of IoT technology's worth from 3.6 billion Thai Baht in 2018 to a substantial 440 billion by the year 2035.

From the current trend of using the Internet of Things (IoT), IoT technology has been applied to predict the occurrence of algae blooms. This technology has been used for Studying the amount of chlorophyll-A at the sea surface [4, 5]. Considering that the phenomenon of whale excrement (algal bloom) constitutes a natural occurrence, the exploration of IoT technology for the purpose of monitoring and surveilling such events emerges as a strategically advantageous pursuit. The upsurge of marine plankton, encompassing bacteria, protozoa, and phytoplankton, characterizes this phenomenon. The presence of deceased algae or phytoplankton, buoyant at the water's surface, obstructs the photosynthesis process of plants and corals, precipitating a direct impact on marine ecology. This cascade effect entails a reduction in water's oxygen content, culminating in the demise of indigenous flora and fauna.

Empirical investigations into the nation's instances of whale excrement occurrences revealed a discernible spectrum of intensity, spanning locales from Bangsaen Beach to Sriracha, encompassing areas such as Ao Udom and Ang Sila. Notably coinciding with the onset of the rainy season spanning June to August, this phase witnesses consecutive days marked by rain, accompanied by overcast skies and gusty winds. Within the ambit of this inquiry, scholars ascertained an element of uncertainty pertaining to the exact origins and modalities of whale excrement's appearance. However, research established the nexus in Chonburi province on Thailand's eastern coastline. According to this comprehensive study, there is a palpable elevation in the quantity of "phytoplankton" blooms, particularly from the genus "Noctiluca". These phytoplankton organisms eventually perish and undergo degradation due to the abundant availability of nutrients under conducive conditions. Wind and cloud cover further accentuate this process. Consequently, the remnants of these organisms, colloquially referred to as "carcasses", are swept ashore by the tide along the coastline [6]. Algal bloom significant affect to environment and people. In this context, the integration of IoT technology assumes paramount importance in the surveillance and tracking of recurrent instances of whale excrement. This implementation not only facilitates data collection but also enables comprehensive analysis and predictive modeling, thereby engendering the capacity to devise remedies, forestall recurrences, and promptly alert tourists to these events. Hence, this study examines the utilization of IoT technology to access data on chlorophyll A content and sea surface temperature.

Materials and Methods

Materials

The materials used in this study were composed of a computer, Spyder (Python 3.9), SeaDAS Program (SeaWiFS Data Analysis System) version 8.2 (available for download from http://seadas.gsfc.nasa.gov). and data Aqua MODIS (available for download from http://oceancolor.gsfc.nasa.gov/).

Methods

The research target of this study was initiated by determining the specific area of the Gulf of Thailand. Implementation of the study involved coding activities utilizing the Python 3.10 programming language. This phase also included the installation of key libraries, including Beautifulsoup 4, Selenium, Webdriver Manager, and a schedule for encoding satellite images. Pertinent data from NASA's Moderate Resolution Imaging Spectrometer (MODIS), specifically chlorophyll A and sea surface temperature measurements, were selected [7]. These data sources were extracted from Terra/Aqua MODIS sensors, with the TERRA satellite serving as the measurement instrument (available for download from http://oceancolor.gsfc.nasa.gov/). Data extraction targeted information pertaining to chlorophyll A content and sea surface temperature from the MODIS satellite images. Rectification of mathematical discrepancies was facilitated through the utilization of the 'Reproject' option within the SeaDAS (SeaWiFS Data Analysis System) program, thereby ensuring data accuracy. Thorough analysis and interpretation of the accumulated data constituted the final phase of the research process.

Results and Discussion

The IoT technology was used to facilitate the evaluation and prediction of the algal bloom phenomenon. The satellite imagery, chlorophyll A content, and sea surface temperature data were encoded by using the satellite image information. The findings can be categorized into three principal segments: 1) the results from the coded access of satellite image data, which displayed chlorophyll A content and sea surface temperature through temporal adjustments for data recording, 2) the SeaDAS (SeaWiFS Data Analysis System) program that was used for analyzing the data and 3) the analysis of chlorophyll A and sea surface temperature from satellite images in the Gulf of Thailand.

Results from coded access of satellite image data

The coding implementation permitted the accessibility of satellite image data, manifesting chlorophyll A content and sea surface temperature through temporal adjustments. This code facilitated the acquisition of satellite images capturing sea surface temperature and chlorophyll A content, particularly in the geographical coordinates encompassing 13.6 to 12.5 degrees north latitude and 99.92 to 101 degrees east longitude within the Gulf of Thailand (Figure 1). This code schedules the regular or as-needed recording of data to capture the MODIS signal.

