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ORIGINAL ARTICLE

Anomalous Appearance of Fish in Tambisan and Clams in Lumut during December 2013-January 2014: An Atmosphere-Ocean Interaction-Based Analysis

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Abstract

Two anomalous events occurred along the coast of north Borneo: (a) large numbers of small pelagic fish ("Tamban") jumped onto the shore at Tambisan in Lahad Datu, Sabah, East Malaysia, on 24 December 2013; and (b) large numbers of live clams appeared at Lumut beach, Brunei Darussalam, on 3 January 2014. The paper attempts to explain the occurrence of these anomalous events by comparing plausible explanations based on atmosphere-oceanic interactions with wind, wave and surface ocean current patterns generated using MeteoInfo, an open-source GIS software. Reanalysed data were obtained from Live Access Servers (LAS), notably NOAA's geophysical fluid dynamics lab using its WaveWatch3 and OceanWatch models. Although the study is not conclusive, it found some patterns that support the proposed hypotheses and provide plausible scientific explanations for the events. The fish incident at Tambisan therefore appears to be caused by ocean currents forcing pelagic shoals into a constricted channel, while the clams at Lumut were mobilised and deposited by waves-generated currents produced by atmospheric circulation a few days leading to the incident. Other factors, such as Internal Waves or Solitons, were also discussed. A major challenge encountered is presenting large number of the maps generated, in printed format, and in a way that does not reduce their readability.

Keywords: Atmosphere-Ocean interaction, Fish and Clams, Anomalous events, Sabah, Brunei.

1. Introduction

As 2013 gave way to 2014, two anomalous events occurred, 10 days apart, at two different sites along the coast of North Borneo as follows: (a) Tambisan in Lahad Datu District, Sabah, East Malayisa, on 24 December 2013; and (b) Lumut, in the Belait District, Brunei Darussalam, on 3 January 2014. The first incident occurred on the northeast coast of North Borneo, which faces the Sulu Sea (SS), while the second took place along an open coast facing the South China Sea (SCS) (Fig 1). At Tambisan, the small fishing village woke up to thousands of small sardine fish (locally known as IkanTamban) literally jumping out of the water and onto the rocky revetments. The village was high with excitement as men, women and children collected large number of live fish in assorted basins, plastic bags and any containers. The incident was captured on video and shared on social media (e.g. YouTube, 2013).

Although large numbers of fish appearing on beaches is not uncommon, in most cases, the fishes tend to be dead, such as at Tainjin (Rega, 2015), Devon (Smith, 2015), Virginia (Hedgpeth, 2015) and Brazil (Telesur, 2014). Indeed, they are becoming more frequent and are a cause for concern. At Tambisan, the fish were however alive and packed at such a high density in the shallow water that they jumped out onto land (refer to the Youtube video above). At Lumut, Brunei, the excitement was over thousands of live clams appearing on the narrow sandy beach just east of the mouth of the Lumut River. The incident similarly drew villagers to the beach to partake in the new year clam fest. The two events were shared on social media, such as Whatsapp and Facebook, and reported by local and regional newspapers, such as the Brunei Times and the Borneo Post. The excitement generated was mainly because both were anomalous events, occurring at such scale for the first time at the respective locations. The unexpected events also raised fear and anxiety amongst the people, as speculations of an impending doom from a tsunami or earthquake grew (Brudirect, 2014).

