Big Data Analytics as a Pedagogical Tool in Oceanography Education within Malaysian Secondary Schools

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ABSTRACT

In the big data era, access to large and complex datasets has become more feasible, which could offer new opportunities for education. This study will propose the use of geospatial interactive online visualisation and analysis infrastructure (GIOVANNI) as a pedagogical tool for oceanography education in secondary schools. The focus is on applying GIOVANNI in oceanography education to analyse spatial and temporal changes in sea Surface temperature (SST) over Peninsular Malaysia's maritime area. Monthly Level 3 data (4 km resolution) obtained from MODIS Aqua for the period of July 2002 to May 2025 was used. Monthly and seasonal average maps were generated to observe spatial SST patterns. Monthly, seasonal and yearly timeseries constructs reveal a slight uptrend in SST. The highest recorded SST was 31.37°C in May 2010, and the lowest was 26.84°C in December 2008. DJF is showing the lowest seasoning temperature, mainly due to the rainy season over this study area. Regionally, the highest SST was observed over the Malacca Straits. This study addresses common questions regarding SST trends, seasonal shifts, and regional anomalies. Through real data analysis, students could develop a more profound understanding of marine environmental dynamics. Integrating GIOVANNI in geography classrooms could promote critical thinking, spatial literacy and scientific curiosity, which aligns with national educational goals.

Keywords:(Big data, GIOVANNI, Pedagogy, Geography, Sea Surface Temperature)

INTRODUCTION

Recently, getting access to large datasets, especially for environmental study, has become easier. This is excellent news for students learning about the environment because it means that they can explore real-world data firsthand rather than just reading it in the textbooks. One powerful example is NASA's GIOVANNI tool. This online portal was created to allow anyone, even without advanced technical skills, to easily view, play, and analyse satellite data. They only need four clicks to run GIOVANNi (Wei et al., 2018). GIOVANNI lets users make maps, timeseries plots, animations, and other visualisations quickly and easily. Bringing GIOVANNI into secondary classrooms can make a real difference. Instead of just talking about how the ocean might be warming, students can actually explore the data themselves. For instance, they could see how SST around Peninsular Malaysia has changed over time. They also could discuss what it might mean for marine life or local weather. Since early 2000, NASA GIOVANI has been a popular service for the analysis and visualisation of NASA Earth datasets. At the beginning of 2023, about 3,000 research publications had been published (Gerasimov et al., 2024). To date, several research papers have been published by scientists around the world that utilise GIOVANNI datasets (Acker, 2022; Kamaruddin et al., 2022; Amin et al., 2023; Liu and Acker, 2024; Bryant et al., 2024; Omokpariola et al., 2025). The GIOVANNI web-based portal also has been used by high school and college students to investigate regional climate change, compare oceanic regions, and

assess the contribution of tropical storms to annual precipitation in selected areas (Wei et al., 2018). There have been local studies using GIOVANNI. For example, researchers looked at temperature trends around Penang Island between 2016 and 2018 by using the GIOVANNI portal (Kamaludin et al., 2022). By using this tool, students are exposed to real satellite data, which allows them to engage directly with authentic scientific information. It enables them to visualise and understand local environmental changes in a clear and intuitive manner. Through this process, they develop essential skills in data analysis, interpretation and critical thinking. Most importantly, students are able to connect theoretical classroom learning to their immediate surroundings, enhancing the relevance and impact of their education. In short, integrating GIOVANNI into school lessons could transform learning into a real investigation. Students can explore and understand our environment directly, which will make science more interactive, relevant and exciting.

Problem Statement

Despite the growing importance of climate literacy and oceanographic understanding in addressing global environmental challenges, oceanographic education at the secondary school level remains limited in several key aspects. Firstly, many classrooms lack access to real-time or historical oceanographic datasets, restricting opportunities for practical, data-driven learning experiences. Secondly, there is minimal exposure among students to scientific tools and platforms such as NASA's GIOVANNI, which impedes the development of essential spatial reasoning and analytical skills. Lastly, students' understanding of complex oceanographic phenomena such as SST trends is often confined to theoretical instruction. This could reduce both engagement and the ability to apply knowledge in real-world contexts.

