Jyothi et al., (2020) investigated the oceanic and atmospheric processes that have contributed to the Rapid Intensification (RI) and Rapid Weakening (RW) of Cyclone Ockhi using the HYbrid Coordinate Ocean Model (HYCOM) simulations and Global Forecast system (GFS) outputs. The environmental conditions prevailed before RI showed the presence of thick warm and fresh waters, ample supply of mid-tropospheric relative humidity, and moderate wind shear. The intrusion of dry air, strong vertical wind shear, and unfavourable oceanic conditions annihilated the storm intensity during the RW stage. Compared to the ocean temperatures, the vertical structure of salinity showed remarkable differences between the RI and RW locations resulting in contrasting upper-ocean stratification.

NWP Forecast Guidance for TC-Ockhi

India Meteorological Department (IMD) refers to many forecast products for preparing warnings for tropical cyclones over the north Indian Ocean. In this case of TC-Ockhi also, IMD had referred to many NWP products from IMD GFS, NCUM, ECMWF and JMA models. An analysis of inferences drawn from these models suggests that none of the models could provide an early forecast guidance for the genesis of TC-Ockhi as a Low/depression and its further intensification. The first model forecast guidance was available from the ECMWF model based on 28 Nov 0000 UTC in which the model indicated formation of a depression and its intensification into a severe cyclonic storm over the Arabian sea. The other models started indicating the formation of this system and its intensification from 29th Nov only. It is very important to note that none of the models correctly indicated the rapid intensification of TC-Ockhi during the course of its travel around the Comorin area.

However, the track forecasts by some of the models in predicting track of TC-Ockhi have been reasonably accurate as shown in Table-4.3 below. Numbers given in the bracket is number of verified forecasts. It can be seen that the Multi-Model Ensemble (MME) of IMD has the lowest errors compared to other models up to 48 hours lead time. Beyond 48 hours, ECMWF performed better than IMD-MME. The forecast errors of IMD-HWRF beyond 24 hours was far inferior compared to other models. The observed track of TC-Ockhi and IMD-MME predictions are given in Fig 4.20 and that of NCUM model are given in Fig 4.21. The models could indicate the recurvature and weakening of the TC-Ockhi very well.

In summary, the NWP models did not provide enough lead time for the IMD about its genesis over the Comorin area and its likely intensification into a cyclonic storm. IMD could get only 36 hours lead time to inform Kerala and Tamil Nadu government officials about its genesis and likely intensification. However, once the TC-Ockhi started moving, the forecast track errors were found reasonable and comparable with the climatological forecast errors. Despite considerable improvements in the prediction of genesis, intensity and track of cyclones in the north Indian Ocean in the recent decade, most of the models failed to capture the genesis of cyclone Ockhi in advance and its rapid intensification.

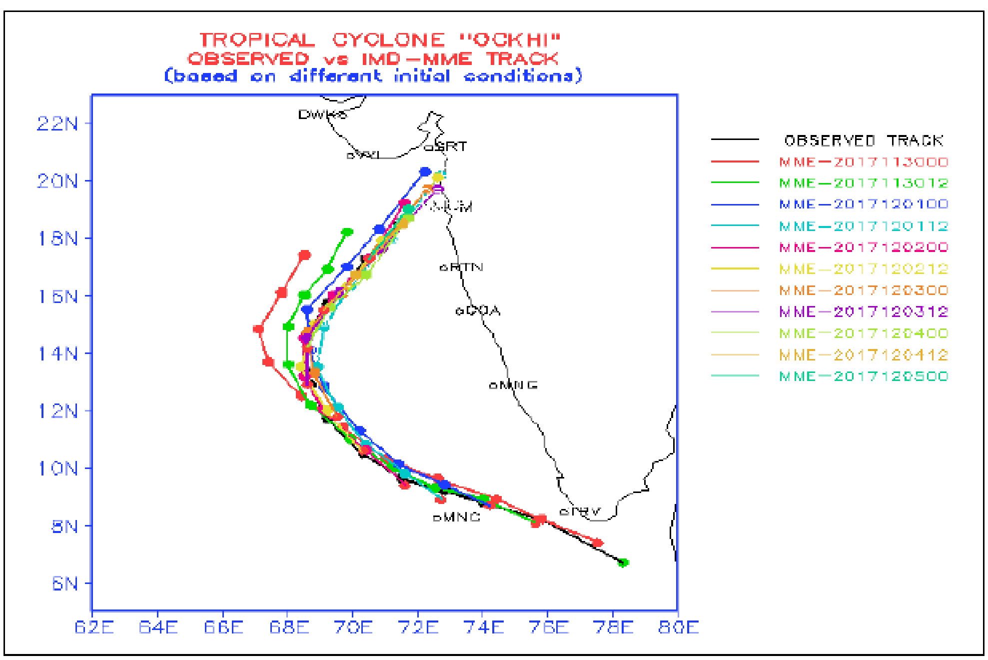

Fig. 4.20. Observed and Predicted track of TC-Ockhi by the IMD-MME prediction system.