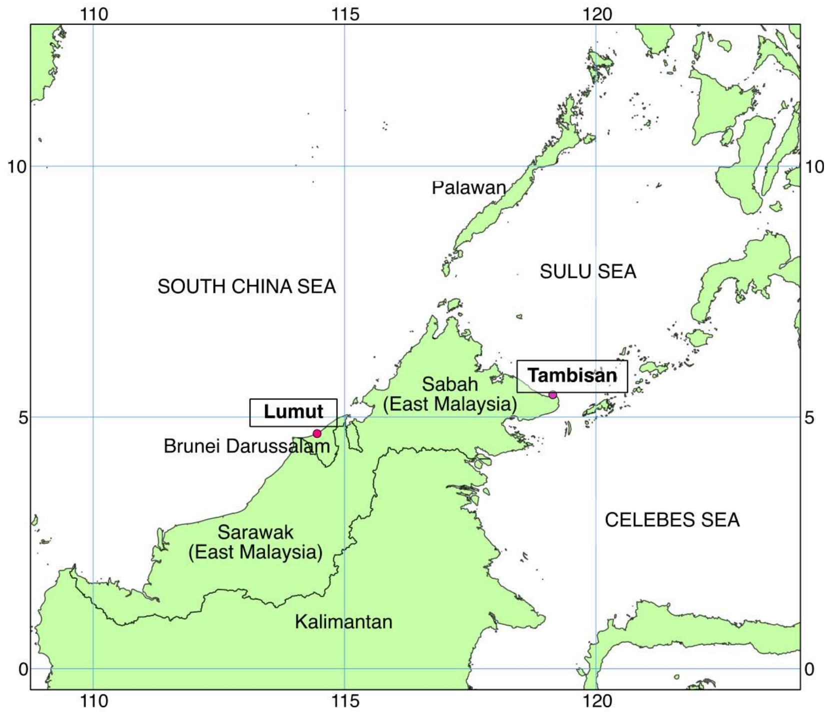

Fig 1: Location of Anomalous Incidents

Authorities stepped in promptly to curb wild speculations and scare mongering, attributing the occurrences to oceanographic or environmental factors. They also cautioned against consumption of the fish and clams until tests have been carried out to confirm that they are safe. The health concerns were founded on the understanding that clams are filter feeders that ingest phytoplankton and other particulate matter available in the natural environment, while the stranded fish were feared to be diseased. Moreover, a Red Tide outbreak had occurred recently. In general, the occurrences represented a major distress to public officials in both Brunei and Sabah, who were confronted with potential health impacts and growing anxiety among the populace due to the general uncertainty surrounding the origin of the fish and clams, and the underlying causes of the phenomena.

This paper aims to address the uncertainties associated with the occurrence of these events. It will begin by examining the scientific explanations put forward in the news media and attempt to substantiate and refine or correct them with scientific (mostly satellite) data provided online by various organisations without charge. In particular, it will examine the (a) synoptic atmospheric-oceanic coupled circulation patterns in the SCS and SS, and (b) how they could have led to the development of the two events. Finally, it will discuss issues encountered in and limitations of the study, and conclude with a more robust explanation of the two events.

2. Hypothesis

In response to the press, the Universiti Malaysia Sabah's (UMS) Borneo Marine Research Institute attributed the fish incident at Tambisan to oceanographic factors. They explained that IkanTamban (sardines) are shoal and pelagic fish that were sensitive to changes in sea temperature, currents and wind-induced turbulence; they generally prefer calm waters. The shoals are generally very large and dense, extending several hundred metres wide and several metres deep. It was also regarded as "not unusual" for sardines to be so close to shore, as they do migrate to waters near the shore "because of environmental and biological factors". When a large high-density shoal enters narrow shelf area, as was the case at Kg Tambisan Darat, jumping onto the shore was not unexpected (Lai, 2013; MalaysianDigest.com, 2013). The channel between Tambisan Island and Kampong Tambisan Darat was only 160-180 m wide.

With regards to the Lumut clam incident, the Department of Fisheries (DOF) asserted that the unusually high number of clams found at Lumut beach could be attributed to "marine environmental factors" (Rajak, 2014). The authority was more concern about health and safety, as there was a recent Red Tide outbreak in Brunei waters. The Ministry of Industry and Primary Resources (MIPR) declared the clams were free from biotoxins, microbiology and heavy metals two weeks after the incident following a series of laboratory tests conducted by its laboratories as well as that of the Singapore Agrifood and Veterinary Authority (AVA) (Airudin, 2014). No further explanations were given regarding the unusually large number of live clams appearing at Lumut on 3 January 2014.

They have however been similar anomalous occurrences around the world. For example, millions of live clams and crabs were washed onto Vladivostok beach in Lazurnaya Bay, Russia, in September 2012 (Sinpetru, 2012). A similarly unusual event was observed on 1 January 2014 at Hythe Beach, in Kent, England, where hundreds of clams (Mya truncate) were washed onshore (Woodland, 2014). According to experts, high winds and rough seas could have disturbed the saltwater clams from the seabed, especially during extremely low tides, such that the buried bivalves were easily "dug out" and "jettisoned onto the strand line" of the intertidal zone. In the Vladivostok case, Typhoon Bolaven of 2012 was the main cause. In both cases, mass beaching of live organisms are attributed to atmospheric-oceanic forces. This was echoed in the Lumut and Tambisan events.

In recent years, ocean-climate inter-connections and their impacts have been widely studied and described in many journal publications and reports. Studies on the Asian Monsoon, in particular, include: severe weather conditions, such as strong winds and tropical cyclones (e.g. Das *et al.,* 2015; Dasari and Dodla, 2014; Zhou *et al.,* 2014), anomalous precipitation associated with offshore troughs and mid-Tropospheric cyclones (e.g. Pradhan *et al.,* 2015); and seasonal and intra-seasonal variability (e.g. Kolusu *et al.,* 2014). This has increased understanding of atmosphere-ocean interactions in general, and of the region, in particular. Current knowledge and data derived from monitoring the regional atmosphere and oceans could help elucidate the mysterious occurrence at Lumut and Tambisan.

