



Did the countrywide lockdown act like a catalyst in turning a cyclone to a super-cyclone AMPHAN?

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Abstract Amid the COVID-19 pandemic and countrywide lockdown, the super-cyclone Amphan collided with the eastern coast of India, majorly affecting the Indian state of West Bengal. The lockdown restricted the industrial emissions of greenhouse gases known for increasing the average global temperature, however the sea-surface temperature (SST) profile over the Bay of Bengal indicated higher than average SST values in preceding 5 years. The unexpected increase in sea-surface temperature might have played a major role in formation cyclonic disturbances over the Bay of Bengal, which might have triggered the formation of super cyclone Amphan. The anomalous increase in average SST could be attributed to the sudden lowering of particulate matter concentration due to the lockdown, which resulted in the increase in levels of solar insolation on the sea-surface due to the absence of particulate matter load, which reflects/absorbs the incoming solar radiation to the surface keeping the sea-surface temperature at lower levels.

Keywords Cyclone Amphan · Pandemic · Lockdown · Criteria Pollutants · Super-cyclone

1 Introduction

The origin of tropical cyclones is one of the unexplained phenomena in dynamical metrology and climate [1, 2].

Tropical cyclone primarily originates over the tropical ocean area and is driven by the heat transfer from the ocean [2]. The formation of tropical cyclone is due to the disturbance occurring near the centre of a precursor disturbance in which the inner stability is high and flow is in near solid body rotation.

A typical tropical cyclone could be characterized by having a low-pressure centre with low level of atmospheric circulation, accompanied by rapidly rotating strong wind and spirally arranged thunderstorm that produce heavy rain or squalls. The study of the intensity of the cyclones are of paramount importance as it decides the area and number of people getting affected upon its impact on the coast. Many concerns are raised on the probable impact of global warming on the intensity of cyclones [3]. The cyclones form over the oceans when the sea-surface temperature exceeds the threshold temperature of 25.5 °C below which the cyclone does not form [4]. With an upsurge of about 1 °C in tropical ocean surface temperature, the wind speed of the cyclone theoretically increases by ~5% [5]. Satheesh and Ramanathan [6] estimated that the presence of aerosols over the Indian Ocean surge the top of atmosphere has reflected radiation by ~10 W m⁻², which result in the decrease of surface's reaching radiation by ~29 W m⁻². The decrease in the aerosol concentration due to the effect of pandemic have resulted in more solar radiation reaching the surface of ocean which in turn triggered the ocean surface temperature to increase significantly. Sea surface temperature (SST), vertical wind shear and humidity are the driving factors that trigger and enhance the formation of tropical cyclones [7]. The weaker wind movement over the BoB results in a sluggish oceanic circulation that keep the SST relatively higher which aids in the formation of cyclone easily [8]. In addition, higher precipitation and constant inflow of fresh water from the Indian rivers of the Ganges and the Brahmaputra results in strong

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near surface stratification which results in the rapid increase of salinity with depth as compared to the surface [9]. These conditions make the conditions ideal for the formation of depression over the sea surface. It is well known that the energy of tropical cyclone comes from the constant supply of moisture, which comes from the warm water below. Climate change and global warming are responsible for increasing the surface temperature of the water and these results in greater evaporation providing greater moisture supply to the cyclones that are formed over water.

SuCS Amphan was one of the most powerful and deadly tropical cyclones that had hit the eastern part of India causing havoc especially in the West Bengal and parts of Bangladesh on 20th May 2020. It was estimated that the SuCS Amphan caused huge damages to the public and private properties. Amphan originated as a depression (D) over the southeastern Bay of Bengal (BoB) on the early morning of 16th May 2020 and later transformed into cyclonic storm (CS) by the evening. While moving north-northwestwards, it intensified as severe cyclonic storm (SCS) over southeast BoB on 17th May 2020. The maximum speed of Amphan was recorded to be 260 kmph (SuCS) but the intensity gradually decreased to very severe cyclonic storm (VSCS) during the onset on the land mass of West Bengal. The Amphan had hit the coast of West Bengal at the speed of 155–165 kmph, which gusted, to 185 kmph.

