4.4. **Track and intensity forecast errors of Tropical Cyclones**

In this section, an analysis is presented on the Track and Intensity forecast errors of Tropical Cyclones over the North Indian Ocean during the NE monsoon (Oct-Dec) season. Data of the period 2012-2021 have been used to complete this analysis. Mohapatra et al. (2013) and Mohapatra et al. (2015) have carried out extensive analysis of tropical cyclone track forecast errors over the North Indian Ocean.

The comparative analysis of track and intensity forecast errors for the post monsoon season (October-December) during 2017-21 and 2012-16 are presented in Fig. 4.9 a and b respectively. The track forecast errors were 82 km, 107 km, 139 km & 272 km during the period 2017-21 for the 24, 48, 72 & 120 hours lead forecasts respectively. However, during the period 2012-2016, the corresponding errors were 88 km, 133 km, 185 km & 348 km. It indicates an improvement of 10% in track forecast errors for lead period up to 24 hours and 15-20% for lead period beyond that up to 120 hours (Fig. 4.9 a) during the recent years.

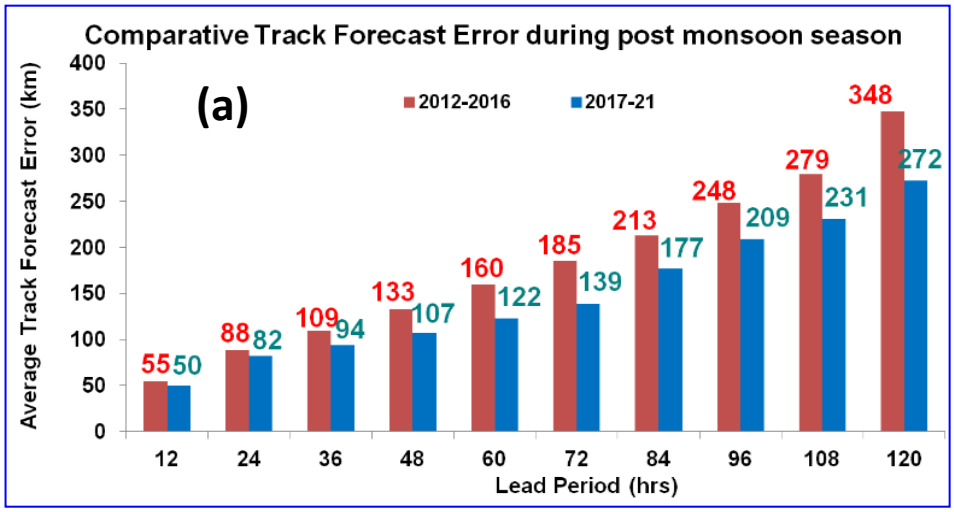
The intensity forecast errors were 8.1 knots, 11.7 knots, 14.2 knots & 15.8 knots during 2017-21 for 24, 48, 72 & 120 hours lead period respectively. The corresponding errors during the period 2012-2016 were 11.9 knots, 16.9 knots, 17.2 knots & 11.6 knots respectively. The intensity of a tropical cyclone is measured based on its maximum wind which is normally quoted in knots. This indicates an improvement of 30% in intensity forecast errors for lead period up to 48 hours and 15-25% for lead period of 60 to 84 hours (Fig. 4.9 b).

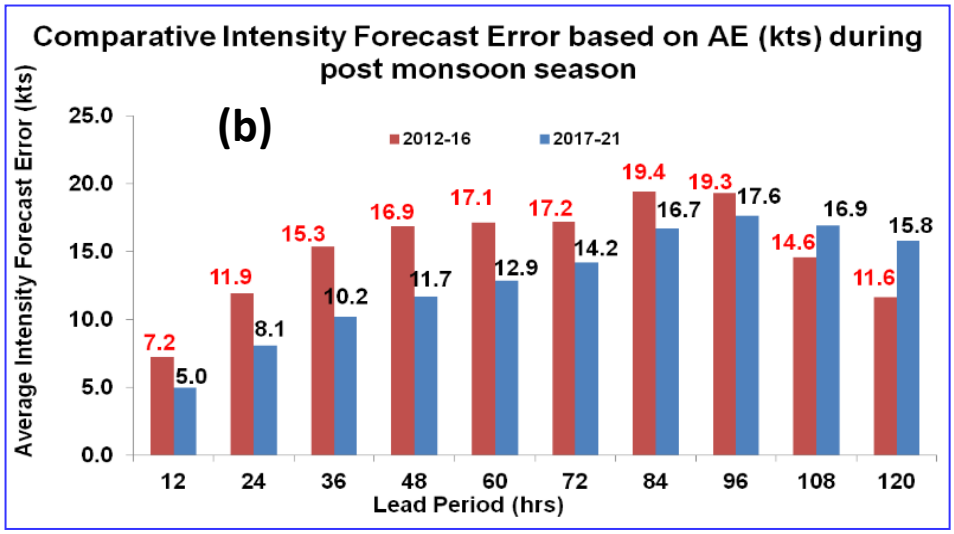
To carry out the analysis of landfall errors, only landfalling cyclones have been considered. There were 9 cyclones in each period making landfall over different places within the region during the NE monsoon season. The comparative analysis of landfall point forecast errors for the NE monsoon season during 2017-21 and 2012-16 are presented in Fig. 4.9 c. The landfall point forecast errors were 41.9 km, 59.3 km & 51.2 km during 2017-21 against 31.6 km, 85.3 km & 82.7 km during 2012-2016 for 24, 48 &

