هيئة الطيران المدني
CIVIL AVIATION AUTHORITY

Handouts on Tropical Cyclones

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1- Definitions, zones and naming, centres of Tropical Cyclones

Tropical Cyclones are intense rotating storms form originally in warm tropical water away from the equator with sustained wind exceeding 64kts. There are different names for the system which are:

1- Hurricanes: N. Atlantic and east north Pacific (from Taino language of central America means god of evil
2- Typhoon: western N. Pacific comes from Chinese means big winds
3- Cyclones in Indian ocean and Australia

The tropical cyclones develop away from the equator towards the north west or south west. The tropical cyclones form between 5- and 20-degrees altitude. The systems will not develop in the equator as the Coriolis force is zero which means that there is no rotation within the equator.

The Coriolis force is defined as an apparent force due to the rotation of the earth and it tends to be zero in the equator. “The Coriolis force causes the wind to deflect to the right of its intended path in the Northern Hemisphere
and to the left of its intended path in the Southern Hemisphere.

2- Naming system

“The process of determining names for tropical cyclones is conducted by the relevant tropical cyclone regional body at its annual/biennial session. There are five tropical cyclone regional bodies, i.e. ESCAP/WMO Typhoon Committee, WMO/ESCAP Panel on Tropical Cyclones, RA I Tropical Cyclone Committee, RA IV Hurricane Committee, and RA V Tropical Cyclone Committee. These bodies establish pre-designated lists of names which are proposed by WMO Members’ National Meteorological and Hydrological Services. The selection of names is based on their familiarity to the people in each region, aiming to aid in the understanding and remembrance of cyclones. The naming procedures can vary, with some regions using alphabetical order and others using the alphabetical order of country names. It is important to note that tropical cyclones are not named after individuals. When selecting a new name, consideration is given to certain factors:

Short in character length for ease of use in communication

Easy to pronounce

Appropriate significance in different languages

Uniqueness – same names cannot be used in other regions.” WMO

Find the names below map for centres from WMO

https://wmo.int/northern-indian-ocean-names-arabian-sea-and-bay-of-bengal

3- Structure

The typical structure of Tropical cyclones is the following:

The eye is the centre of the system where the condition is basically clear skies and light wind. The diameter of the Tropical cyclones varies between 30 to 64 km and the surface pressure is the lowest within the eye.

The eyewall is the adjacent feature to the eye consists of severe thunderstorms which can extend vertically up to 15 kms. Associated with strong wind and heavy. the strongest wind is within the eyewall. The wind gets stronger as it approaches the centre due to angular momentum. In other words, the object moves faster as they move towards the centre. The outer eyewall is moving slower than the inner eyewall which can replace the inner eyewall with time. The predominant cloud type is cumulonimbus

The rain bands (spiral clouds) are the spiral rain belts around the eye and the diameter can exceed 500 km. These bands are associated with heavy bursts and strong winds, but there are areas of free clouds.

Why we have this structure?

As the Tropical cyclones consists of organised thunderstorms, the moist air moving towards the centre it rises and condense to produce the heavy rain. So, the air parcel loses the moisture as it is lifted up. When it reaches the top starts to flow outwards. The divergence aloft will generate clockwise rotation, also the upwards motion form high pressure aloft which form a subsiding region. The release of latent heat will warm the air and keep it rising which leads to the high pressure aloft. The sink of warm air is the reason behind the clear skies.

4- Classification

The classification differs from region to region. It is just like the names of the cyclones i.e. typhoon, hurricanes. The Indian meteorological department have slightly different classification scale comparing to the other reginal centre and due to the complexity of the IMD classification, Oman has established a different scale to use and communicate. All scales depend on the sustained wind speed around the centre, but the difference is due to wind speed calculation. i.e. 1-min sustained speed or 10-min sustained speed or 3-min sustained speed. Oman used 10- min sustained wind speed where India use 3-min sustained speed, but Joint Typhoon warning centre uses 1-min sustained wind speed.

"ASCAT uses radar to measure the electromagnetic backscatter from the wind-roughened ocean surface, from which data on wind speed and direction can be derived. The measuring principle relies on the fact that winds over the sea cause small-scale disturbances of the sea surface, which modify its radar backscattering characteristics in a particular way. These backscattering properties are well known and are dependent on both the wind speed over the sea and the direction of the wind with respect to the point from which the sea surface is observed. Once MetOp is in its polar orbit 800 kilometres above the surface of the Earth and the solar panels are in position, ASCAT's two three-metre long antenna arms are gently deployed into a fixed V-shaped position at +135° and -135° with respect to the spacecraft flight direction. Each of the antenna arms provides the fore-beam of one swath and the aft-beam of the other. ASCAT transmits well-characterised pulses of microwave energy towards the sea surface and receives and records the resulting echoes for transmission to the ground station. Data on wind speed and direction can then be derived."