2 Methodology

2.1 Study area

The tropical cyclones are generally formed over ocean surface where the sea-surface temperature increases above 25.5 °C over tropical regions of the world. The Bay of Bengal is located on the eastern side of the Indian subcontinent where regular occurrences of tropical cyclone formations are witnessed every year. The formation and degree of its magnitude depends on the variations of the sea-surface temperature, generally during the pre-monsoon and post-monsoon periods (April–October months). Being situated on the northern hemisphere, the tropical cyclones after their formation, and moves towards their west. The tropical cyclones originating over the Bay of Bengal region hits the eastern coast of India causing devastations and loss of lives and properties each year. The degree of devastation depends on the wind speed of the cyclone. For this study, we have taken an area of over 300,000 km² (16.5° N–21.5° N and 87.5° E–92.5° E) to monitor the SST variations accountable for the origin of cyclone.

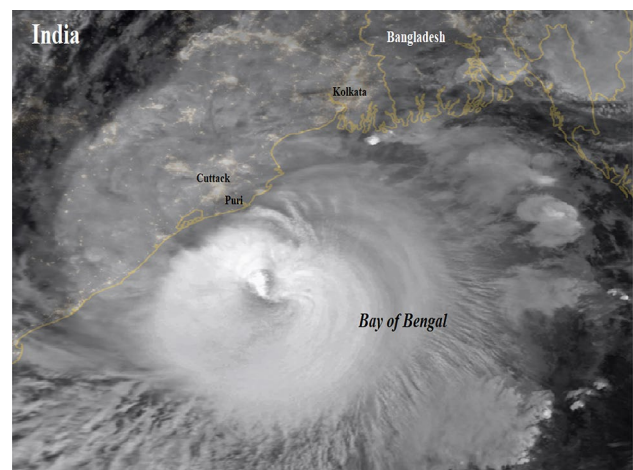


Fig. 1 Tropical cyclone Amphan image taken from Terra-MODIS [10]

Table 1 Classification of tropical cyclones based on their associated wind speed

S. no.	Type of disturbances	Associated wind speed (kmph)
1	Low pressure area (LPA)	< 31 kmph
2	Depression (D)	31–49 kmph
3	Deep depression (DD)	50–61 kmph
4	Cyclonic storm (CS)	62–88 kmph
5	Severe cyclonic storm (SCS)	89–118 kmph
6	Very severe cyclonic storm (VSCS)	119–221 kmph
7	Super cyclonic storm (SuCS)	> 222 kmph

2.2 Tropical cyclone classification

The tropical cyclones are primarily classified based on their speed and the relative damage caused upon collision with the landmass. Figure 1 shows the image of tropical cyclone Amphan taken from space.

The eye of the cyclone is characterized by intense low-pressure areas with warm temperature with the pressure gradually increasing on the outer side. The amount of pressure drop at the eye is directly proportional to the strength of the cyclone. The Indian Meteorological Department (IMD) classifies cyclones into 7 categories based on their associated wind speed (see Table 1).

The variations in monthly average values of sea-surface temperature over the Bay of Bengal encompassing an area over 300,000 km² was recorded for the present study. The average monthly variations in SST during May 2020 were compared to past 5 years' SST values for the month of May (2016–2019). The data of SST over the defined coordinates were taken from the NASA Earth Observatory (NEO).

Additionally, the concentration levels of particulate matter (PM_{2.5} and PM₁₀) were also recorded over the defined study area, which were taken from the <https://earth.nullschool.net>. A similar study by Zhao et al. [11] stated that the cyclone “Fani” could have intensified to a super-cyclonic category only if such large-scale lockdown were imposed during that period. The cyclone ‘Fani’ occurred during April–May 2019 (249.45 kmph; 932 hPa) over the same region of Bay of Bengal.

