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Chapter 3

Tornadoes disaster in India and their impacts

Desastre de tornado en India y sus efectos

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ABSTRACT

A tornado is a natural disaster that keeps on coming in India and other countries. Many people have lost their lives in India due to this disaster. The history of Tornadoes in India dates back from 1838 to 2021. Many properties, animals, humans, and ecosystems have been damaged. Tornadoes have occurred in most of the states of India like West Bengal, Assam, Delhi, Odisha, Punjab, Haryana, etc. The formation of tornadoes, the structure of a tornado, cause of tornado, life cycle, and classification, biggest tornadoes ever in India, Negative Impacts of Tornadoes, Positive Impacts of Tornadoes, and safety of tornadoes are discussed in detail in this review.

Keywords: Tornado, formation, life cycle, classification, biggest tornadoes ever in India, effects, and safety.

RESUMEN

Tornado es un desastre natural que sigue llegando a la India y otros países. Muchas personas han perdido la vida en la India debido a este desastre. La historia de los tornados en India se remonta a 1838 hasta 2021. Muchas propiedades, animales, humanos y ecosistemas han sido dañados. Se han producido tornados en la mayoría de los estados de la India, como Bengala Occidental, Assam, Delhi, Odisha, Punjab, Haryana, etc. En esta revisión se analizan en detalle la formación de tornados, la estructura de los tornados, las causas de los tornados, el ciclo de vida y la clasificación, el tornado más grande jamás visto en la India, los efectos negativos de los tornados, los efectos positivos de los tornados y la seguridad de los tornados.

PALABRAS CLAVE: Tornado, formación, ciclo de vida, clasificación, el tornado más grande jamás visto en India, impacto y seguridad.

INTRODUCTION

Tornadoes are rare weather phenomena involving a violently rotating column of air, which is in contact with both a cumulonimbus cloud base and the surface of the earth. Tornadoes, generated by powerful thunderstorms, can kill and devastate a neighborhood in seconds. Tornadoes come in many sizes, but usually take the form of a visible condensation funnel, the narrow end of which touches the Earth and is often surrounded by a cloud of debris. Given the rarity of the phenomenon and the potential damage, tornadoes are classified as "extreme weather events [1]. India is also not exempt from such tornadoes. Several local storms, including tornadoes, damaging hail, and gusts of wind, are common. in the eastern parts of India, particularly in West Bengal and Orissa during the pre-monsoon season (March-May) and cause loss of life and property almost every year [2, to 5].Understanding the dynamics/physics of isolated heavy precipitation and other typical dynamical features associated with systems such as severe thunderstorms, squall lines, tornadoes, and strong convection embedded in synoptic scale systems is essential for better prediction [5, 6].Though the physical mechanism for severe thunderstorms is well understood, the detection and prediction of occurrences of these events in the Indian region are still challenging. Simulation of severe thunderstorms with high-resolution mesoscale models has been attempted by many Indian researchers recently [5, to 8], successfully simulated a severe thunderstorm, which produced a tornado (F0 on the Fujita-Pearson scale) close to Ludhiana airport (Punjab), the northwest region of India (30.800 N, 76.050E), on August 15, 2007, using WRF– NMM model [5]. For several decades, considerable efforts have been made to unravel the generation mechanism and structure of tornadoes. However, due to the short lifetimes and small horizontal scales of the vortices, no comprehensive data has been obtained revealing their structure and formation process. However, the recent developments in computer technology and mesoscale numerical models have allowed a numerical simulation to be a promising tool to reveal the dynamics of tornadoes [5, 10].

Figure: 1 Tornado in India [11].

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TORNADO FORMATION

During a supercell storm, the rotation is focused and lowered by downdrafts (downdrafts of cold, dense air). Between the formation of tornadoes, the rotation can be concentrated enough to form a narrow column of rapidly rotating air. When this column of violently rotating air reaches the ground, a tornado is formed. The presence of a condensation funnel—a funnel-shaped cloud that forms due to the greatly reduced pressure of the tornado's vortex—makes the tornado observable as a tornado forms. The visibility of tornadoes can be aided by dust and other debris carried by strong winds [12].

