# Did the Countrywide Lockdown act like a catalyst in turning a cyclone into a Super-cyclone AMPHAN?

Amit Kumar Chowdhury[1], Arnab Mondal[1], Suvendu Manna[1], Paulami Ghosh[1], and Surajit Mondal[1]

[1]Affiliation not available

August 16, 2021

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

**Amit K. Chowdhury[1], Arnab Mondal[2], Suvendu Manna[3], Paulami Ghosh[4], Surajit Mondal[5]**

[1] *Power System Operation Corporation Ltd.*

[2] *CSIR-National Physical Laboratory, Dr. KS Krishnan Marg, New Delhi, India*

[3] *Dept. of Heath Safety and Environment, School of Engineering, UPES, Dehradun*

[4] *Dept. of Microbiology, School of Heath Science, UPES, Dehradun*

[5] *Dept. of Electrical and Electronics Engineering, School of Engineering, UPES, Dehradun*

**Abstract** :

Amid the CoVID-19 pandemic and country-wide lockdown, the super-cyclone Amphan collided with the eastern coast of India, hitting mainly the Indian state of West Bengal. This article tried to find an answer to such a devastating super cyclone during the pandemic-related lockdown. Although lockdown restricts almost all types of industrial emission known for increasing the average surface temperature, the temperature profile indicated no indication of temperature fall during the entire lockdown. Moreover, the temperature profile indicated that during the lockdown period the average sea surface temperature was much higher than the last five years. This suggested that this unexpected increase in sea-surface temperature might play a major role in the formation of super cyclone Amphan. This temperature increase could be attributed to the sudden lowering of criteria pollutants like aerosol concentration due to lockdown. This might have an indirect impact on the formation of a super-cyclone as it increased the radiative budget of the earth. The increment in the radiative budget might have increased sea surface temperature that caused the transformation of a cyclonic depression into a super-cyclonic storm Amphan.

**Keywords:** CoVID-19; Lockdown; Pandemic; SuCS Amphan; Tropical Cyclone

**Introduction:**

The origin of tropical cyclones is one of the unexplained phenomena in dynamical metrology and climate (Dunkerton et al., 2009; K. Emanuel, 2003). Tropical cyclone primarily originates over the tropical ocean area and is driven by the heat transfer from the ocean (K. Emanuel, 2003). The formation of a tropical cyclone is due to the disturbance occurring near the center 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 center with a low level of atmospheric circulation, accompanied by rapidly rotating strong wind and spirally arranged thunderstorms that produce heavy rain or squalls. The study of the intensity of the cyclones is of paramount importance as it decides the area and number of people getting affected by its impact on the coast. Many concerns are raised on the probable impact of global warming on the intensity of cyclones (K. Emanuel, 2005). 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 (Tory & Dare, 2015). With an upsurge of about 1°C in tropical ocean surface temperature, the wind speed of the cyclone theoretically increases by ˜5% (K. A. Emanuel, 1987). Satheesh & Ramanathan (2000) estimated that the presence of aerosols over the Indian ocean surge the top of the atmosphere's reflected radiation by ˜10 $Wm^{-2}$ which results in the decrease of surface's reaching radiation by ˜29 $Wm^{-2}$. The decrease in the aerosol concentration due to the effect of the pandemic has resulted in more solar radiation reaching the surface of the ocean which in turn triggered the ocean surface temperature to increase significantly. Figure 1 shows the image of the tropical cyclone Amphan taken from space.