After that, the code was divided into two sections: one for retrieving data on chlorophyll content and the other for retrieving data on sea surface temperature. The final step involves creating the code that instructs the other two portions of the code to function as a whole. There is a designated work period.

The time setting for recording information on sea surface temperature and chlorophyll A content was shown in Figure 2. The configuration of Case #1 recorded the data every 9 and 12 minutes immediately, while the data were planned to be recorded once per day at 22.21 or 22.24 p.m. in Case #2 (Figure 2).

The data were saved at pre-defined intervals, and this information was subsequently utilized to generate an NetCDF (Network Common Data Form) for chlorophyll A content calculations. Image recording of chlorophyll A content is and sea surface temperature. Images that were successfully recorded showed chlorophyll content. The image that successfully recorded the level of chlorophyll A and temperature of the sea surface were called L2.OC.NRT, and L2.SST.NRT respectively.

The SeaDAS (SeaWiFS Data Analysis System) program was used for analyzing the data.

When receiving data from the satellite downloaded to the SeaDAS programs, Bands Chlor_a (sea surface temperature) were chosen and then opened as shown in Figure 3.

```
#map

driver.find_element(By.CSS_SELECTOR,"input[name='n']").send_keys("13.6")
driver.find_element(By.CSS_SELECTOR,"input[name='w']").send_keys("99.92")
driver.find_element(By.CSS_SELECTOR,"input[name='e']").send_keys("101")
driver.find_element(By.CSS_SELECTOR,"input[name='s']").send_keys("12.5")
driver.find_element(By.CSS_SELECTOR,"input[value='Find swaths']").click()
```

Figure 1 The coordinates of the Gulf of Thailand area.

```
    print("L2.SST.NRT [illegible]")

#case 1
schedule.every(9).seconds.do(first_file)
schedule.every(20).seconds.do(second_file)


#case 2
#schedule.every().day.at("22:21").do(first_file)
#schedule.every().day.at("22:24").do(second_file)

while True:
    schedule.run_pending()
    time.sleep(1)
```

Figure 2 selecting the time that satellite data is recorded

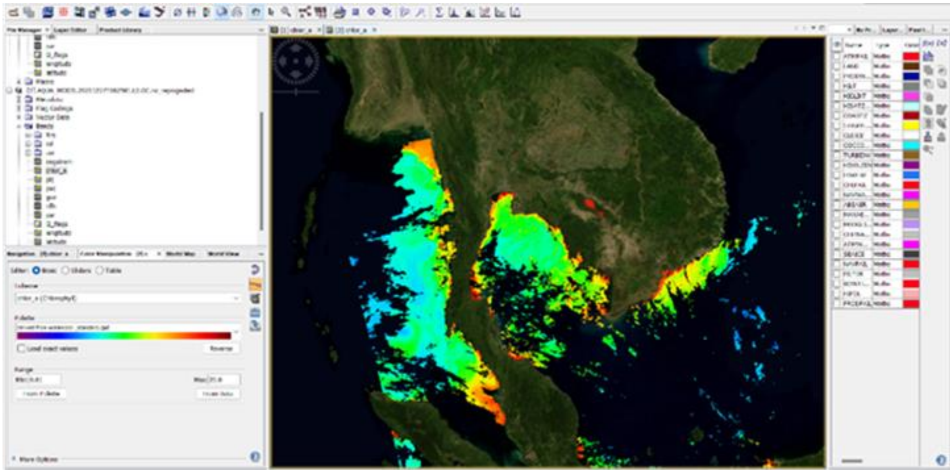

Figure 3 Analyzing satellite data with the SeaDAS (SeaWiFS Data Analysis System) program

For seven days duration (January 7 to January 13, 2566), the software granted access to experimental data. The study employed satellite images to discern chlorophyll A content and sea surface temperature.

As shown in Figure 4, chlorophyll A levels was about 4.35 mg/m^{-3} on January 7 and 2.71 mg/m^{3} on January 8. On January 10–12, the highest concentrations of chlorophyll A were 2.31 mg/m^{-3}, 2.40 mg/m^{-3}, and 2.60 mg/m^{-3}, respectively. The pinnacle concentration of chlorophyll A of 3.73 mg/m^{-3} was observed on January 13.