2.1 Tambisan Fish Incident

Kampong Tambisan is a small fishing village located in a sheltered narrow channel between the Sabah mainland and Tambisan Island at the southwest corner of the Sulu Sea (SS) (Fig 2). The area is a rich fishing ground enclosed by archipelagos and the northeast coast of Borneo. The SS is shallow within 100 km from the coasts and islands, but plunges to a depth in excess of 4,000 m in the south-eastern half of the basin. According to Wyrtki (1961, in Frische and Quadfasel, 1990), near-surface oceanic circulation in the SS is mainly governed by seasonally reversing monsoon winds. Deep circulation is however driven by an inflow of "intermediate water" forced in from the SCS through the Mindoro Strait (sill depth 420 m), which supplies the intermediate and bottom waters of the Sulu Sea. The International Nusantara Stratification and Transport (INSTANT) program estimated this flow rate via the Mindoro Strait to be about 300,000 m^3/s (Arnold, n.d.). The Mindanao Current also contributes about 200,000 m^3/s to the SS, flowing via the passage between Negros and Zamboanga from the Western Pacific. The deep oceanic current, which is part of the Indonesian Through Flow (ITF), exits the SS and flows into the Celebes Sea through the Sibutu Passage off the Tambisan coast. A slight shift in oceanic circulation direction towards the north coupled with an increased in current speed (and associated turbulence) could quite easily force any fish shoals in the area into the narrow Tambisan channel. This could be verified by examining atmospheric and oceanic circulation pattern during the event.

2.2 Lumut Clam Incident

Clams are found in the narrow littoral zone along Brunei coast. However, they are generally small in size and do not occur in large numbers. Shell harvesting is therefore not commonly done along Brunei's open coast. This is largely due to the fact that the open coast receives moderately high energy from the SCS. Coupled with low sediment supply, the beach is narrow, thin and highly dynamic. Oblique constructive waves build up beaches but they also drive rapid longshore drift up-or down-coast, depending on wave direction. Destructive waves generated by storms in the SCS erode the beach face and deposit the sand offshore. The clam incident at Lumut suggests an accumulation of sediments and organisms moved to the coast in a short period of time. The necessary force could only be supplied by large (long wavelength; long period) strong (high energy) waves. This would have to come from the sea and be large enough to dislodge seabed sediments, together with the clams and transport them to the shore. A drastic change in wave direction (so that sediments transport and longshore drift converges) over the few days before the 3 January would aid in accumulating the clams in the Lumut area, rather than spreading them along the coastline. Details of coastal dynamics can be found in Silvestre *et al.* (1992), Sandal (1996) and Yong (2009). Fig 3 shows the Lumut area, where the event occurred. Additionally, since 2005, a set of breakwaters has been installed at the mouth of the Lumut River not far to the west, which would give rise to a wave shadow, thus enhancing deposition in the Lumut coast. Reports of