Objectives

The objectives of this study are:

1. To integrate satellite-based datasets (GIOVANNI) into the teaching and learning of geography, focusing on oceanography.
2. To demonstrate the generation of maps and time series data using SST around Malaysian waters as an example.

PRODUCT DESCRIPTION & METHODOLOGY

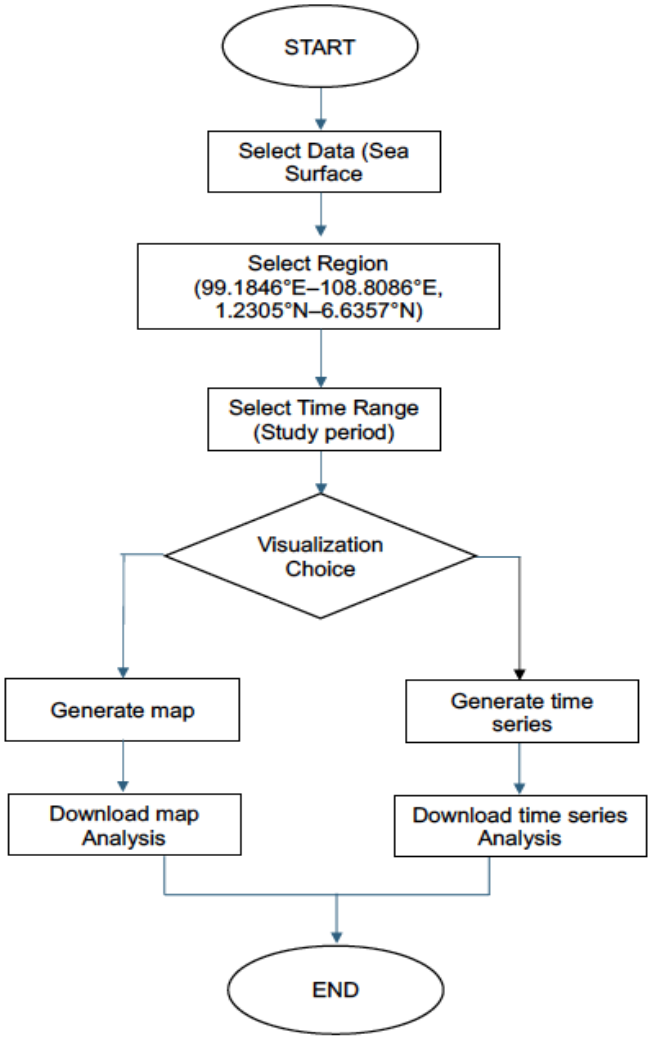
Product

The Proposed Product Is an Educational Innovation That Integrates Giovanni Satellite Datasets into Secondary School Geography Learning. The Product Consists of a Digital Teaching and Learning Module That Guides Teachers and Students in Accessing, Visualising, and Interpreting Sea Surface Temperature Data Around Malaysian Waters. Through This Product, Students are able to Generate Maps and Time Series, Conduct Mini Research Projects, and Relate Their Findings to Local and Global Climate Phenomena.