CAUSE OF THE TORNADO

When hot and humid air appears with cold and dry air, tornadoes appear. In general, thunderstorms when the coldest and densest air is pushed on the hottest air, are the cause of Tornados. Updates are caused by hot air which increases through the cold air. When the resistance or direction of the wind changes, the updraft begins to rotate [12].

STRUCTURE OF A TORNADO

Tornadoes with a fully developed arrow have single arrow areas. The main axis of circulation, as shown in the diagram, is in the central zone, a roughly cylindrical zone of low atmospheric pressure bounded by the maximum tangential winds. If a visible funnel cloud forms in the central area, it is observable. The condensation funnel is a column of water droplets that forms the funnel cloud [13]. A tornado may not have a condensation cone if the weather is extremely dry. Near-surface air in the so-called boundary layer converges from all directions into the "corner region" of a tornado in response to reduced pressure in the central core. The wind "turns the curve" from being mostly horizontal to vertical as it enters the central region and begins its upward spiral, giving this region its name. The area around the corner is really dangerous. A dust whirlwind or debris spurt is common as the explosion now lifts the ripped material off the surface. The turbulent air boundary layer feeding the corner region is typically tens of meters deep. The core is surrounded by a weakly rotating outer layer above the boundary layer [13].

LIFE CYCLE

The life cycle of a tornado generally consists of 3 phases:

Phase 1 The beginning - The mesocyclone begins to move towards the ground with the RFD. A small funnel seems to be building at the bottom of a cloudy wall. When the RFD hits the ground, the surrounding debris lifts up, damaging even heavy objects. The funnel hits the ground immediately after the RFD, forming a tornado [14].

Phase 2 Duration - The main source of energy is the hot wind provided by the RFD. Once it moves a certain distance, the RFD will cool down. The distance traveled depends on the cooling rate of the RFD. If the RFD is no longer able to provide warmer airflow to the tornado, it will begin to decrease [14].

Phase 3 The end - Once it's warm air supply is cut, the vortex or the central axis begins to weaken and shrivels away for some time.
As it weakens, the mesocyclone also begins to disappear. However, a new mesocyclone can start very close to the dying one, so it follows the same cycle and gives rise to another tornado [14].

CLASSIFICATION

How far a tornado can travel depends on its size. The path of destruction varies from a few meters to hundreds of miles. Wind speed determines the intensity of the tornado. The following table shows the classification based on the Fujita scale [14.]

Table: 1 The six categories are listed here, in order of increasing intensity.

Fujita scale	Wind speed (mph) [15, 17]	Wind speed estimate (km/h) [15, 17]	Frequency[16, 17]	Potential damage[15, 17]
F0	40-72	64–116	44.14%	Light damage. Small trees are felled and bushes uprooted. Shingles are torn from roofs, car and building windows are blown out, medium to large branches are snapped from tall trees, sheds are badly damaged, and small objects are thrown and blown away (e.g., lawn chairs, plastic tables, exercise equipment, mattresses). The barns are damaged.
F1	73-112	117–180	34.24%	Moderate damage. Roofs stripped of tiles or vegetation. Small

				areas of the roof can be blown out of the house. Doors and garage doors blown inside, tracks ripped from houses, mobile homes overturned or rolled to one side, small trees uprooted, large trees broken or blown up, telephone poles broken, outbuildings and barns blown away. Cars occasionally rolled over or overturned and moderate damage to the roof and sides of the sheds. The corn stalks are slightly bent and leafless.
F2	113-157	181–253	16.17%	Significant damage. Whole roofs were ripped from frame houses, frame house interiors damaged and small to medium sized trees uprooted. Weak structures such as garages, warehouses and mobile homes are completely destroyed.
F3	158-206	254–332	4.35%	Severe damage. Roofs and many exterior walls of half-timbered houses were swept away, all trees uprooted and/or lifted in their path, two-story houses see their second floors destroyed, high-rise buildings have blown out many windows, radio pylons dynamited, metal constructions (i.e. factories, power stations, construction sites) are badly damaged, partially destroyed. Large vehicles such as tractors, buses, and forklifts are blown up from their original position.
F4	207-260	333–418	1.00%	Devastating damage. Trees are partially debarked, cars are mangled and thrown in the air, frame homes are completely destroyed and some may be swept away, moving trains are blown off railroad tracks, and barns are leveled.
F5	261-318	419–512	0.10%	Incredible damage. Cars are mutilated and thrown hundreds,

				perhaps thousands of meters away. Log houses, brick houses, and small businesses are swept away, trees are stripped of their bark, corn stalks are flattened or torn from the ground, skyscrapers suffer severe structural damage, and the grass is torn from the ground. Wood and any small solid material become dangerous bullets.

mph = Miles per hour.