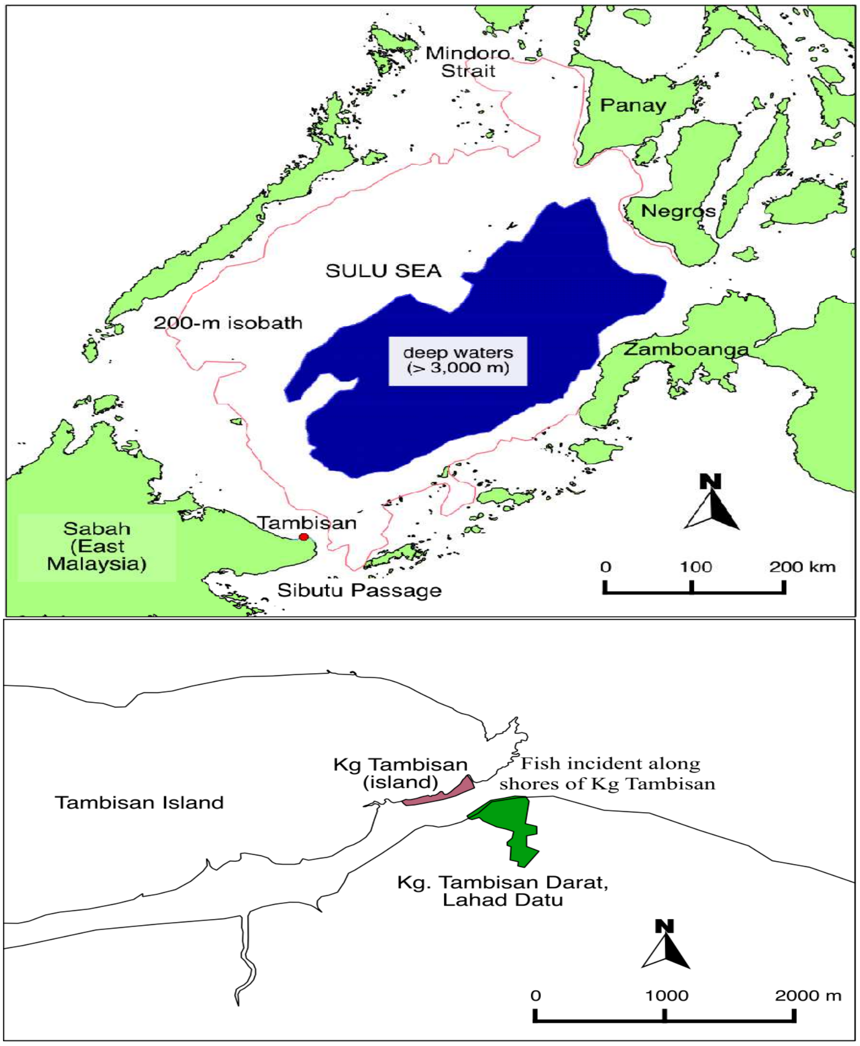

Fig 2: Tambisan, LahadDatu, Sabah, East Malaysia

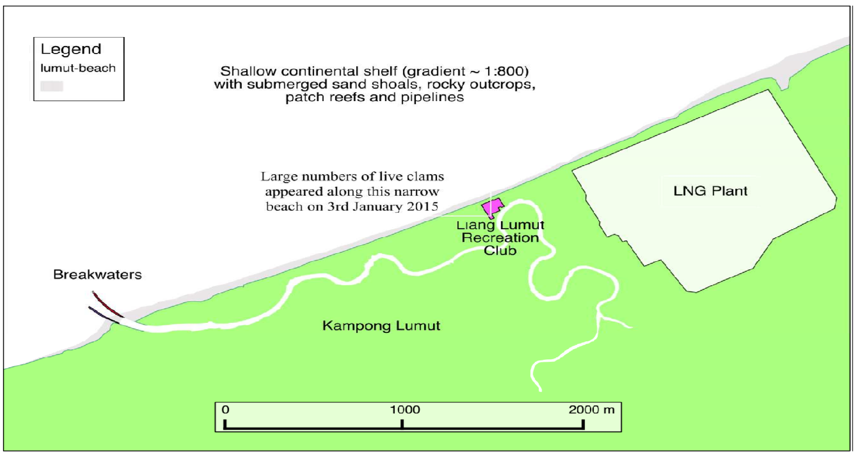

Fig 3: Lumut, Brunei Darussalam

similar clams occurrence at Tutong, which also have break waters at the river mouth, might corroborate this hypothesis.

3. Materials and Methods

Oceanographic and environmental data are generally expensive to acquire and therefore many environmental studies are done without good coverage of relevant data. However, with advancement in satellite remote sensing techniques, services and research, as well as a paradigm shift in communication and information mediated by the Internet, it is becoming increasingly possible to access such data – or simulated versions of them – from a number of Internet sites, often at no charge to researchers.

This study employs MeteoInfo (a GIS software) to visualise, process and analyse atmospheric and oceanic data from a number of online sources. The data was imported in vector, streamline and contour formats, and image processing carried out in NetCDF format. The Satellite Remote Sensing (SRS) data were obtained from various Live Access Servers (LAS). The variables of interest are mostly reanalysed data and include: wind vector (speed and direction), ocean current speed and direction, significant wave height (SWH) and swell significant wave height (SSWH). The time frame of the data set began on 20 December 2013 and ended on 6 January 2014, encompassing both the anomalous events. The data sets and sources used are shown in Table 1.

The results are presented in colour maps showing various combinations of atmospheric and oceanic indicators at daily resolution for specific regions. A large number of maps were generated and analysed using the software MeteoInfo to examine the interconnection between wind speed/stress, ocean current and wave heights. A few key maps are presented in this paper to support the explanation proposed for the two anomalous events. The paper will also examine the two sites and their environment in greater detail to capture the contextual characteristics from other studies.