3 Result and discussion

This study illustrates the monthly averaged sea-surface temperature conditions over the Bay of Bengal (16.5° N–21.5° N and 87.5° E–92.5° E) for the year 2020 with past 5 years data over same latitudes and longitudes for a detailed comparison between the cyclonic disturbance and associated formations. Table 2 lists different cyclones that originated in the past 5 years during the months of April–May. The sea-surface temperature profile of BoB during the years 2016–2020 for the month of May is given in Table 3. It is clear from the table below that the sea-surface temperature during May 2020 as compared to the preceding years of 2016–2019. The data provided in the table shows that the temperature profile of sea-surface during May 2020 is similar to that of May 2016. During the year 2016, the CS Roanu (~85 kmph) had hit the coasts of Sri Lanka and Bangladesh. The mean recorded SST during May 2016 was 30.2 °C (highest 31.65 °C; lowest 29.32 °C) while the mean recorded SST for May 2020 was 30.3 °C (highest 31.5 °C; lowest 28.74 °C). Despite such similarities in the sea-surface temperature, the CS Roanu’s impact was limited and not much severe as compared to the CuCS Amphan. The mean sea-surface temperature for the years 2017, 2018 and 2019 remained below 30 °C during the months of May and hence no significant cyclones of higher intensity were recorded.

From Fig. 2, it is quite evident that the sea-surface temperature indeed increased during the month of May, 2020 which might have resulted into the transformation of the SuCS from a normal depression being formed on the ocean

surface. The figure also shows the concentration of sea-surface temperatures during the months of May for the years 2016–2019 which clearly are of lesser values as compared to the higher values of SST during May 2020.

A similar cyclone “Fani” (April–May 2019; 249.45 kmph; 932 hPa) that formed in the same region over the BoB could have intensified easily to super-cyclone (SuCS) if only such a large scale lockdown were imposed in the year 2019 [11].

3.1 Relationship between SuCS Amphan and lockdown

Apart from the natural factors as mentioned above, the countrywide lockdown in India might have had an indirect impact on the formation of SuCS Amphan by increasing the average sea surface temperature as seen from Table 3. The lockdown had rendered the atmosphere over the Indian sub-continent and the neighbouring ocean relatively clean [15]. The depressions over the BoB are natural phenomenon but the countrywide lockdown might have driven the transformation of Amphan into a super cyclone by changing the radiative budget of earth surface. Due to the closure of the industries, factories and transportation, the inflow of particulate matter concentration load over the BoB reduced drastically [16–19]. Particulate matters such as black carbons (BC) are those aerosols which have the ability of absorbing heat from Sunlight there by reducing the heating of the sea surface water [20]. Decreased amounts of particulate matters can be seen in Figs. 3a and c, which might have triggered the increase of the average sea surface temperature due to the direct absorption of heat from the sunlight.

Figure 3 depicts the preconditions of particulate matters (PM_{2.5} and PM₁₀) along with sea-surface temperature and SST anomaly over the Bay of Bengal on the day of origin of a depression (D) and simultaneously transforming into a cyclonic storm (CS) which later escalated into a super cyclonic storm (SuCS) Amphan.

It is a well-known fact that the particulate matter which gets dissolved in water is known to have an impact on formation of clouds [22]. Under normal conditions a lot of particulate matter gets transported from Indo-Gangetic plain to the Bay of Bengal [23]. During regular conditions greater

Table 2 Pre-monsoon tropical cyclones originating in the Bay of Bengal during the months of April–May in past years (2016–2019)

Year of origin	Cyclone name	Date of formation–date of dissipation	Highest wind speed reported	Areas affected	References
2016	Roanu	19 May 2016–23 May 2016	86.4 kmph	Sri Lanka, Eastern coast of India, Bangladesh	[12]
2017	Mora	28 May 2017–31 May 2017	114 kmph	Bangladesh, North-eastern India, Myanmar	[13]
2018	–	–	–	–	–
2019	Fani	26 April 2019–5 May 2019	175 kmph	Odisha, West Bengal, Andhra Pradesh, Bangladesh	[14]

Table 3 Mean sea-surface temperature profile of Bay of Bengal for the month of May 2016–2020 (Source: NASA Earth Observations). (Color figure online)