Tornadoes are known by different names in different places. They are more common in the United States, where they are called twisters. They are called hurricanes in the Atlantic and Eastern Pacific, typhoons in the Western Pacific and cyclones in the South Pacific, Indian Ocean and Bay of Bengal [14].

It is generally believed that a hurricane, typhoon or cyclone can give rise to a tornado under certain circumstances. However, the reverse is not true for a hurricane, which forms in water, unlike a tornado, which only forms on land. Most tornadoes go through the above stages during their life cycle, but there are always a few exceptions [14].

TYPES

Multiple vortexes: A multi-vortex tornado is a type of tornado in which two or more columns of air spin around their own axes while orbiting around a common center. A multi-vortex structure can occur in almost any circulation but is very often seen in intense tornadoes. These vortices often cause small areas of increased damage along the tornado's main path [18, to 20] This is a separate phenomenon from a satellite tornado, which is a smaller tornado very close to a satellite tornado that forms a large and powerful tornado contained within the same mesocyclone. The satellite tornado appears to "orbit" the larger tornado (hence its name), giving the appearance of a large multi-vortex tornado. However, a satellite tornado is a circulation in its own right and much smaller than the main funnel [19].

Waterspout: A waterspout is defined by the National Weather Service as a tornado over water. However, researchers generally distinguish between "fair weather" waterspouts and tornado waterspouts (i.e. those associated with a mesocyclone). Fair weather waterspouts are less severe but much more common and resemble dust devils and field pants. They form at the base of Cumulus Congestus over tropical and subtropical waters. They

have relatively low winds and smooth laminar walls and generally move very slowly. They are most common in the Florida Keys and the northern Adriatic [18, to 23].

Tornado water trumpets, on the other hand, are more powerful tornadoes than water. They form on the water in the same way as mesocyclonic tornadoes or are stronger tornadoes that pass through water. Because they result from severe thunderstorms and can last much longer, faster, and longer than tornadoes in good weather, they are more dangerous [24]. In official tornado statistics, tornadoes are generally not counted unless they affect the earth, although some European meteorological bureaus count tornadoes and tornadoes together [18, 19, and 25].

Landspout: A waterspout or dust tube tornado is a tornado that is not associated with a mesocyclone. The name comes from their characterization of “fair weather waterspouts on earth”. Waterspouts and associated waterspouts share many distinguishing characteristics, including relative weakness, short lifespan, and a small, smooth condensation funnel that often does not reach the surface. Landspouts also produce a distinctive laminar dust cloud when they contact the ground, due to their different mechanics from true isoform tornadoes. Although generally weaker than conventional tornadoes, they can generate strong winds that can cause serious damage [18, 19, and 20].

Similar circulations:

Gustnado: A gustnado, or gust front tornado, is a small vertical vortex associated with a front burst or downburst. Since they are not connected to a cloud base, it is debated whether or not gustnado are tornadoes. They are formed when fast-moving cold, dry runoff air from a thunderstorm is blown through a mass of stationary, warm, humid air near the runoff boundary, resulting in a “rolling” effect (often illustrated by a rolling cloud). If the low wind shear is strong enough, the rotation can be rotated vertically or diagonally and make contact with the ground. The result is a gustnado [18, 19, and 26].

Dust Devil: A dust devil (also known as a vortex) resembles a tornado in that it is a swirling vertical column of air. However, they form under clear skies and are no stronger than the faintest tornadoes. They form when a strong convective updraft near the ground forms on a hot day. If there is enough low-level wind shear, the rising column of hot air can develop a small cyclonic motion that can be seen close to the ground. They are not considered tornadoes because they form in good weather and are not associated with clouds. However, they can sometimes cause more damage [18, 27, and 28].