4. Findings

The time frame of the study falls within the Northeast Monsoon (NEM) season, where the dominant winds flow from the northeast direction across the region, including the SCS. The winds swing towards the southeast as they cross the equator due to the Coriolis Effect. This pattern is observed in Fig 4, which shows the sea level pressure (SLP) in Pascals (Pa) and wind speed pattern (WSP) in metres per second (m/s) on 20 December 2013.

On this day, a low-pressure area had developed in the northern tip of Sumatra, giving rise to a vortex, which reached speeds of 45 m/s and persisted until the following day, when a new broad vortex appears to be forming over the Brunei-Miri area. The vortex became fully developed off the Brunei-Sarawak coast the following day (22 December) and persisted for 3 days (until 24 December). Fig 5-a shows the SLP and WPS pattern on the 23 December. Note the low-pressure vortex located in the SCS between West Malaysia and Borneo (off Kuching). The high wind speeds (> 40 m/s) are expected to generate strong swell waves, which would arrive at the Borneo coast from the northwest. In the SS, winds were westerly and much weaker (maximum speed - “strong breeze”, according to the Beaufort Wind Scale). Surface oceanic currents are therefore not expected to be strong.

Fig 5-b shows the swell wave height (SWH) in metres in the SCS and adjacent Sulu Sea on 23 December. It can be seen that the high-speed (>40 m/s) winds blowing across northern SCS generated very large swells in excess of 4 m high. SWH were still quite high (up to 2 m) in many areas when the waves arrived at the Borneo coast. Of particular interest are the 1-2 m waves entering the Sulu Sea via the Mindoro Strait in between Palawan and the Mindoro-West Visayas region. Although wind-generated waves could only affect shallow waters less than half their wavelengths (<3 m) and therefore not capable of generating currents that could travel to the Tambisan area, they inject a significant amount energy into the SS system (which is generally quite low energy) a day or so before the unusual fish event.

Fig 5-c shows the surface ocean current compiled from one week (19-25 December, 2013). Its shows gentle surface current (speeds 0.3-0.6 m/s) flowing in a counter clockwise direction along the northern margin to the Tambisan area in the southwest. This is expected from the relatively weak winds blowing across the region from the east-northeast. In contrast, strong winds from storms generate a number of small vortices and a large one in the SCS region. The current pattern in the SS does indicate movement towards the Tambisan area, which could lead Tamban shoals to the area. However, its low magnitude suggests that this pattern is more likely to be the usual condition and therefore unlikely to lead to unusual occurrence, such as the one observed on 24 December. More information is needed to understand flow pattern in the area, which is very complex and dynamic (Frische and Quadfasel, 1990; Gordon, n.d.). A non-geophysical trigger for the event is also a possibility, such as large number of predators.

Table 1: Data and data Sources Used

Data	Source
Daily wind speed and wind stress data for the SCS	NOAA Geophysical Fluid Dynamics Lab, via its Curator Data Portal / GFDL CM2.1 SRESA1FI-1 Run 1 fossil fuel intensive experiment / atmos / daily / Jan 2001-Dec 2100 (Website 10)
Ocean surface velocity and surface zonal currents (maximum mask)	PODAAC OSCAR (Ocean Surface Currents Analyses Real-time) (Website 11)
Daily ocean currents data (2012; 2013; 2014)	OSCAR (Website 12)
Ocean surface meridional maximum mask (m/s	PODAAC OSCAR, OPeNDAP (Website 13)
Significant Wave height and Swell Wave	NOAA National Center for Environmental Prediction (NCEP), using Wave Watch 3 (WW3) Model
Weekly ocean currents	Oceanwatch (Website 14)