S. no.	Latitude	Longitude	2016 (°C)	2017 (°C)	2018 (°C)	2019 (°C)	2020 (°C)
1	21.5° N	87.5° E	30.05	29.61	28.44	29.03	29.61
2	21.5° N	88.5° E	29.76	29.9	28.74	28.88	29.61
3	21.5° N	89.5° E	29.76	29.46	28.44	28.88	29.61
4	21.5° N	90.5° E	30.19	30.19	29.17	29.17	30.92
5	21.5° N	91.5° E	30.19	30.05	28.74	30.48	30.78
7	20.5° N	87.5° E	29.9	29.17	27.57	28.3	29.03
8	20.5° N	88.5° E	29.46	29.46	28.3	28.88	29.03
9	20.5° N	89.5° E	29.76	29.76	28.3	29.03	29.76
10	20.5° N	90.5° E	30.34	29.76	28.88	29.32	30.19
11	20.5° N	91.5° E	30.63	29.32	29.46	29.76	29.61
12	20.5° N	92.5° E	30.34	29.76	29.76	29.9	29.9
13	19.5° N	87.5° E	30.05	29.03	28.15	28.59	28.74
14	19.5° N	88.5° E	30.05	29.46	28.59	28.59	29.76
15	19.5° N	89.5° E	30.05	29.46	29.03	29.03	31.5
16	19.5° N	90.5° E	29.9	29.61	29.17	29.32	30.05
17	19.5° N	91.5° E	30.19	29.61	30.05	29.46	30.48
18	19.5° N	92.5° E	30.19	29.61	29.46	29.61	31.36
19	18.5° N	87.5° E	29.32	29.61	29.03	28.59	29.61
20	18.5° N	88.5° E	29.9	29.9	28.44	29.03	30.19
21	18.5° N	89.5° E	30.48	29.9	28.88	29.17	30.05
22	18.5° N	90.5° E	30.48	29.9	30.05	29.32	30.05
23	18.5° N	91.5° E	30.05	30.19	29.61	29.32	30.63
24	18.5° N	92.5° E	30.48	29.9	29.32	29.46	30.92
25	17.5° N	87.5° E	29.9	29.76	29.61	28.88	30.05
26	17.5° N	88.5° E	30.34	30.05	28.74	28.88	29.61
27	17.5° N	89.5° E	30.48	30.48	30.63	29.03	30.48
28	17.5° N	90.5° E	30.05	30.48	30.48	29.46	30.92
29	17.5° N	91.5° E	30.34	29.76	29.9	29.32	30.78
30	17.5° N	92.5° E	30.63	29.76	30.48	29.61	31.5
31	16.5° N	87.5° E	30.34	30.19	29.17	28.74	30.34
32	16.5° N	88.5° E	30.63	30.19	29.32	29.17	30.19
33	16.5° N	89.5° E	31.65	30.48	30.63	29.61	30.78
34	16.5° N	90.5° E	30.05	30.34	30.78	29.46	31.36
35	16.5° N	91.5° E	30.34	30.63	30.19	29.46	31.5
36	16.5° N	92.5° E	30.34	29.9	30.78	29.61	31.21