METHODOLOGY

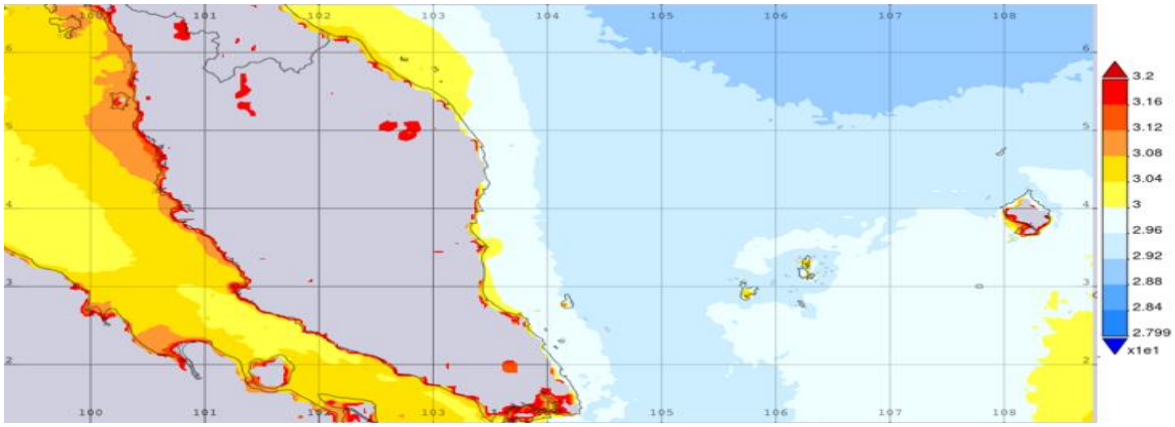
The GIOVANNI version 4 system was used for the analysis. There were multiple steps in the approach. Sea Surface Temperature was first entered in the keywords section. The variable panel displayed 12 of the 2054 parameters. The sea surface temperature (water alone) at 4 microns was selected. The MODIS sensor aboard the Aqua satellite provided this Level 3 parameter. Geographic items that had been combined, processed, and projected onto a standardised global grid during predetermined time intervals (daily, 8-day, or monthly) made up MODIS Level 3 data. The monthly Level 3 SST was selected for this investigation. Second, the study area's latitude and longitude coordinates were specified, defining the spatial scope of interest. A box was drawn across the Malaysia region when the left icon on the right side of the Select Region (Bounding Box or Shape) panel was clicked. The study area encompassed the latitude range of 1.2305°N to 6.6357°N and the longitude range of 99.1846°E to 108.8086°E. The start and end dates were then adjusted to correspond with the necessary study period to establish the temporal domain. Two kinds of visualisations and analyses were carried out after the data, region, and time were chosen. To investigate the spatial distribution of the SST throughout

the study area, a time-averaged map was first created. Before being used further, the created map was downloaded, and its quality was assessed. The temporal SST within the designated region was then analysed using an area-averaged time series. To conduct additional statistical analysis, the time series results were also obtained. This workflow made it possible to carefully examine the dataset's temporal and spatial features. The flowchart below provides a summary of the entire procedure.



RESULT

Figure 1: Time average map for the period 1980 to 2024



The spatial distribution of sea surface temperature (SST) in the study area from 1980 to 2024 indicates that the average SST range is between 29°C and 32°C. The maximum sea surface temperature, reaching 32°C, was

consistently recorded in the coastal region, especially along the Malacca Strait. Conversely, the minimum SST values, approximately 29°C, were observed in the northeast region of Peninsular Malaysia. This spatial variation signifies the impact of coastal dynamics and regional circulation patterns, wherein the confined and shallow waters of the strait tend to retain heat. Conversely, over open waters, the temperature persists at a lower level.