Fire Vortex: Small tornado-like circulations can occur near any source of intense surface heat. Those that occur near intense wildfires are known as fire whirlwinds. They are not considered tornadoes except in the rare event

that they combine with a pyrocumulus or other cumuliform cloud overhead. Fire whirlwinds are generally not as powerful as the tornadoes associated with thunderstorms. However, they can cause significant harm [18, 28].

Steam Devils: A steam devil is a rotating updraft between 50 and 200 meters (160 and 660 feet) wide that contain steam or smoke. These formations do not have high wind speeds, but only make a few revolutions per minute. Steam devils are very rare. They are usually formed by the smoke coming from the chimney of a power plant. Hot springs and deserts can also be good places for the formation of a tighter, faster spinning steam devil. The phenomenon can occur over water when cold arctic air circulates over relatively warm water [18, 29].

TORNADO DISTRIBUTION

Polar regions are rare and latitudes above 50°N and 50°S are rare. Thunderstorms are more common in temperate and tropical climates. Tornadoes have been reported on every continent except Antarctica. Tornadoes are the deadliest in the United States. Canada has the second highest number of tornadoes in the world. Bangladesh is the most tornado-prone country in the Indian subcontinent. There are approximately 1,800 thunderstorms in the world at any given time [13].

Table: 2 Biggest tornadoes ever in India

S. No	Date	Area	Reported damage	Source
1.	8 April 1838	Calcutta India	Not available	[30, 32]
2.	06 June 1903	Muketsar (Punjab India) Not available	Not available	[31, 33]
3.	1907 (date not mentioned)	Peshawar (Pakistan)	Not available	[31, 33]
4.	05 April 1933	Peshawar (Pakistan)	Not available	[31, 33]
5.	19 April 1963	Assam, India	Not available	[30, 34]
6.	10 March 1975	Ludhiana (Punjab, India)	10 people were killed, 150 injured, and about houses 800 damaged	[31, 33]
7.	17 March 1978	New Delhi (India)	28 people were killed and 700 others injured	[31, 33]
8.	10 April 1978	Odisha, India	Not available	[30, 34, and 35]

9.	10 March 1981	Gujranwala and Sheikhupura districts (Punjab, Pakistan)	56 people were killed and 600 others injured	[31]
10.	9 April 1993	West Bengal, India	Not available	[34]
11.	24 March 1998	West Bengal and Odisha, India	Not available	[34]
12.	15 August 2007	Sahanewal, near Ludhiana Airport, Punjab (India)	A few trees were uprooted, the roof of a tube well room blown away, and standing crops damaged	[30, 36]
13.	31 March 2009	Odisha, India	300 homes and 11 villages were destroyed.	[30, 36]
14.	22 July 2010	Ahlisadar, Fatehabad , Haryana (India)	Standing crops damaged	[31]
15.	13 August 2010	Ahlisadar, Fatehabad , Haryana (India)	No damage reported	[31]
16.	26 August 2013	Ranchi, Jharkhand, India	A tornado was reported on the outskirts of the town of Ranchi. It caused severe damage to Ranchi airport	[30, 37]
17.	25 May 2021	Hooghly – North 24 Parganas, West Bengal	A rare tornado in West Bengal damaged 80 houses. Two people died after being electrocuted. The incident happened before the landfall of Cyclone Yaas.	[30, 38]

IMPACTS OF TORNADOES

Negative Impacts of Tornadoes

1. Injuries and Loss of life: The violence of tornadoes can cause serious injuries and loss of life. Statistically, tornadoes cause 1,500 injuries each year. An average of 80 deaths are recorded each year as a result of devastating tornadoes. These numbers indicate that tornadoes are a life-threatening phenomenon that should be treated as a national disaster. Although tornadoes still claim casualties, scientists are working hard to develop powerful technologies that include detection and warning systems to get residents out of the door before it hits [39].