As shown in Figure 5, the SeaDes program was employed for the analysis of sea surface temperature data. The results revealed that the maximum temperatures on January 7 and 8 reached 29 ^{o}C and 28 ^{o}C, respectively. On January 9–11, the highest sea surface temperatures were 28 ^{o}C. The highest sea surface temperatures on January 12 and 13 were 28.91 ^{o}C and 28.4 ^{o}C.

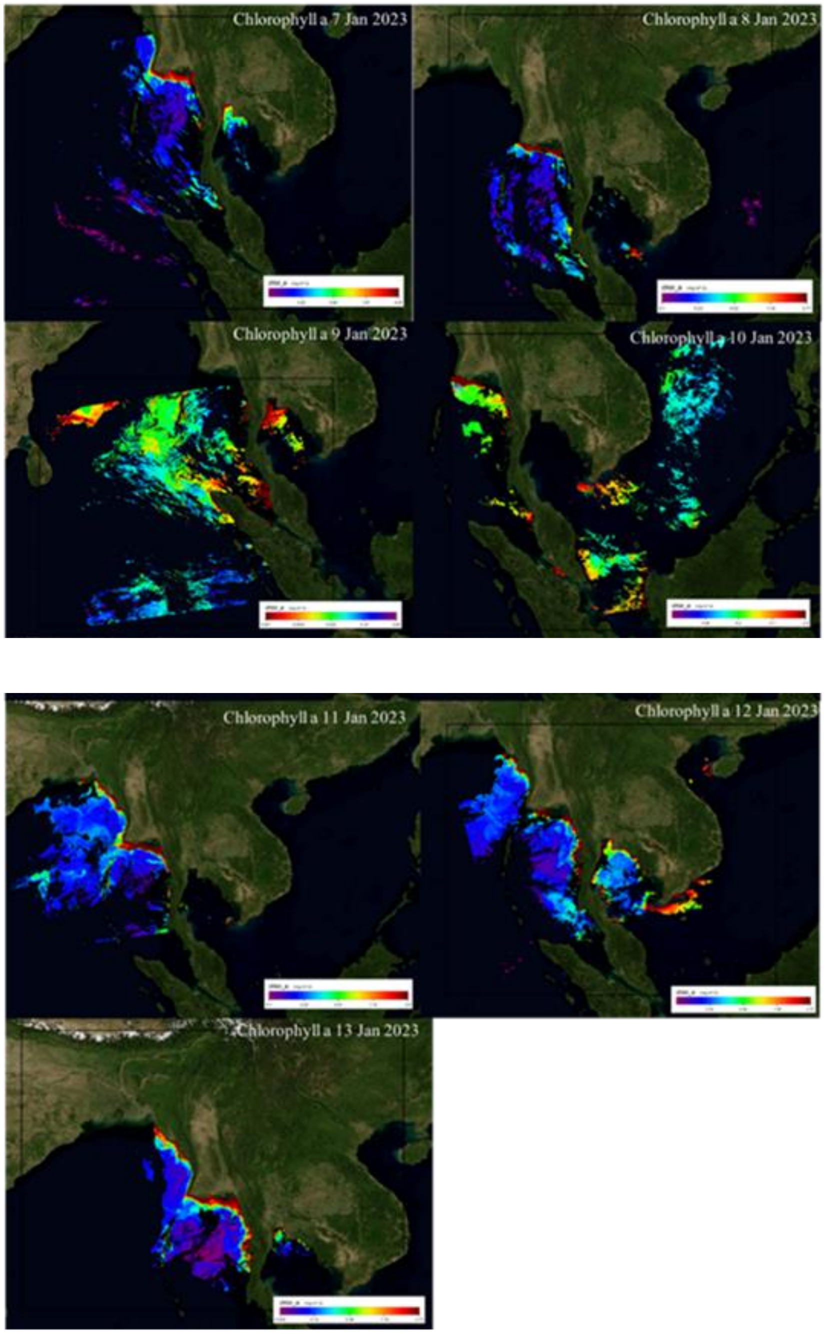

Figure 4 Analysis of satellite images utilizing the SeaDes program - depiction of extracted chlorophyll A content data from the MODIS Receiver (January 7–13, 2023)