Figure 2: Yearly time series

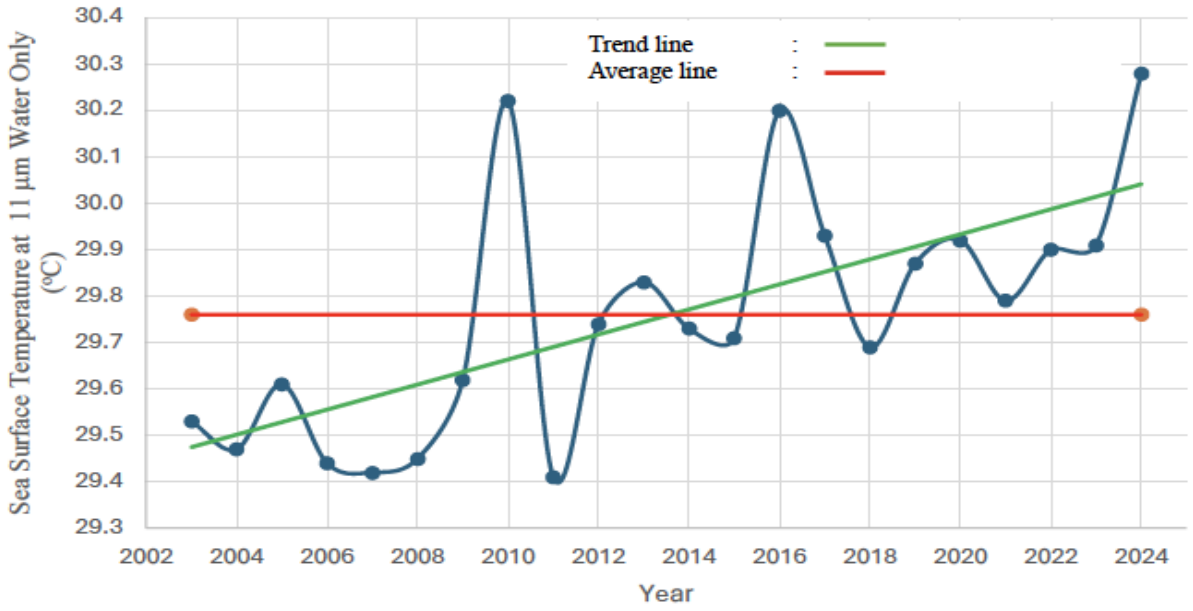


Figure 2 shows the annual time series of SST from 1980 to 2024. The mean SST for this study period is 29.8°C as denoted by the red line. The SST exhibits an increasingly trend, indicating a steady warming of the study area during the last two decades. The maximum SST 30.3°C was documented in 2024 and the minimum SST of 29.4°C observed in 2011. This upward trend underscores the possible influence of prolonged climate variability and global warming on regional SST trends.

Figure 3: Monthly time series

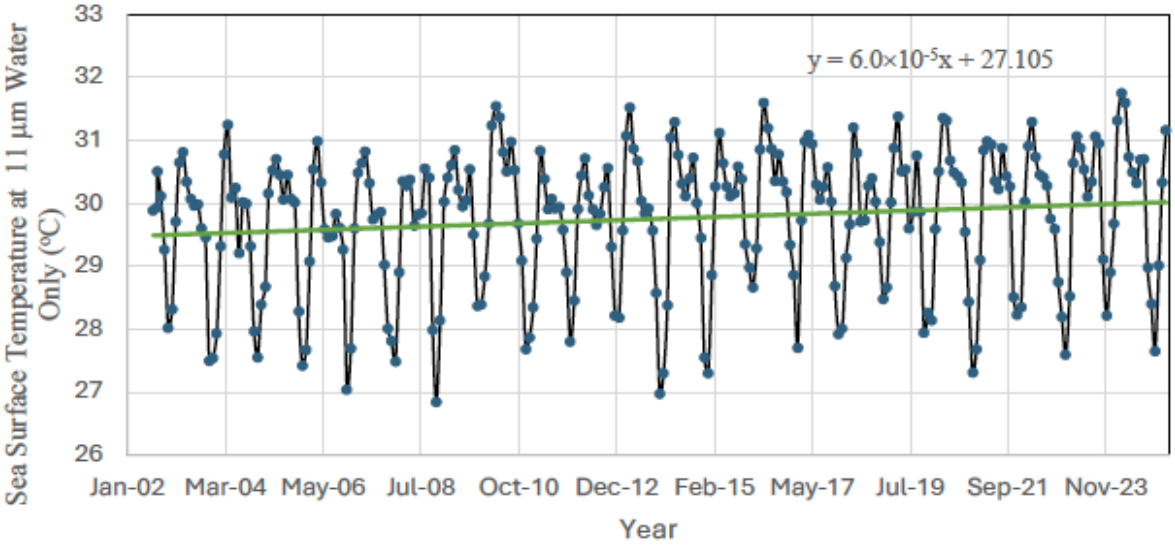


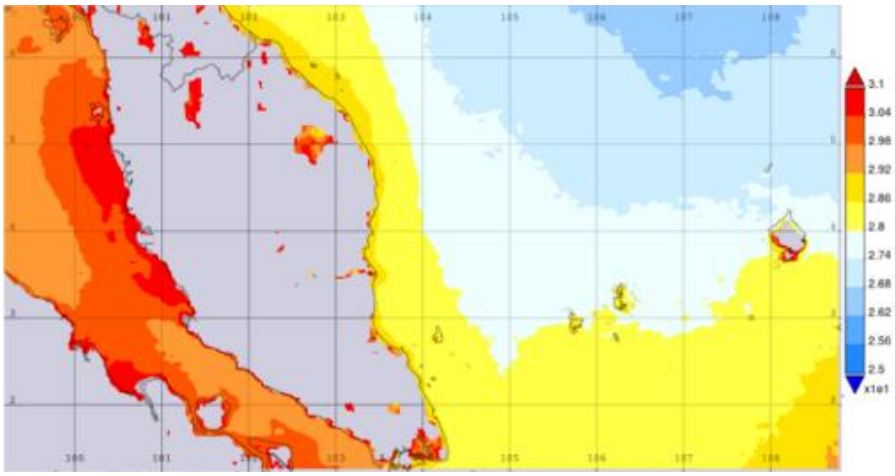
Figure 3 shows the monthly SST trends throughout the study period. the green line indicates an overall upward trend, reflecting a gradual warming pattern over time. The highest SST was recorded in May 2024 which reached 31.7°C, while the lowest SST of 26.8°C was observed in January 2009. These fluctuations highlight the strong influence of seasonal variability, where warmer conditions are typically associated with the inter-monsoon periods and cooler conditions coincide with the northeast monsoon.