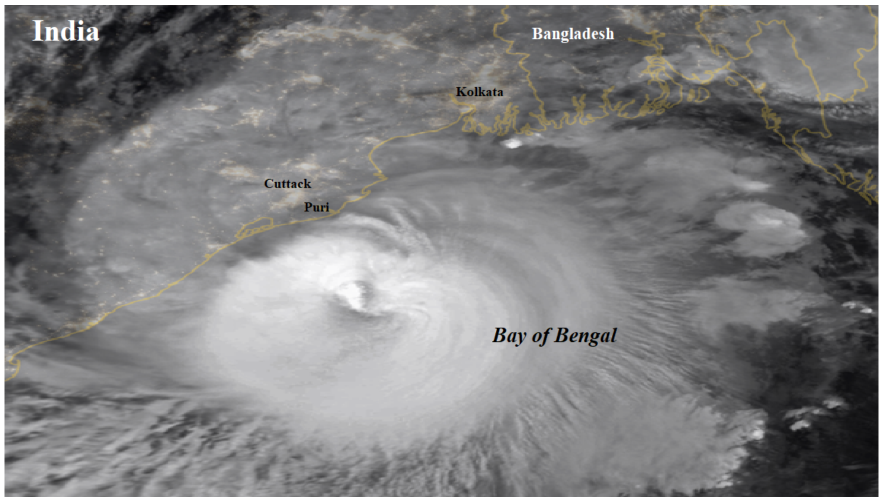


Figure 1: Tropical cyclone Amphan image taken from Terra-MODIS (Source: NASA Earth Observatory; https://earthobservatory.nasa.gov)

**Cyclone Categories** :

The tropical cyclones are primarily classified based on their speed and the relative damage caused upon collision with the landmass. The eye of the cyclone is characterized by intense low-pressure areas with warm temperatures 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** ).

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 |

**Super-cyclone Amphan** :

SuCS Amphan was one of the most powerful and deadly tropical cyclones that had hit the eastern part of

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

India causing havoc especially in West Bengal and parts of Bangladesh on 20$^{th}$ 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 south-eastern Bay of Bengal (BoB) on the early morning of 16$^{th}$ May 2020 and later transformed into a cyclonic storm (CS) by the evening. While moving north-northwestwards, it intensified as a severe cyclonic storm (SCS) over southeast BoB on 17$^{th}$ 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 landmass of West Bengal. The Amphan had hit the coast of West Bengal at the speed of 155-165 kmph which gusted to 185 kmph.

**Discussion:**

Sea surface temperature (SST), vertical wind shear and humidity are the driving factors that trigger and enhance the formation of tropical cyclones (Tao & Zhang, 2014). The weaker wind movement over the BoB results in a sluggish oceanic circulation that keeps the SST relatively higher which aids in the formation of cyclones easily (Shenoi, 2002). In addition, higher precipitation and constant inflow of fresh water from the Indian rivers of the Ganges and the Brahmaputra results in strong near-surface stratification which results in the rapid increase of salinity with depth as compared to the surface (Shetye et al., 1996). These conditions make the conditions ideal for the formation of a depression over the sea surface.

It is well-known that the energy of tropical cyclones 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 this results in greater evaporation providing greater moisture supply to the cyclones that are formed over water.

The sea-surface temperature of certain coordinates 16.5 $^{o}$N - 21.5 $^{o}$N and 87.5 $^{o}$E - 92.5 $^{o}$E which lay over the Bay of Bengal were taken from the NASA Earth Observatory (NEO). **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 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 $^{o}$C (highest 31.65 $^{o}$C; lowest 29.32 $^{o}$C) while the mean recorded SST for May 2020 was 30.3 $^{o}$C (highest 31.5 $^{o}$C; lowest 28.74 $^{o}$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 during May and hence no significant cyclones of higher intensity were recorded.

From **Figure 2** , it is quite evident that the sea-surface temperature indeed increased during May 2020 which might have resulted in 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 May for the years 2016-2019 which are of lesser values as compared to the higher values of SST during May 2020.

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 |
|---|---|---|---|
| 2016 | Roanu | 19 May 2016 – 23 May 2016 | 86.4 kmph |
| 2017 | Mora | 28 May 2017 – 31 May 2017 | 114 kmph |
| 2018 | - | - | - |
| 2019 | Fani | 26 April 2019 – 5 May 2019 | 175 kmph |

Table 3: Mean sea-surface temperature profile of Bay of Bengal for the month of May 2016-2020 (Source: NASA Earth Observatuions)



Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

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

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

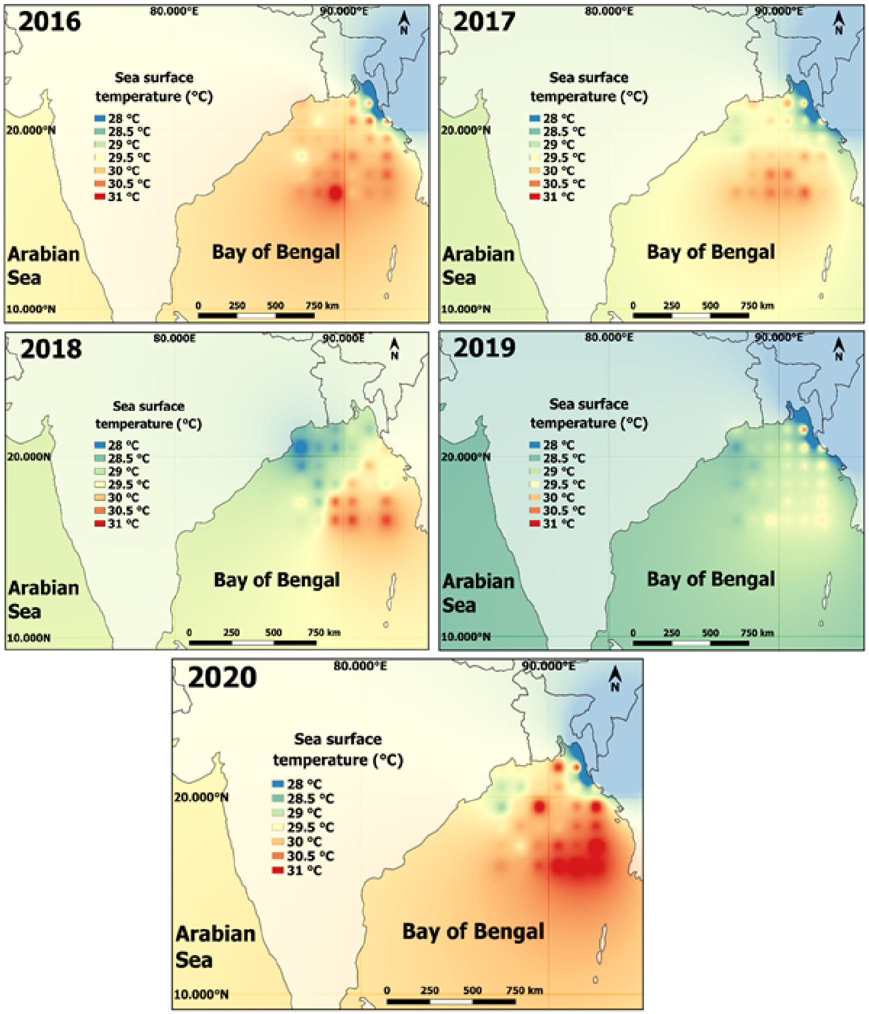


Figure 2: Variation in sea-surface temperature for the months of May during past 5 years

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 (Zhao et al., 2020).

**Relationship between SuCS Amphan and Lockdown**

Apart from the natural factors mentioned above, the country-wide 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 neighboring ocean relatively clean. The depressions over the BoB are a natural phenomenon but the country-wide lockdown might have driven the transformation of Amphan into a super cyclone by changing the radiative budget of the earth's surface. Due to the closure of the industries, factories and transportation, the inflow of particulate matter concentration load over the BoB reduced drastically (Karuppasamy et al., 2020; Mahato et al., 2020; Singh et al., 2020; Vadrevu et al., 2020). Particulate matters such as black carbons (BC) are those aerosols that can absorb heat from Sunlight thereby reducing the heating of the sea surface water (Ramanathan & Carmichael, 2008). Decreased amounts of particulate matter can be seen in figures 3(a) and (c), which might have triggered the increase of the average sea surface temperature due to the direct

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

absorption of heat from the sunlight.