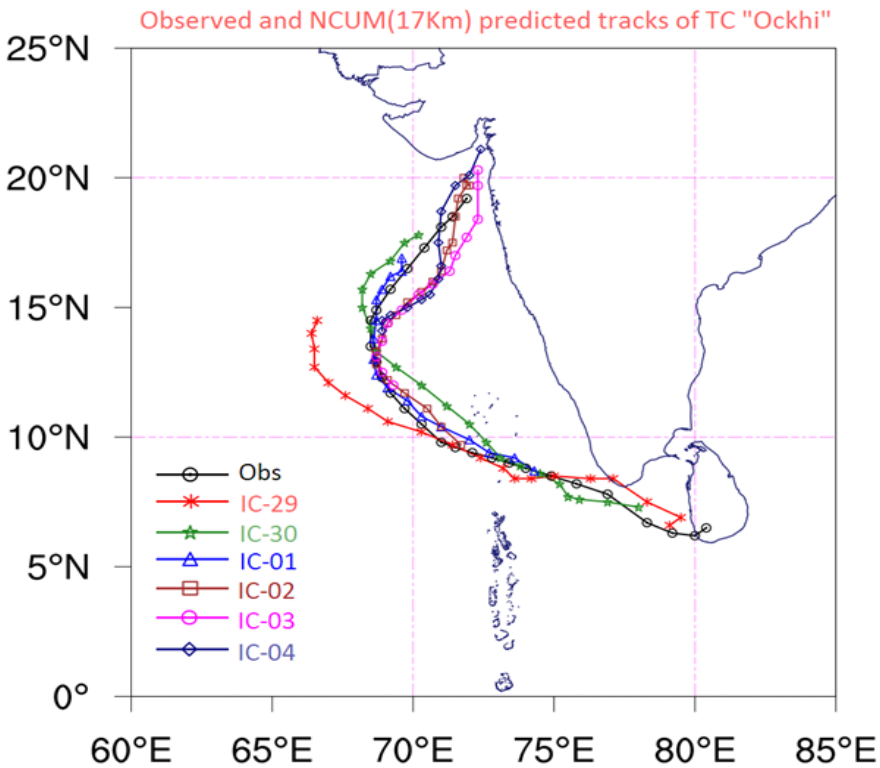

Fig. 4.21. Observed and Predicted track of TC-Ockhi by the NCUM prediction system.

A detailed study is required to understand why the NWP models could not provide adequate lead time in predicting the genesis and the further intensification of TC-Ockhi. One of the reasons could be that its genesis was very close to the equator. The models might have had problems in predicting its genesis near the equator. It may be mentioned that the models referred by IMD for forecast guidance are atmospheric models and do not treat the oceanic conditions and ocean-atmosphere coupling explicitly. This leads to an inference that even for short to medium range forecasting of weather systems like Tropical Cyclones, a coupled modelling strategy may be required.

This may be considered as a special case in which the NWP models had problems in predicting its genesis and rapid intensification. Otherwise, the recent NWP models are known for their accurate prediction of tropical cyclones.

Table 4.3

TC-OCKHI Average Track Forecast Errors in km by different models

(Source: IMD report)

Lead time	12 hrs	24 hrs	36 hrs	48 hrs	60 hrs	72 hrs
IMD-GFS	51(11)	68(10)	98(9)	117(8)	123(7)	145(6)
IMD-WRF	59(11)	115(10)	166(9)	226(8)	271(7)	278(6)
JMA	70(11)	70(10)	85(9)	103(8)	148(7)	215(6)
NCEP-GFS	60(11)	65(10)	75(9)	110(8)	91(7)	104(6)
UKMO	42(11)	63(10)	76(9)	122(8)	146(7)	173(6)
ECMWF	58(11)	69(10)	64(9)	62(8)	86(7)	100(6)
IMD-HWRF	58(21)	99(20)	130(18)	180(16)	234(14)	251(12)
IMD/MME	29(11)	44(10)	58(9)	86(8)	100(7)	112(6)
NCUM	82(13)	122(12)	129(11)	121(10)	144(9)	180(8)
NEPS	90(7)	134(6)	178(6)	217(5)	211(5)	208(4)

4.7. **Easterly Waves/Troughs in Easterlies**

From the Table 4.1, it is observed that easterly waves/trough in easterlies form a substantial portion of synoptic systems affecting south peninsula during the NE monsoon season. However, there are not adequate studies on easterly waves forming over the Indian Ocean.

Easterly wave is a wave within the broad easterly current and moves from east to west, generally more slowly than the current in which it is embedded. Although best described in terms of its wave like characteristics in the wind field, it also consists of a weak trough of low pressure. Easterly waves do not extend across the equatorial trough. To the west of the trough line in an easterly wave, there is generally found divergence, a shallow moist layer, and exceptionally fine weather. The moist layer rises rapidly near