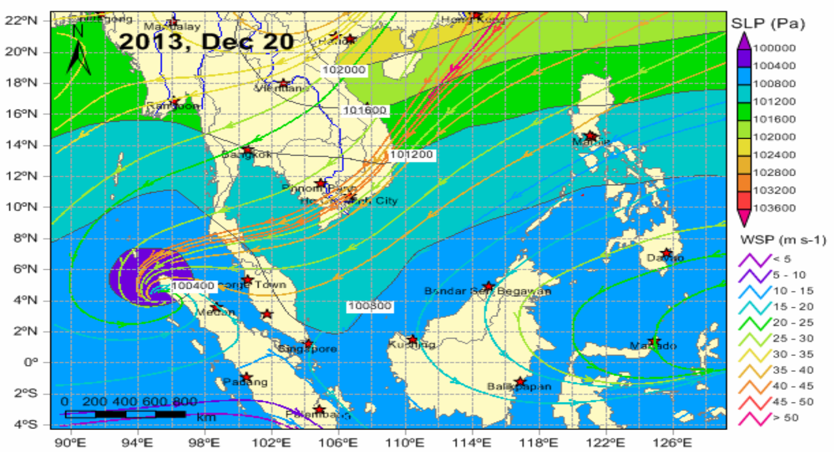

Fig 4: SLP and WPS, 20 December 2013

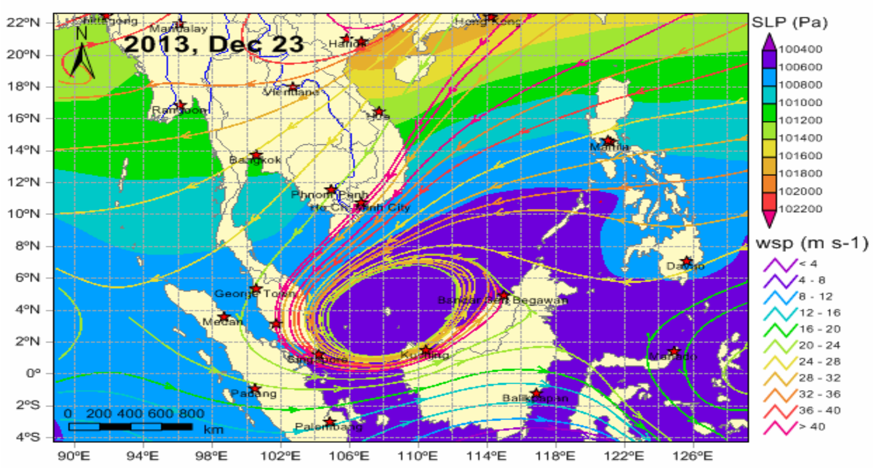

Fig 5-a: SLP and WPS, 23 December 2013

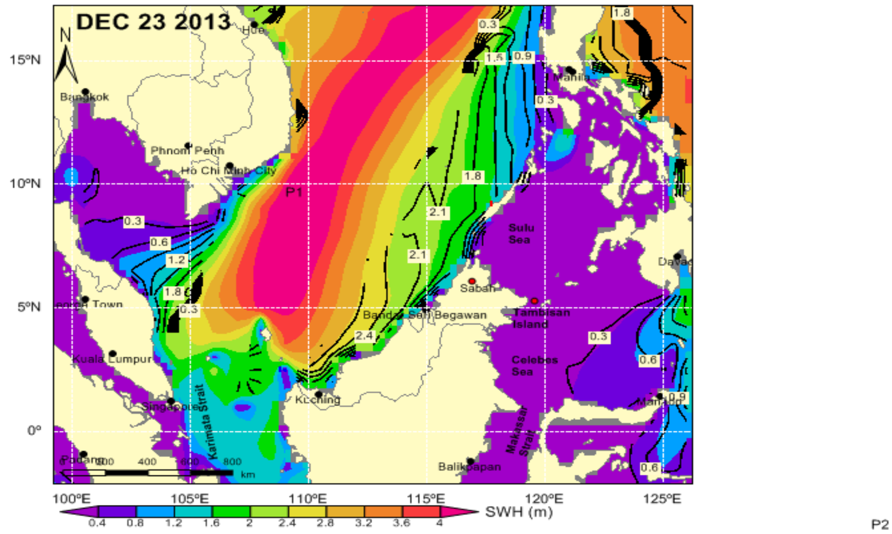

Fig 5-b: SWH, 23 December 2013

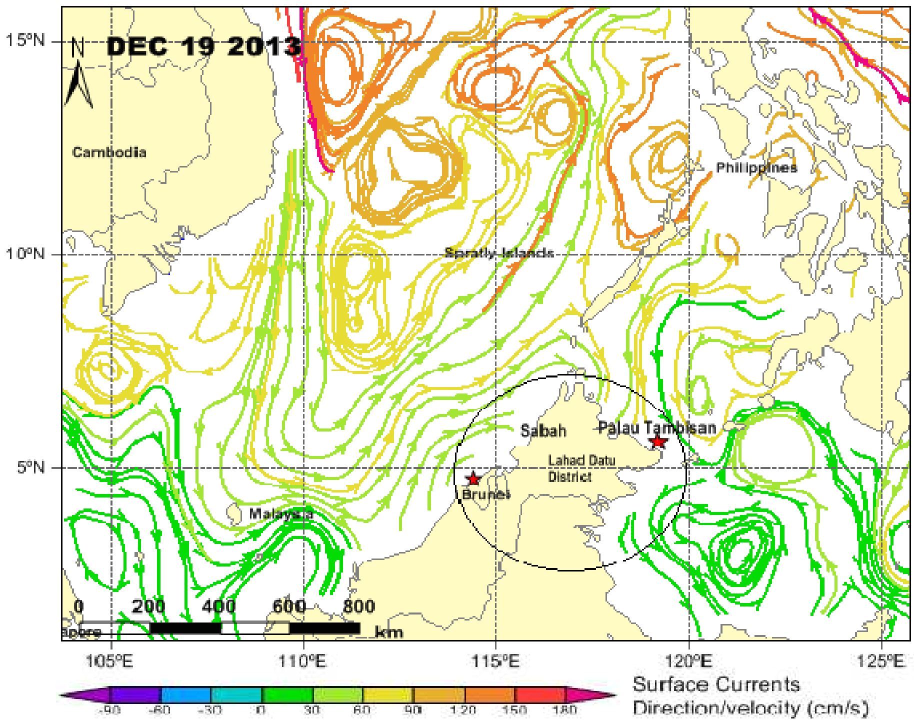

Fig 5-c: Surface Current, 19-25 December 2013

The wind data shows that atmospheric conditions returned to a more typical NEM pattern from 25 to 27 December. On 28 December, a vortex began to form off Kuching, developing into a large vortex between Kuching and Pahang, West Malaysia. Fig 6-a shows the wind pattern on 1 January, when the vortex is weakening. The wind system reverts to a typical NEM pattern with low wind speeds in the Lumut region the following day leading into the clam event. The vortex on 1 January 2014 however reached velocities beyond Gale speeds, generating high waves that arrived almost parallel to the Brunei coast. But wave direction in the following day was highly oblique (from the west). This could generate strong longshore movement in a direction (towards the east) that is counter to the seasonal trend (towards the west). This would support the hypothesis of beach sand accumulation by opposing (converging) longshore drift. The strong waves arriving at the coast could have dislodged sediments and organisms from the shallow coastal seabed and deposited them onshore. Furthermore, large storm waves often erode the beach, transporting sediments and organism offshore. However, moderate energy waves with heights in the 1-2 m range, as observed on 2 January, are likely to be more constructive than destructive. Fig 6-b shows significant wave heights on 2 January 2014.

5. Discussion

The data used in the study are largely simulated data, based on equations/ models developed on the inter-relation between atmospheric and oceanic forcing and responses, and dynamic ocean surface topography data. It does not capture factors that are still not known or not amenable to observation or measurement. The ocean circulation patterns in SCS, and particularly in the SS, are complex and heterogeneous vertically and-