Figure 4: Seasonal time series

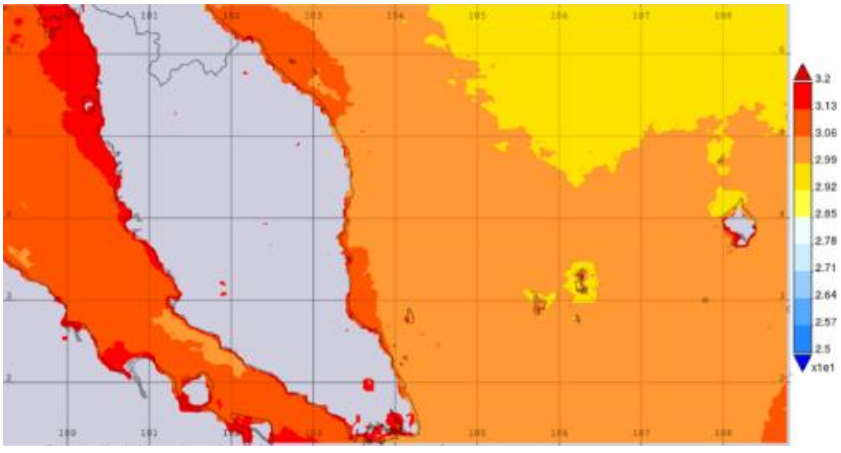
Figure 4 illustrates the seasonal SST trends over the study period. The lowest SST values were recorded during the DJF season (December-February), which coincides with the northeast monsoon season. During this season, stronger winds and enhanced mixing contribute to cooling the surface water. Overall, SST value varied between 27.5°C and 29°C across the season. Both seasonal trends exhibit a slight upward pattern.