2. Economic damage: Tornadoes can cause serious damage to a country's economy. In 2011, deadly tornadoes in the United States cost the economy an estimated $23 billion in damage. A tornado is so powerful that it can destroy the whole house in seconds, leaving the family homeless and financially in limbo. Other economic effects of tornadoes include skyrocketing insurance premiums after payments, which can send the already devastated family into economic collapse [39].
3. Environmental pollution: A strong tornado can destroy oil pipelines; chemical containers break, which can lead to contamination of groundwater with oil, raw sewage, dioxide, asbestos, and other toxic pollutants. Other waste, such as medical waste, industrial waste, and household chemicals, can be dispensed on a large scale, causing environmental pollution. On numerous occasions, severe thunderstorms cause torrential rains and, when added to tornadoes, can lead to long-term risks to Mother Nature, such as an increased risk of disease transmission through contaminated water and soil [39].
4. Vegetation Destruction: Tornadoes are strong enough to eradicate trees and other vegetation in their path. A strong tornado on May 25, 2011, in CBS Sacramento uprooted some 25,000 almond trees. Farmers in the area reported that it would take more than 5 years for the trees to grow back and become profitable. In 1953, a strong tornado caused crop damage worth approximately $ 4.3 billion [39].
5. Impacts on ecosystem: When a tornado uproots trees, sunlight penetrates forest areas that were once covered, affecting the animals' habitats. Tornadoes can also destroy the entire habitat, killing and displacing huge numbers of animals. A powerful tornado is also capable of damaging healthy soil by draining topsoil, which is essential for feeding crops and other plants [39].
6. Mental effects: According to research from the American Psychological Association, tornadoes can cause long-term mental health problems. Some people who have experienced tornadoes firsthand show strong emotional reactions that may be abnormal or normal. Natural disasters can trigger traumatic memories when the victim relives the phenomenon and experiences severe anxiety, depression, withdrawal, and increased fear of loss and death [39].

Positive Impacts of Tornadoes

1. The benefit to local animals and species: A tornado is capable of knocking down berries from trees, and these are great sources of food for most animals and poultry. Animals and poultry get the chance to get additional sources of nutrients for their well-being [39].

2. Skill level improvement for contractors and workers: When a tornado sweeps down a neighborhood, contractors and workers develop better roofing techniques that are resistant to tornadoes. This greatly improves their skill levels [39].

3. Benefit of pollination: Tornadoes contribute to the massive pollination of flowers, which would never be achieved by bees and animals alone. Pollination encourages the rapid reproduction of local plant species [39].

4. Can Help Restore Communities of Concern: A tornado is a connecting factor. Fats in the local community can be smoothed out when a tornado engulfs the area. People will come together to rebuild property and infrastructure [39].

5. Clears Old Vegetation: Tornadoes destroy virtually everything in their path, including vegetation. This means that the old vegetation is wiped out and the new vegetation can grow back. The United States experiences more tornadoes than any other country in the world. More than 800 tornadoes occur each year. The central government intervened to minimize the serious consequences by issuing watches and tornado warnings. The watches are intended to educate the public about the potential dangers of the weather. Radio stations were also set up to notify people in real time of the possibility of tornadoes. With the development of powerful technologies, people could easily avoid tornadoes in the future [39].

SAFETY

While tornadoes can strike in the blink of an eye, there are precautions and preventative measures that can be taken to increase the chances of survival. Authorities such as the Storm Prediction Center in the United States recommend having a predetermined plan if a tornado warning is issued. When a warning is given, entering a basement or first-floor room of a solid building greatly increases survival [18, 40]. In tornado-prone areas, many buildings have underground cellars that have saved thousands of lives [18, 41]. Some countries have weather agencies that distribute tornado forecasts and raise alert levels for a potential tornado (such as tornado watches and warnings in the United States and Canada). Weather radios issue an alert when a severe weather alert is issued for the local area, mainly available only in the United States. Unless the tornado is distant and visible, forecasters advise motorists to park well at the edge of the curb (so as not to block emergency traffic) and find sturdy shelter. If there is no stable shelter nearby, heading to a ditch is the next best option. Freeway overpasses are one of the worst places to seek shelter during tornadoes, as the confined space can be exposed to increased wind speed and debris below the overpass [18, 42].

CONCLUSION

A tornado is a natural calamity that India has claimed many lives due to this disaster. The history of Tornadoes in India dates back from 1838 to 2021. It has caused damage to property, animals, humans, and the ecosystem. The areas affected by the tornado are West Bengal, Assam, Delhi, Odisha, Punjab, Haryana, etc. To deal with tornadoes, the government needs to monitor their causes with GIS and wait in advance for safety in those areas.

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