72 hours lead period respectively. The comparative analysis indicates that there is a significant improvement of 30-40% in landfall point forecast errors for lead period of 48-96 hours. However, there is no significant change in landfall point forecast errors up to a lead period of 36 hours during the two periods. It is needless to mention here that the diameter of the central region (eye) of the TC is about 10-100 km, and an average about 50 km. No significant change in the forecast errors up to 36 hours which vary from about 15-60 km can be attributed to the above fact. Further within 36 hours, the landfalling TCs are monitored with the help of the coastal hourly observations as well as Doppler weather radar observations, leading to lower detection error. It is very interesting to note that the landfall forecast errors during the recent epoch are much less than the previous epoch. This could be mainly attributed to the excellent modelling strategy used by the IMD; availability of global models with higher resolution with plenty of assimilated data. The global models used for predicting the track and the landfall point have the spatial resolution of about 12-25 km. Hence, there is scope to reduce the landfall point errors for higher lead periods like 48-120 hours with improvement in model resolution, data assimilation supported by augmented direct & remotely sensed observational system.

Cangialosi et al. (2020) have discussed the Hurricane forecast errors over the Atlantic Ocean since 1960s to 2019. It has been well documented that the National Hurricane Center (NHC) has made significant improvements in Atlantic basin tropical cyclone (TC) track forecasting during the past half century. In contrast, NHC's TC intensity forecast errors changed little from the 1970s to the early 2000s. Recently, however, there has been a notable decrease in TC intensity forecast error and an increase in intensity forecast skill. The advancement of NWP models, especially as supported in the past decade, creation of the consensus aids, development of rapid intensification guidance, and the ability of the NHC forecasters to add value to the TC guidance has greatly improved intensity forecast skill over the Atlantic Ocean.

The study by Cangialosi et al. (2020) revealed that the track forecast errors over the Atlantic Ocean during the period 2010-2019 are 83 km, 110 km, 185 km and 213 km respectively for 24 hr, 48 hr, 72 hr and 120 hr forecasts. Similarly for Hurricane Intensity forecasts the errors are 8 knots, 12 knots, 14 knots and 15 knots respectively for 24 hr, 48 hr, 72 hr and 120 hr forecasts during the same period. This suggests, the tropical cyclone forecast intensity errors over the North Indian Ocean are larger compared to the intensity forecasts errors for the Atlantic Ocean. Therefore, more efforts should be made to reduce track and intensity forecast errors of tropical cyclones over the North Indian Ocean.





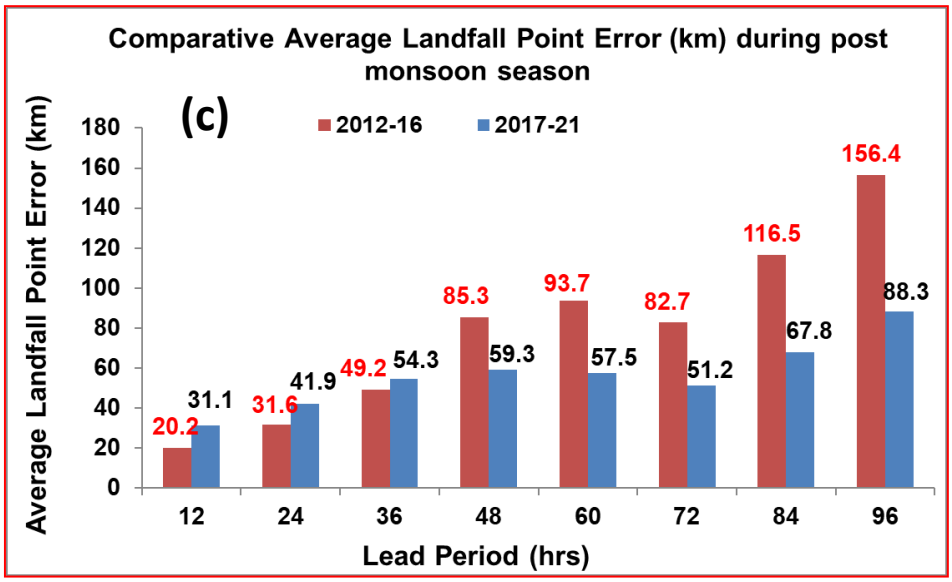


Fig. 4.9. Comparative operational (a) track and (b) intensity and (c) Landfall forecast in the post monsoon season during 2017-21 against 2012-16**.**

4.5. **A case study of Tropical Cyclone Ockhi**

In this section, the details of the tropical cyclone (TC-OCKHI) are discussed to bring out various forecasting issues and challenges related to the cyclone during the NE monsoon season. The TC- Ockhi was responsible for deaths of over 350 people from southern Tamil Nadu and Kerala, between 30 Nov and 3 Dec 2017. There were also some unidentified fishers from the north-eastern states of India who were lost at sea while working on-board fishing vessels. The full force of the storm was borne by fishermen at sea, unlike the previous cyclones over the Arabian sea (Manas Roshan 2019).

The TC OCKHI formed as a low pressure area over southwest Bay of Bengal (BOB) and adjoining areas of south Sri Lanka on 28th Nov /0300 UTC and became well marked on 29th /0000 UTC over the same region. The vertical wind shear of horizontal wind was moderate to high (15-30 knots) over the southwest Bay of Bengal and adjoining Sri Lanka coast. Under the favourable environmental conditions, it concentrated into a Depression (D) over southwest BOB off southeast Sri Lanka coast on 29th / 0300 UTC.