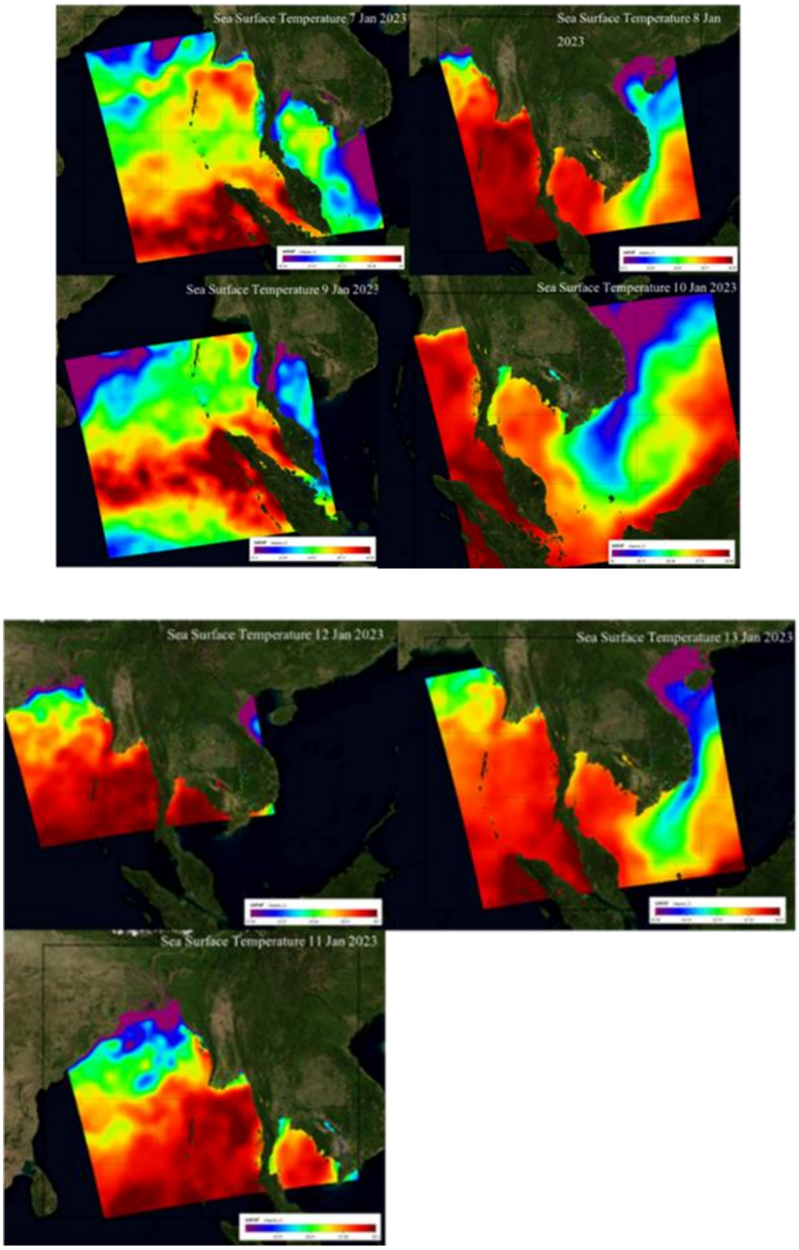

Figure 5 Recorded sea surface temperature data results from the MODIS receiver utilizing the SeaDes Program for satellite image analysis (January 7–13, 2023)

The results of the satellite images that were analyzed by MODIS-Terra and SeaDAS-Aqua programs showed that they could evaluate the level of chlorophyll-A and temperature of the sea surface. However, it has been reported that chlorophyll-a diffusion from MODIS-Terra and MODIS-Aqua monthly satellite data with chlorophyll data collected in the field by research vessels in 2012 showed that most of these field results were consistent with MODIS data [8].

Furthermore, the levels of chlorophyll-A and the sea surface temperature were determined to be compatible with the information from the Geo-Informatics and Space Technology Development Agency (Public Organization) (Figure 6). This study demonstrates the dependability of chlorophyll-A content data and the sea surface temperature measurements collected from satellites.

