Q4

What is sea surface temperature rise? How does it affect the formation of tropical cyclones?

UPSC Civil Services Mains 2024 · GS I · 10 marks · Geophysical Phenomena

Important Geophysical phenomena such as earthquakes, tsunami, volcanic activity, cyclone etc., geographical features and their location-changes in critical geographical features (including water-bodies and ice-caps) and in flora and fauna and the effects of such changes.

Core demand of the question

- Explain what sea surface temperature rise is
- Show how that rise affects the formation of tropical cyclones

Revision summary

SST is the temperature of the ocean surface mixed layer that exchanges heat with the air.

SST rise is long-term warming plus more marine heatwaves, because oceans store greenhouse heat.

Tropical cyclones need warm water, Coriolis force, low shear and a seed disturbance.

Warmer seas expand the fuel area and raise potential intensity and rainfall.

Global storm counts need not jump in lockstep. Intense and rapidly intensifying storms are the clearer risk.

The Bay of Bengal and the Arabian Sea must be read with monsoon shear, not with SST alone.

Introduction

Sea surface temperature (SST) is the warmth of the ocean's skin and mixed layer. This is the water that actually touches the air. A **rise** in SST means that this layer is becoming warmer over years, and also during marine heatwaves. The ocean has stored most of the extra heat of a greenhouse climate. Tropical cyclones draw energy from that warmth. Warmer water does not create a storm from nothing. It does change how easily a storm can start and how strong it can become.

Body

What SST rise is

SST is measured by ships, buoys and satellites. **Rise** is the long-term warming of that surface, plus more frequent **marine heatwaves**. The energy is not only a thermometer reading. A warmer mixed layer holds more **enthalpy** and feeds more **water vapour** into the air. Global mean SST has increased over the industrial period because oceans absorbed most of the extra heat from human-caused warming. Regional maps matter. The **tropical Atlantic**, the **Bay of Bengal** and the **Arabian Sea** can warm at different rates. Local cyclone seasons therefore do not all tell the same story.

- **Layer, not the deep abyss:** Cyclones feel the upper tens of metres. A thin hot skin over cold water behaves differently from a deep warm pool.
- **Moisture:** Clausius-Clapeyron physics means warmer seas load the air with more vapour for rain and latent heat.
- **Not a uniform bath:** El Niño-Southern Oscillation and monsoon winds still rearrange warmth from year to year.

How formation and strength of cyclones change

A tropical cyclone usually needs **SST near or above about 26-27°C** over a sufficient depth. It also needs Coriolis force, weak vertical wind shear, and a pre-existing disturbance. SST rise **widens** the area and season that can meet the heat threshold. More **latent heat** released in the eyewall can raise the **potential intensity**. That is the theoretical ceiling on wind speed. Warm seas also favour **rapid intensification** when shear is low. Heavier rain, a larger **storm surge** on a higher background sea level, and storms that keep strength closer to landfall are the impact side.

Formation is still limited by **shear, dry air and the monsoon trough**. A hotter ocean can even **increase** shear or change tracks in some basins. The global count of storms therefore need not rise as fast as the count of **intense** storms. The Arabian Sea's recent severe cyclones sit in this debate. The basin is warmer, but it is still shaped by monsoon shear.

- **Threshold:** More of the tropical belt sits above the classical 26-27°C fuel line.
- **Intensity:** Higher potential intensity and rapid intensification occur when other conditions align.
- **Rain and surge:** A wetter atmosphere and higher seas make landfall more destructive even if wind categories look familiar.

SST rise is therefore a **necessary amplifier**. It is not the only switch that starts a cyclone.

Flow diagram

Greenhouse heat in ocean -> SST rise and marine heatwaves

SST rise and marine heatwaves -> More vapour and latent heat

SST rise and marine heatwaves -> Wider 26-27C fuel zone

More vapour and latent heat -> Stronger cyclone potential

Wider 26-27C fuel zone -> Stronger cyclone potential

Shear dry air trough -> still required Stronger cyclone potential

Conclusion

Sea surface temperature rise is the warming of the ocean's working skin. Tropical cyclones use that skin as fuel. A hotter sea makes genesis easier where other ingredients exist. It also raises the ceiling on rain, surge and peak winds. Coastal planning has to treat the ocean thermometer as part of disaster law, not only as climate news.

Facts & figures

SST threshold

Textbook tropical cyclogenesis is favoured when sea surface temperatures are near or above about 26-27°C over a sufficient depth.

Ocean heat uptake

The global ocean has absorbed the large majority of excess heat from anthropogenic warming, which shows up partly as SST rise.

Potential intensity

A theoretical upper bound on cyclone wind speed that increases with a warmer, moister sea surface when shear is not destructive.

Rapid intensification

A sharp rise in cyclone winds over a short period, more likely over a deep warm layer when vertical shear is weak.