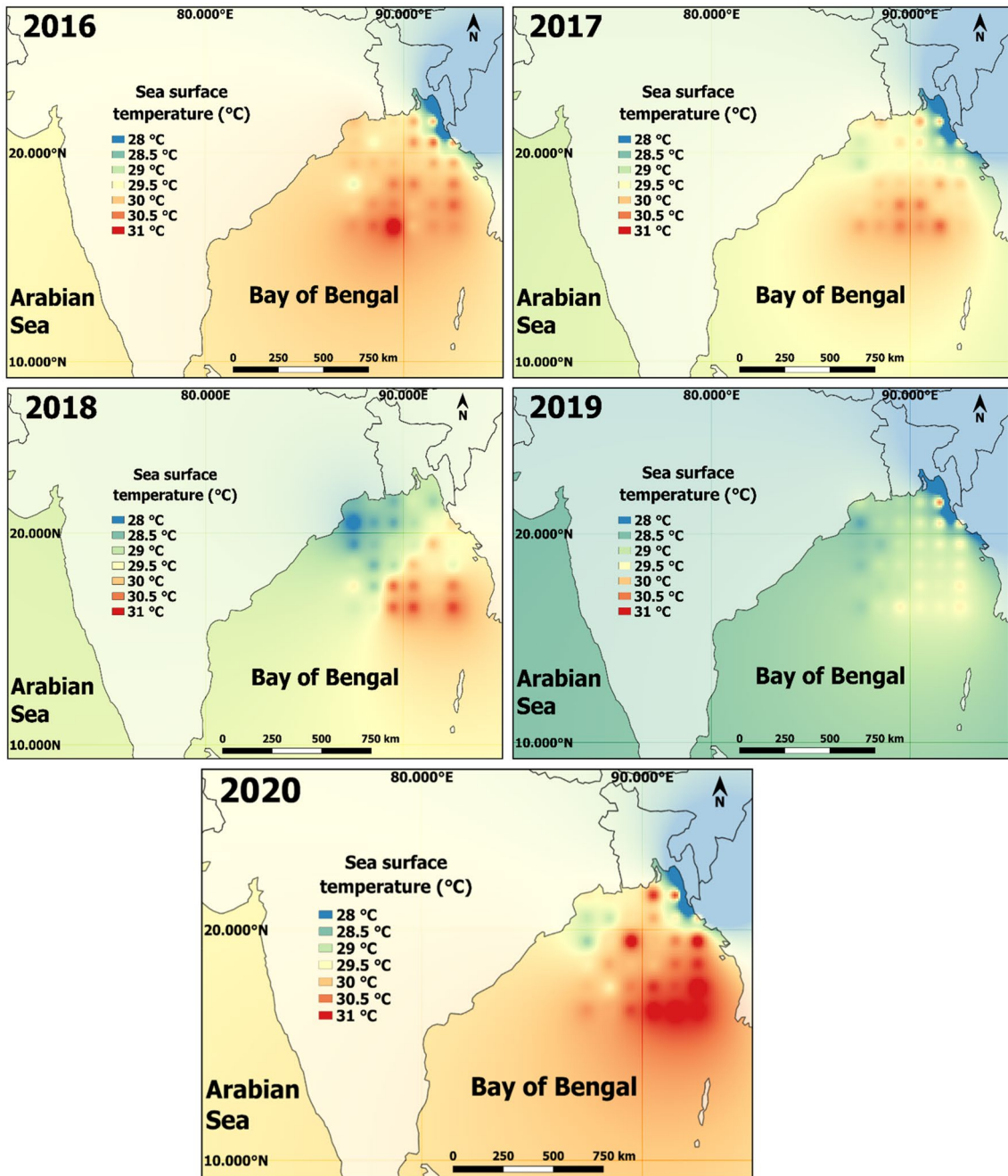


Fig. 2 Variation in sea-surface temperature for the months of May during past 5 years