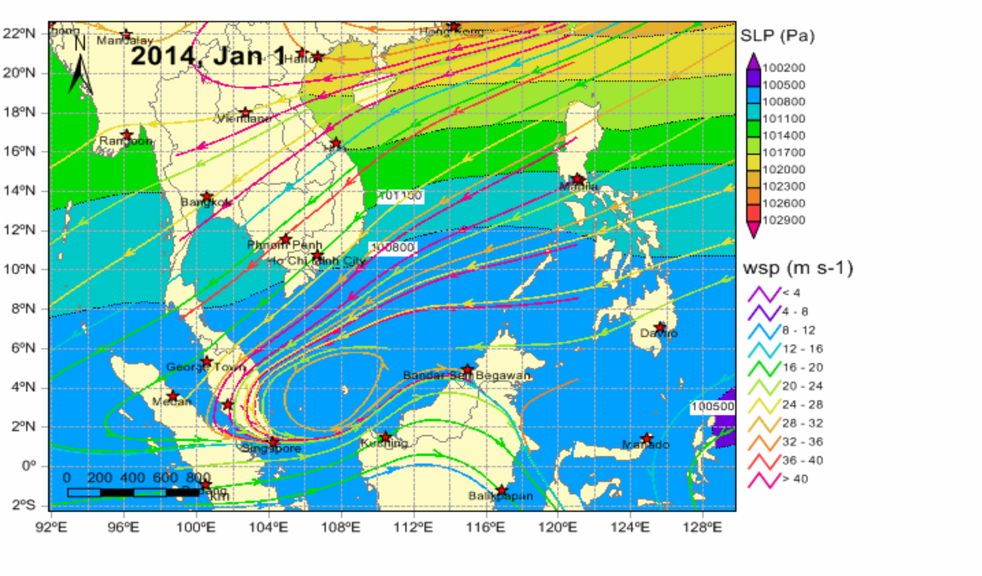

Fig 6-a: SLP and WPS, 1 January 2014

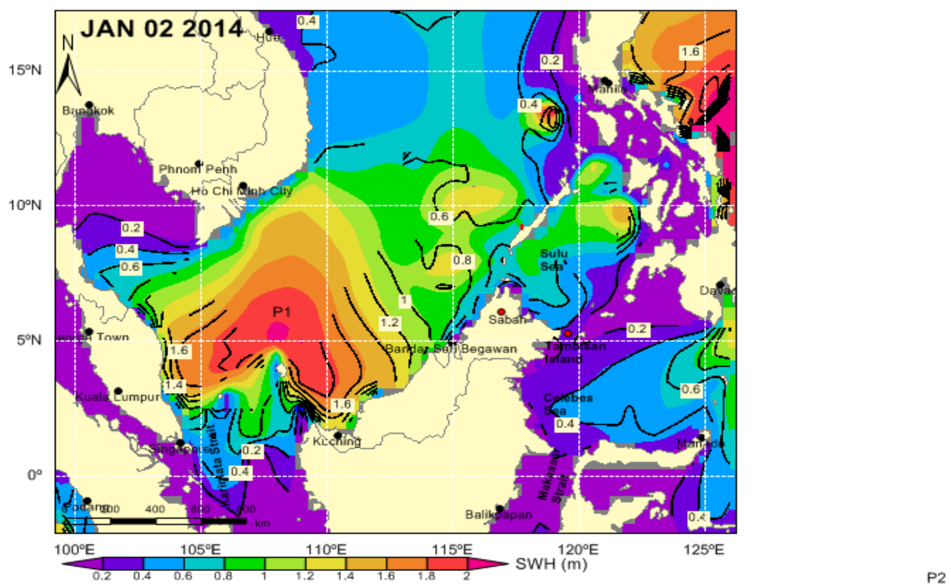

Fig 6-b: SWH, 2 January 2014

horizontally, due to complex basin topography and resultant complex flow paths, which also change seasonally and with El Nino Southern Oscillation (ENSO) (Gordon, n.d.). Marine and coastal organisms are affected by deep oceanic circulation, but there is still much to learn about these interconnections and therefore they are not included in the present study.

An interesting fact regarding the Sulu Sea is that large internal waves (oceanic solitons) have been observed and studied since the 1970's (Global Ocean Associates, 2002). These solitary waves have been observed with amplitude up to 90 m, wavelengths of 5-16 km, speeds in excess of 2.0 m/s and lasting for over 2.5 days. They appear to originate in the shallow gaps in the southern margin of the Sulu Sea, such as the Sibuti Passage, between Pearl Bank and Doc Can Island, and between Pearl Bank and the Talatam Shoal, and they propagates north towards the northern margin of the sea and surrounding coastline. Tambisan, which is located just west of their points of origin, would experienced strong currents along its coast, particularly, if it coincided with the oceanic current and wave-generated near shore currents observed on 23-24 December. There is therefore a need to investigate further to confirm if a soliton had occurred during the time of the Tambisan fish incident.

A recent study by Scripps Oceanography (2015) found "giant" solitons in the SCS, which can reach 500 m in amplitude. They appear to originate in the Luzon Strait area and capable of producing 10,000 times the amount of turbulence typically found in the ocean. Although surface wind and wave data appears to explain the Lumut clam event quite adequately, their exceptionally high concentration on 3 January, 2014 might also be due in part to a soliton in the SCS, which would easily move large amounts of sediments, nutrients and organisms shoreward; in contrast, large storm waves tend to erode than deposit.

6. Conclusion

Access to ocean and atmosphere data has allowed for studies of the unusual fish and clam events in Tambisan and Lumut that is based on scientific analysis. Although the study is not conclusive, particularly with the Tambisan event, the study has reduced uncertainties and speculations, allowing for further investigation to fully understand the two incidents. The study shows that the Tambisan fish event could be explained by coupled ocean current circulation patterns. However, there is a need to learn more about the effects of deep ocean currents, which flow through the area and which influences fish migration paths, as well as occurrence of internal ocean waves, which do occur in the Sulu Sea. A soliton could certainly nudge shoals of small fish in the area into the narrow channel at Tambisan. As for the clam incident, analysis of atmospheric-oceanic interaction strongly suggests that a wind vortex, which developed less than a week before the clam event could lead to its occurrence. The vortex generated moderately strong waves, which moved sediments and clams shoreward and caused them to accumulate along Lumut due to converging longshore/littoral drift. The main problem encountered in the study is the difficulty in presenting the findings in traditional publication, due to: (i) the large number of maps generated, which revealed interesting changing daily patterns, but most of which cannot be included for practical reasons; (ii) complicated colour-coded patterns representing various combinations of variables, which are not easy to read in print; and (iii) the relatively low resolution of images generated by the software, which is not of the quality required for publication.

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