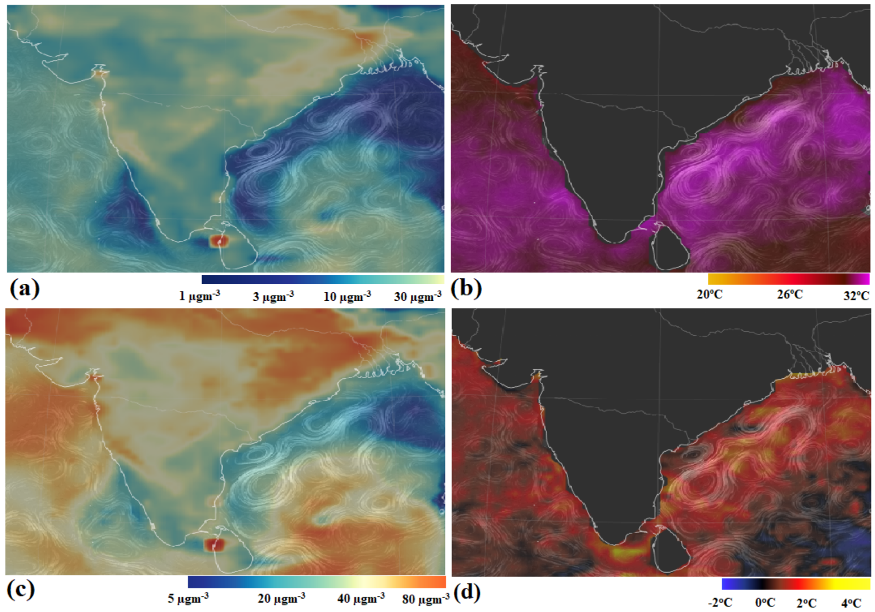


Figure 3: (a) $PM_{2.5}$; (b) SST; (c) $PM_{10}$; (d) SST Anomaly on the day SuCS formation took place over the Bay of Bengal on 16$^{th}$ May 2020 (source: https://earth.nullschool.net)

**Figure 3** depicts the preconditions of particulate matters ($PM_{2.5}$ and $PM_{10}$) 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 the formation of clouds (McNeill, 2015). Under normal conditions, a lot of particulate matter gets transported from the Indo-Gangetic plain to the Bay of Bengal (Sen et al., 2017). During regular conditions greater 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 ˜30% while an increment of sea-surface temperature by ˜1–2 ºC as compared to the preceding year (Vinoj & Swain, 2020). The decline in the concentrations of both aerosols and the clouds combined effectively increased the sea-surface temperature which compounded the warming of oceans due to 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 (Vinoj & Swain, 2020).

**Figure 4** shows the flow-chart depicting the probable formation of SuCS Amphan which might have resulted due to the impact of country-wide lockdown in India.



Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

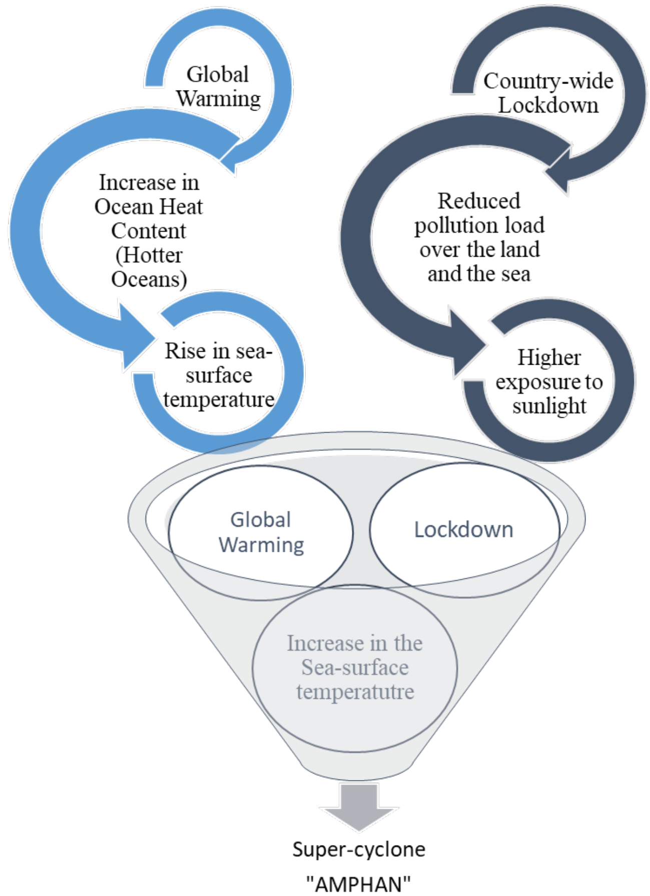


Figure 4: Flow chart depicting the probable formation of SuCS Amphan

### Conclusion

Ideally, due to the CoVID-19 related, restrictions in anthropogenic activities decrease the average sea-surface temperature. However, it was noted that the average sea surface temperature increased in May 2020 which was much higher than the last five year's average sea surface temperature. This could be one of the reasons for the formation of super cyclonic storm-Amphan. Sudden loss of particulate matter in the inflow air would have affects the normal functioning of the earth's hydrological cycles by restricting the formation of clouds. Also, less particulate matter 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. The last five year's data on average sea surface temperature indicated that during the 2020 monsoon session had the highest temperature. This could be one of the major reasons for the genesis of a 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.

### Acknowledgement

Authors gratefully acknowledge the Indian Meteorological Department (IMD), *Ministry of Earth Sciences, Govt of India* for the information on the tropical cyclones impacting India and neighboring nations through their website https://mausam.imd.gov.in/. Authors would also like to acknowledge the *CAMS / Copernicus / European Commission + ECMWF* for the particulate matter data and *OSTIA / UK Met Office + GHRSST*

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

+ *CMEMS* for the SST and SSTA data obtained on the website https://earth.nullschool.net. The authors would also like to thank NASA Earth Observatory for the data of the sea-surface temperature and the image of SuCS Amphan taken from space on the website https://earthobservatory.nasa.gov/.

**Declaration of Competing Interests**

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 in no way related to any of the points discussed.

**Funding Support:**

The authors declare that they have not received any funding for the present work.

**References**

Chauhan, A., Singh, R. P., Dash, P., & Kumar, R. (2021). Impact of tropical cyclone "Fani" on land, ocean, atmospheric and meteorological parameters. *Marine Pollution Bulletin* , *162* , 111844. https://doi.org/10.1016/j.marpolbul.2020.111844

Dunkerton, T. J., Montgomery, M. T., & Wang, Z. (2009). Tropical cyclogenesis in a tropical wave critical layer: Easterly waves.*Atmospheric Chemistry and Physics* , *9* (15), 5587–5646. https://doi.org/10.5194/acp-9-5587-2009

Emanuel, K. (2003). T ROPICAL C YCLONES. *Annual Review of Earth and Planetary Sciences* , *31* (1), 75–104. https://doi.org/10.1146/annurev.earth.31.100901.141259

Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* , *436* (7051), 686–688. https://doi.org/10.1038/nature03906

Emanuel, K. A. (1987). The dependence of hurricane intensity on climate.*Nature* , *326* (6112), 483–485. https://doi.org/10.1038/326483a0

Karuppasamy, M. B., Seshachalam, S., Natesan, U., Ayyamperumal, R., Karuppannan, S., Gopalakrishnan, G., & Nazir, N. (2020). Air pollution improvement and mortality rate during COVID-19 pandemic in India: Global intersectional study. *Air Quality, Atmosphere & Health* ,*13* (11), 1375–1384. https://doi.org/10.1007/s11869-020-00892-w

Mahato, S., Pal, S., & Ghosh, K. G. (2020). Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India.*Science of The Total Environment* , *730* , 139086. https://doi.org/10.1016/j.scitotenv.2020.139086

Mandal, S., Sil, S., Shee, A., & Venkatesan, R. (2018). Upper Ocean and Subsurface Variability in the Bay of Bengal During Cyclone ROANU: A Synergistic View Using In Situ and Satellite Observations. *Pure and Applied Geophysics* , *175* (12), 4605–4624. https://doi.org/10.1007/s00024-018-1932-8

McNeill, V. F. (2015). Aqueous Organic Chemistry in the Atmosphere: Sources and Chemical Processing of Organic Aerosols. *Environmental Science & Technology* , *49* (3), 1237–1244. https://doi.org/10.1021/es5043707