5- Ingredients and favourable conditions

The Tropical cyclones need some conditions to form and develop which are the main drivers for the systems. The conditions are the following:

i. **Warm, moist air over the tropics** which help the thunderstorms to develop which in turn deepen the instability in the atmosphere. The instability is important to strengthen the thunderstorms and intensify the surface low.
ii. **Warm ocean**: the warm Ocean is essential to develop such a strong system because the warmth provide the fuel of moisture to feed the system and maintain it. The typical temperature is 26.5 C or greater, but the warm water should extend downward to a depth of 200 m. The deep warm air is important because the system mixes the water effectively once it gains enough energy which bring colder water up to the surface and if the subsurface water is colder than the threshold, it will supress the system as the moisture will be cut off.
iii. **5-degree latitude to the north or south** from the equator, because the Coriolis force tends to be zero in the equator and increases with the latitude. So, the disturbance can not rotate by itself.
iv. **Pre-existing disturbance (area of low pressure):** The cyclones cannot develop spontaneously without a trigger to draw the air into an area of low pressure. The pre-existence helps to develop the system and to start rotating. Also, these conditions help to have a convergence mechanism to lift the moist air upwards.
v. **Weak to no vertical wind shear:** The wind shear is basically the change in wind speed and direction with the altitude. If the wind shear exists that means that the growing disturbance will get disrupted and if the cyclone moves towards an area of strong wind shear, it will weaken due to tilting or interfering with the deep convection. Sometimes the wind shear decouples the low and upper level which cut off the source of moisture. But that does not mean the upper level clouds will disappear instantly.

6- Formation developing and dissipation

i- Formation

The Tropical cyclones need a trigger to form and develop such as a pre-existing area of low pressure to initiate the vorticity and rotation. The well-known theory of organised convection theory which describe the initiation of Tropical cyclones shows that the cyclones forms when the thunderstorms become organised which means that the latent heat is confined in a limited area. The instability is important to keep the moist air rising which leads to more feeding into the atmosphere which in turn release more latent heat due to the condensation process. This heat will warm the air more and creating high pressure aloft which form a divergence zone aloft and the warm air flows outwards away from the thunderstorms. This situation will lead to surface pressure drop and area of low-pressure forms. As the air moves inwards its speed increases. The increase in the speed will lead to rough sea which in turn increases the friction. The friction will cause the wind to converge and ascend. This process acts as a loop.

ii- Maturity

The loop we have mentioned in (i) is a continuous process as long as the upper level outflow is greater than surface inflow. When the area is saturated with thunderstorms, the system will use all the energy which means the air temperature is no longer rising and the surface pressure level off. Based on the theory, when the surface convergence exceeds the outflow aloft, the surface pressure will increase and the storm dies.
The tropical cyclones can live for a while if they remain in a warm air.

iii- Dissipation

The tropical cyclones dissipate when the energy source is cut off as they are approaching the land or moving over colder temperature which cause the system to lose the energy or even moving to shallow surface and the studies shows if the temperature drops by 2.5 C the energy is cut off. When the system approaches the land will rapidly weaken due to weaking in the wind strength due to the increase in surface friction and ,also, the wind flow inwards more to the centre which increase the surface pressure.

iv- Stages

1. Disturbance
2. Area of low pressure < 17 knots
3. Deep Depression 17 to 33 knots
4. Tropical storm 34 to 63 knots
5. Tropical cyclone ≥ 64 knots
6. Dissipation

7- Climatology of Tropical cyclones over Oman.

Oman is one of the affected countries by Tropical systems in Indian ocean. There is no specific frequency for the cyclones which struck Oman, but the seasons are well-known. The Indian ocean surface temperature rise as the amount of solar radiation received over the surface is sufficient. Most of cyclones form between April and early June, and the other period is from late September to November. At these two periods, the ocean can effectively get heat with weaker wind shear comparing to the monsoon months where the upwelling is profoundly affecting the SST as well as the strengthened wind shear.

Tropical cyclones' seasons can be divided into three seasons:

Pre-monsoon, monsoon, post-monsoon.

During the period between April and early June before the effect of the Monsoon, ocean can be warmed up effectively because the main driver for warming process suppression is the active winds which enhance the mixing mechanism. In this period there is no significant pressure gradients within the region which allow for almost calm situation. The pressure gradient between two parts of the region near or over the Indian ocean drive the wind and later on June when the low deepens over Indian subcontinent, the monsoon wind starts to blow to the northeast part of Indian ocean. The jet stream and low-level flow cross the equator start to develop between May and June and the maximum low-level wind speed and surface cooling due to the upwelling is during July and August. By October the low-level circulation and monsoon trough is displaced to near the equator. The rare formation of cyclones during monsoon as the monsoon trough located over northern Indian subcontinent and the development begins when the trough displaced to near the equator. The wind stress associated with low level jet forces an offshore Ekman flow, upwelling along Arabian sea and eastern Africa. During pre and post monsoon the jest stream is near the equator and the positive vorticity is coupled with warmer region. During the monsoon there is intense upper level easterlies which in turn strengthen the wind shear and the low-level Somalian jet enhance the upwelling mechanism. The withdraw of the monsoon trough to near the equator occurs during pre and post monsoon periods where the monsoon trough is located 5 to 10 N latitude. One of the good ways to determine the effect of the low-level jet is chlorophyll concentration monitoring products which show how the upwelling change the concentration by moving the chlorophyll upwards from the lower levels.

8- Impacts and devastations

The tropical cyclones can be destructive in different ways. For instance, floods, inundation, high waves, strong winds etc. One of the impacts is caused by floods or flash flooding which destroy the infrastructure and of course causing death. As the rain is intense the amount of the rainfall washes out the nearby areas especially along rivers and wadis as well as low laying areas. Lots of residential and urban areas get inundated which coincide with lose of lives. Also, the soil erosion which washout the soil from any areas confronting the run off. The soil characteristics, run off speed and rainfall intensity play a key role soil erosion. Moving to the coastal areas and trading activities, the high waves and swells are very destructive along the coast and also, affecting ships tracks as well as the ports.

The satellite imageries show the amount of water in the soil and plants. It is clearly shown that the run off caused soil erosion and destroyed farms and residential areas. Also, we can take from these imageries an idea of the amount of rain that fell into the area.