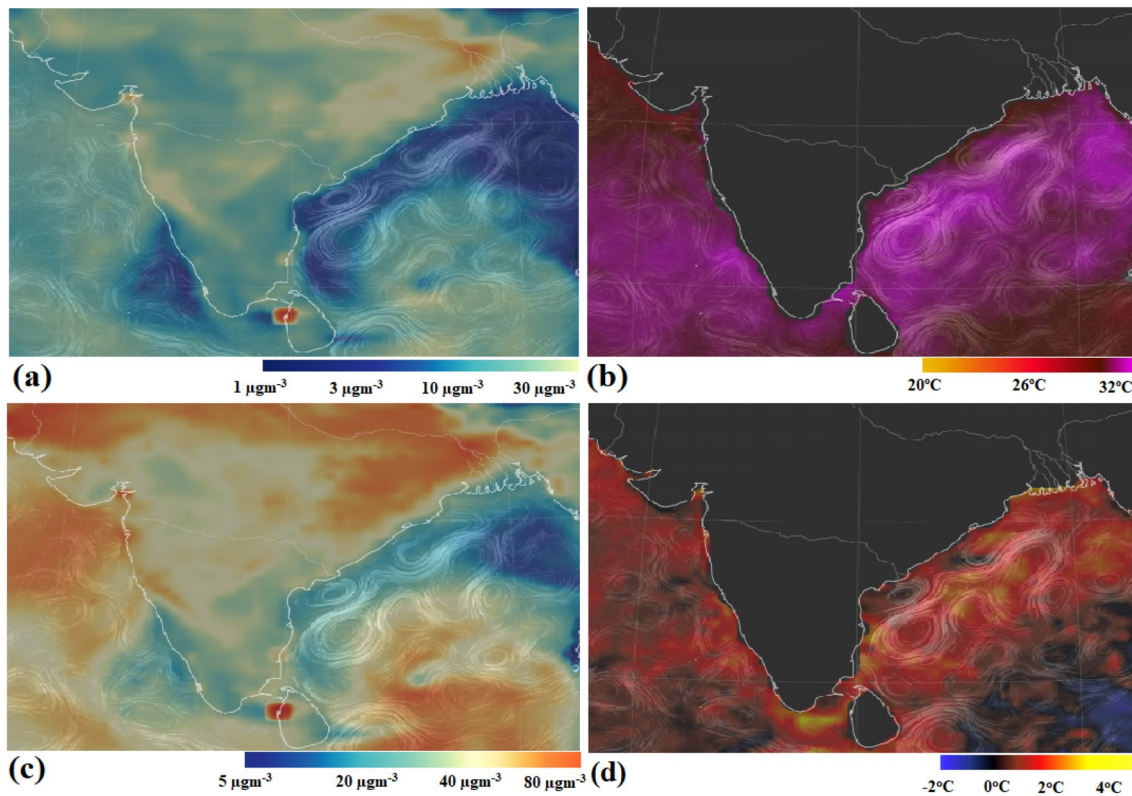


Fig. 3 Particulate matters and sea surface temperature during the super-cyclone: **a** PM_{2.5}; **b** SST; **c** PM₁₀; **d** SST Anomaly on the day SuCS formation took place over the Bay of Bengal on 16th May 2020

with prior permission [21]; **a** and **c** "Generated using Copernicus Atmosphere Monitoring Service Information (2020)"; **b** and **d** "UK Met Office, 2005. OSTIA L4 SST Analysis. Ver. 1.0"