Ramanathan, V., & Carmichael, G. (2008). Global and regional climate changes due to black carbon. *Nature Geoscience* , *1* (4), 221–227. https://doi.org/10.1038/ngeo156

Satheesh, S. K., & Ramanathan, V. (2000). Large differences in tropical aerosol forcing at the top of the atmosphere and Earth's surface.*Nature* , *405* (6782), 60–63. https://doi.org/10.1038/35011039

Sen, A., Abdelmaksoud, A. S., Nazeer Ahammed, Y., Alghamdi, M. iA., Banerjee, T., Bhat, M. A., Chatterjee, A., Choudhuri, A. K., Das, T., Dhir, A., Dhyani, P. P., Gadi, R., Ghosh, S., Kumar, K., Khan, A. H., Khoder, M., Maharaj Kumari, K., Kuniyal, J. C., Kumar, M., . . . Mandal, T. K. (2017). Variations

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

in particulate matter over Indo-Gangetic Plains and Indo-Himalayan Range during four field campaigns in winter monsoon and summer monsoon: Role of pollution pathways. *Atmospheric Environment* , *154* , 200–224. https://doi.org/10.1016/j.atmosenv.2016.12.054

Sharma, D. C. (2017). Cyclone Mora devastates south Asia. *The Lancet* , *389* (10086), 2273. https://doi.org/10.1016/S0140-6736(17)31580-5

Shenoi, S. S. C. (2002). Differences in heat budgets of the near-surface Arabian Sea and Bay of Bengal: Implications for the summer monsoon.*Journal of Geophysical Research* , *107* (C6), 3052. https://doi.org/10.1029/2000JC000679

Shetye, S. R., Gouveia, A. D., Shankar, D., Shenoi, S. S. C., Vinayachandran, P. N., Sundar, D., Michael, G. S., & Nampoothiri, G. (1996). Hydrography and circulation in the western Bay of Bengal during the northeast monsoon. *Journal of Geophysical Research: Oceans* ,*101* (C6), 14011–14025. https://doi.org/10.1029/95JC03307

Singh, V., Singh, S., Biswal, A., Kesarkar, A. P., Mor, S., & Ravindra, K. (2020). Diurnal and temporal changes in air pollution during COVID-19 strict lockdown over different regions of India. *Environmental Pollution* , *266* , 115368. https://doi.org/10.1016/j.envpol.2020.115368

Tao, D., & Zhang, F. (2014). Effect of environmental shear, sea-surface temperature, and ambient moisture on the formation and predictability of tropical cyclones: An ensemble-mean perspective. *Journal of Advances in Modeling Earth Systems* , *6* (2), 384–404. https://doi.org/10.1002/2014MS000314

Tory, K. J., & Dare, R. A. (2015). Sea Surface Temperature Thresholds for Tropical Cyclone Formation. *Journal of Climate* ,*28* (20), 8171–8183. https://doi.org/10.1175/JCLI-D-14-00637.1

Vadrevu, K. P., Eaturu, A., Biswas, S., Lasko, K., Sahu, S., Garg, J. K., & Justice, C. (2020). Spatial and temporal variations of air pollution over 41 cities of India during the COVID-19 lockdown period.*Scientific Reports* , *10* (1), 16574. https://doi.org/10.1038/s41598-020-72271-5

Vinoj, V., & Swain, D. (2020). *Did COVID-19 Lockdown Brew "Amphan" into a Super Cyclone?* [Preprint]. EARTH SCIENCES. https://doi.org/10.20944/preprints202007.0033.v1

Zhao, L., Simon Wang, S.-Y., Becker, E., Yoon, J.-H., & Mukherjee, A. (2020). Cyclone Fani: The tug-of-war between regional warming and anthropogenic aerosol effects. *Environmental Research Letters* ,*15* (9), 094020. https://doi.org/10.1088/1748-9326/ab91e7

Posted on Authorea 16 Aug 2021 — CC-BY 4.0 — https://doi.org/10.22541/au.162912528.89970116/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.