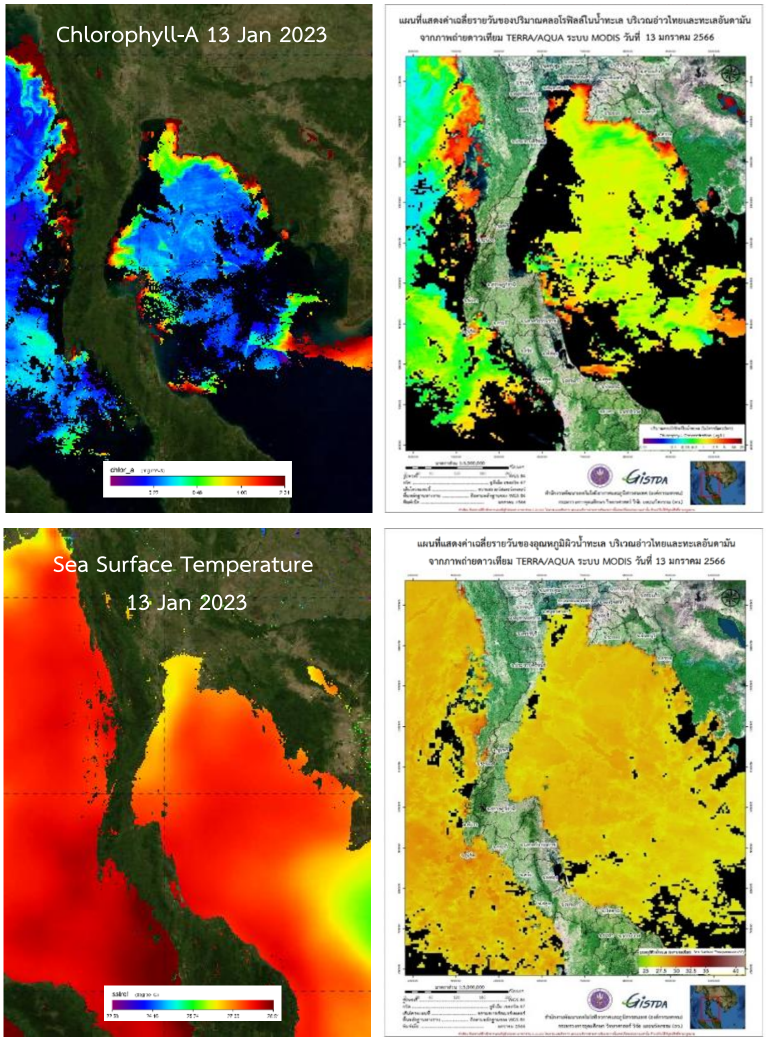

Figure 6 chlorophyll A and sea surface temperatures January 13, 2023 Compare with pictures from Geo-Informatics and Space Technology Development Agency (Public Organization) [9]

Conclusion

The IoT technology was used to improve the access data on sea surface temperature and chlorophyll-A. Considering about using the SeaDes program which displays values from satellites and digital image analysis, the access MODIS satellite data are capable of digital images analysis from satellite data displays the temperature of the sea surface and the concentration of chlorophyll-A from image registration. The data appears as a color bar that showed the amount of chlorophyll and the sea surface temperature. However, the satellite imaging system has a limitation in terms of a passive sensor satellite data system which is unable to image the research region of MODIS. The further research could be the extension of data comparison from satellite photos with measurements of sea surface temperature and chlorophyll content in the appropriate locations.

References

[1] Sethi, P. and Sarangi, S. R. 2017. Internet of things: Architectures, protocols, and applications. Journal of Electrical & Computer Engineering. 2017: 1-25.

[2] Wang, K., Khoo, K. S., Leong, H. Y. et al. 2021. How does the Internet of Things

(IoT) help in microalgae biorefinery? Biotechnology Advances. 2021: 107819.

[3] Frost & Sullivan and the Digital Economy Promotion Agency (depa). (n.d.). Thailand Digital Technology Foresight 2035. From https://depa.or.th/storage/app/media/file/depa-Technology-Foresight-Final-Report-EN-250320.pdf. (accessed April 26, 2024)

[4] Dien, T. W. and Hai, P. H. 2006. Using SeaWiFS satellite data for monitoring algal bloom in Vietnam waters, the South China Sea. Coastal Marine Science. 30(1): 44-48.

[5] Tang, D., Kawamura, H., Lee, M. A. and Dien, T. V. 2003. Seasonal and spatial distribution of chlorophyll-a concentrations and water conditions in the Gulf of Tonkin, South China Sea. Remote Sensing of Environment. 85: 475-483.

[6] Department of Fisheries, Coastal Aquaculture Technology and Innovation Research and Development Center, Songkhla. from http://www.nicaonline.com. (accessed 20 May 2022).

[7] NASA. n.d. MODIS Moderate Resolution Imaging Spectroradiometer. From https://modis.gsfc.nasa.gov/about/specifications.php. (accessed July 8, 2022)

[8] Sanitmajaro, W. 2019. Water quality and chlorophyll A content with MODIS data in Thai territorial waters. Fishing Vessels and Marine Fisheries Control Group. Fishing and Fleets Management Division Department of Fisheries.

[9] Geo-Informatics and Space Technology Development Agency. 2023. Chlorophyll A and sea surface temperatures January 13, 2023. from https://www.gistda.or.th (accessed April 26, 2024)