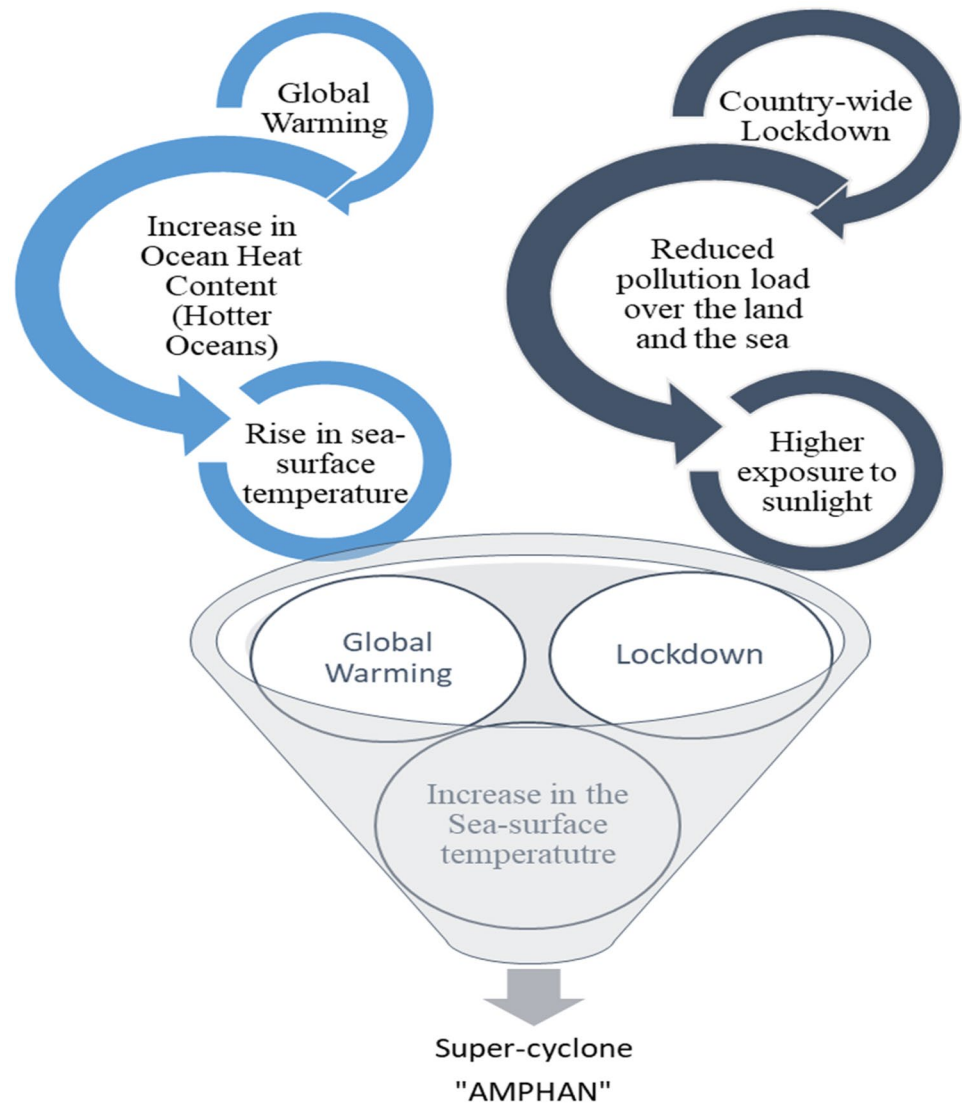
availability of particulate matter introduces more aerosols into the atmosphere which helps the formation of clouds but as a result of lockdown PM emissions have gone down hence fewer aerosols were available for cloud formation. Clouds having very high albedo (ability to reflect sunlight) which helps in keeping the water a little cooler which would restrict the constant supply of moisture to the cyclone.

Therefore, the atmosphere over the BoB was rendered relatively clean due to the substantial decline in the anthropogenic activities and consequent lowering of aerosol loading by $\sim 30\%$ while an increment of sea-surface temperature by $\sim 1\text{--}2^{\circ}\text{C}$ as compared to the preceding year [24]. The declining in the concentrations of both aerosols and the clouds combined effectively increased the sea-surface temperature, which compounded the warming of oceans due to the global warming. The conditions like pre-existing high summer SST, climate change enhanced Ocean Heat Content (OHC) and lockdown induced decline in aerosols & clouds perfectly blended for the potential subsequent intensification of the cyclonic activity [24]. Figure 4 shows the flow-chart depicting the probable formation of SuCS Amphan which might have resulted due to the impact of countrywide lockdown in India.

4 Conclusion

Ideally, due to the CoVID-19 related, restrictions in anthropogenic activities decreases the average sea-surface temperature. However, it was noted that the average sea surface temperature increased in May 2020 that was much higher than the last 5-year's average sea surface temperature. This could be one of the reasons of formation of super cyclonic storm-Amphan. Sudden loss of particulate matters in the inflow air would have affects the normal functioning of the earth's hydrological cycles by restricting the formation of clouds. In addition, less particulate matters in the atmosphere might have had enhanced the surface temperature of the ocean. These factors might have played a vital role in accelerating the formation of low air pressure that eventually transformed into a super cyclone. Last 5 year's data on average sea surface temperature indicated that during 2020 monsoon session had the highest temperature. This could be one of the major reasons for genesis of super cyclone. This article also pointed that CoVID-19 related lockdown and related environmental changes would have boosted the cyclogenesis of a super-cyclone Amphan.

Fig. 4 Flow chart depicting the probable formation of SuCS Amphan



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Declarations

Conflict of interest The authors declare that they have no competing interests. The concepts deliberated in this paper are the personal views of the authors, their respective organizations are no way related to any of the points discussed.

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