Figure 5: Seasonal area average map

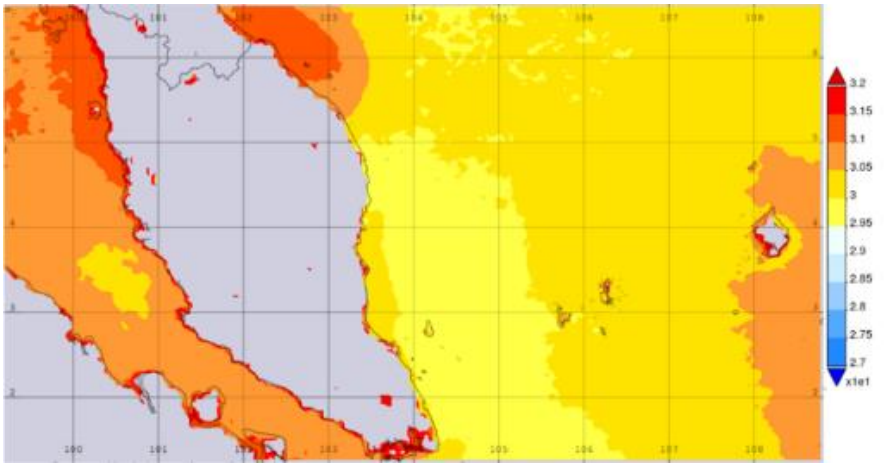
December, January, February



March, April, May



June, July, August



September, October, November

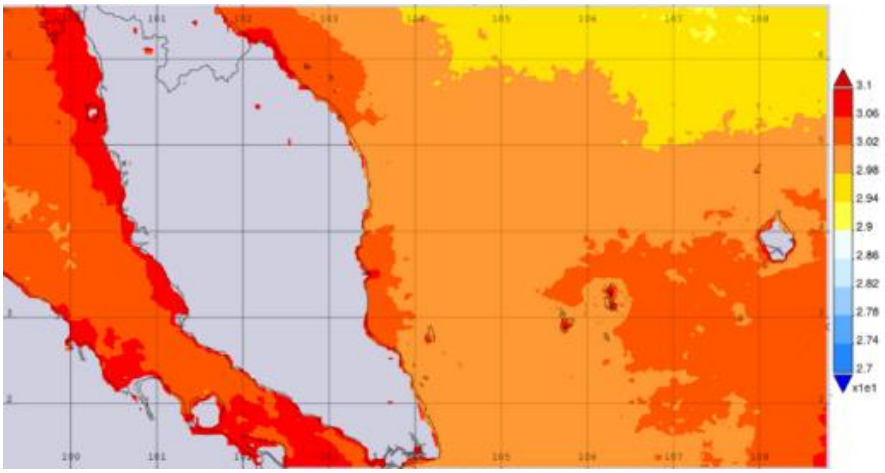


Figure 5 presents the seasonal average map of SST across Peninsular Malaysia. During the DJF season, relatively low SST values were observed along the northeast coast of Peninsular Malaysia, while higher temperatures were observed in the Malacca strait. In the MAM season, highest SST values were again concentrated in the Malacca Strait, with moderate temperatures recorded over the South China Sea. The JJA season showed moderate SST conditions on both sides of Peninsular Malaysia, whereas in the SON season, higher SST values were observed across both the Malacca Strait and the South China Sea. These spatial variations reflect the strong influence of monsoonal wind systems and regional circulation on SST distribution.

POTENTIAL FINDINGS AND COMMERCIALISATION

Findings

When analysing SST datasets, students are expected to uncover significant findings. They may identify long-term SST trends in Malaysian maritime regions. The finding could be used to link climate change with coral bleaching. Seasonal comparison may reveal the influence of the northeast and Southwest monsoon seasons on SST variation. Students may also discover correlations between local SST patterns and global climate phenomena such as El Niño and La Niña. Most importantly, these findings have strong relevance for communities, as SST variations affect fisheries, coastal tourism, and even disaster preparedness.

Commercialization

The proposed innovation also carries commercial potential. One possible outcome is the development of digital learning modules that guide students step by step in analysing and interpreting GIOVANNI datasets. Teacher training workshops can be organised to equip educators with the skills they need to adopt this method in their classrooms. Additionally, STEM education kits, which combine datasets, hands-on activities and teacher manuals, could be packaged and distributed to schools nationwide.

NOVELTY AND RECOMMENDATIONS

The novelty of this proposal lies in the integration of real-time satellite data into secondary school geography lessons. While geography has traditionally been taught using maps and static resources, the introduction of GIOVANNI data represents a shift toward inquiry-driven and data-orientated education. This approach combines STEM and data science, encouraging students to engage with geospatial analysis, climate science, and information technology. Furthermore, it connects classroom knowledge to society challenges, such as climate change, coral reef health, and sustainable fisheries, which are rarely directly linked to school-level geography lessons.

Future research should aim to extend the scope and application of this study in several directions. Firstly, pilot classroom studies involving students and teachers are needed to evaluate the effectiveness of the GIOVANNI based module in terms of learning outcomes, engagement and critical thinking. Secondly, adopting formal pedagogical frameworks such as TPACK or Inquiry-Based learning would strengthen the educational design and ensure alignment with established teaching practices. Thirdly, expanding beyond SST to include datasets such as chlorophyll-a (Chl-a) precipitation and sea level rise would allow for more comprehensive ocean-climate understanding.

Additionally, future work would focus on teacher training and support, including structured workshops and instructional guides to build teacher capacity. Student-centred evaluation methods such as pre-tests and post-tests, surveys and reflections would also be employed to capture the learning experience more effectively. To enhance accessibility, offline datasets and simplified visualization could be developed for schools with limited internet access. Finally, scalability would be explored by integrating the proposed module into the national curriculum with the support from the Ministry of Education and relevant NGOs.

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